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The impact of assumed knowledge entry standards on undergraduate mathematics teaching in Australia

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Over the last two decades, many Australian universities have relaxed their selection requirements for mathematics-dependent degrees, shifting from hard prerequisites to assumed knowledge standards which provide students with an indication of the prior learning that is expected. This has been regarded by some as a positive move, since students who may be returning to study, or who are changing career paths but do not have particular prerequisite study, now have more flexible pathways. However, there is mounting evidence to indicate that there are also significant negative impacts associated with assumed knowledge approaches, with large numbers of students enrolling in degrees without the stated assumed knowledge. For students, there are negative impacts on pass rates and retention rates and limitations to pathways within particular degrees. For institutions, the necessity to offer additional mathematics subjects at a lower level than normal and more support services for under-prepared students impacts on workloads and resources. In this paper, we discuss early research from the First Year in Maths project, which begins to shed light on the realities of a system that may in fact be too flexible.

Keywords: tertiary mathematics; mathematics education; prerequisites; prior learning

Subject classification codes: 97D10; 97D99

1. Introduction

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 courses without the required mathematical background. Factors contributing to this growth include the rise in the total number of undergraduate enrolments and the significant changes to entry standards for mathematics-dependent degrees, which has greatly increased the range of commencing students' abilities and knowledge. However, it is not widely acknowledged that the removal of specific mathematics prerequisite entry requirements and their replacement by 'assumed knowledge' statements has had a significant flow-on impact to the teaching of undergraduate mathematics. While a number of studies have compared the pass rates of students with and without the required level of secondary school mathematics, there has been little study of the impact on the way academics teach, assess and manage first-year programmes.

Many factors affect student progression and success in tertiary study, so it is difficult to attribute specific outcomes, such as high failure rates in first-year mathematics subjects,

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solely to the change to assumed knowledge requirements. Nevertheless, there is mounting anecdotal evidence that indicates that the change in entry requirements has indeed had a substantial impact on student progression.[1,2] Individual institutions have developed a variety of responses to the problem of students enrolling without the necessary assumed knowledge, such as, bridging subjects,[1] extended mathematics support services and curriculum renewal, with varying degrees of success, but to date no particular strategy has provided a complete solution.[3–5] It is also likely that the falling enrolments in intermediate and higher level mathematics subjects in secondary schools is related to the change in degree entry standards, but there is no definitive evidence at present.[6,7]

The First Year in Maths (FYiMaths) project[2] collected national data on the key issues affecting the teaching and coordination of first-year mathematics programmes.[8] This research found that the main challenge for academics teaching first-year tertiary mathematics was the diversity of students' prior knowledge. Many participants in our study attributed the increasing difficulties to the widespread changes in entry standards, which allowed students to enrol in degrees without the 'assumed knowledge' in mathematics. As a consequence, students may enter university with a level of mathematics two years below the expected level. This article reviews and presents current research on the impact of assumed knowledge entry standards and underpreparation in mathematics on student progression and teaching practices and discusses the findings of the FYiMaths project.

2. Context

Since the early 1990s, many universities have changed their entry requirements for mathematics-dependent degrees. Prior to this, some universities had required students to have completed the most advanced mathematics subject in secondary school (such as Specialist Mathematics (VIC) or Mathematics C (QLD), to be eligible for entry, but then reduced the requirement to intermediate mathematics (Mathematical Methods (Vic) and Mathematics B (QLD)). Gradually, these remaining prerequisites began to be removed altogether and were replaced at most universities with entry standards that 'assumed knowledge' in particular subjects. This weakening of entry standards was largely driven by declining numbers of engineering enrolments in the late 1990s to early 2000s and competition between universities for the shrinking pool of students wanting to study programmes like engineering and science at that time.[9] To compensate for the change in requirements, universities adapted their curricula by introducing new subjects that allowed students to study intermediate and advanced 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.[10] On the positive side, the relaxing of prerequisites provided additional opportunities to students, particularly those who were unable to study advanced mathematics subjects at school.[3][11,12]

The definition and description of assumed knowledge varies greatly between universities with some providing comprehensive and accessible explanations within the entry requirements of each degree programme on their websites, and others providing only minimal information with further details available on linked webpages. The use of the term is often vague and inconsistent across universities, as indicated by these examples;

> Assumed knowledge refers to the level of knowledge known to facilitate understanding of the study material. It may be difficult to succeed without that knowledge. . .it is assumed that through secondary school studies or other equivalent studies a student will have achieved

a level of knowledge of the subject area (eg. Mathematics) that is considered desirable for successful university level study.

Others are more specific in referring to completion of particular subjects

'a student is assumed to have passed a relevant subject in the HSC' or not;

You don't need to have studied specific subjects at school to apply for any of our undergraduate courses. But we do assume you have a minimum level of knowledge in certain subject areas before you start your course. We call this 'assumed knowledge'.

The extent to which this information is understood or is readily accessed by prospective university students, secondary teachers and careers advisers is unclear, although evidence from academics teaching in first-year mathematics would suggest that there is a great deal of confusion across the secondary school sector.[1,13]

While prerequisites are strictly administered by university admissions procedures, the assumed knowledge entry standards are not enforced and student backgrounds are not usually vetted. Most universities have online enrolment procedures and students are able to choose subjects without seeking approval or fulfilling specific requirements. This means that many students enrol in degrees without the assumed knowledge and, in fact, may not have completed any mathematics study in the last two years of secondary school.

The knowledge assumed, as stated by universities, is intended to indicate the base level on which the first-year tertiary curriculum builds, but with many students falling far short of this point there is a significant gap to fill in terms of students' knowledge, skills and proficiency. How universities have managed this disjunction varies widely and reflects the differences in their student cohorts, school curricula in each state, structures of individual degree programmes and financial resources of each university. Some universities have embarked on broad first-year mathematics curriculum renewal and now offer multiple levels of first-year subjects for students to choose from depending on their particular background and intended degree. Many offer bridging subjects, which vary in length from a few days to weeks, or a full semester covering a range of content from specific mathematics topics, to the equivalent of full-year school subjects. In some universities, students receive credit towards their degree for these subjects, whilst others require completion as a pre-degree condition. Financial considerations range from students paying upfront fees for the subjects, to others including this additional cost as part of the fee structure for the degree programme. However, the ability of these bridging subjects to teach students the required assumed knowledge is not clear and can depend on the prior mathematical experiences and background of the students and on the content of bridging subject.[3,4,11]

The necessity to adequately cover secondary school mathematics content applies pressure on the available space within a degree, creating challenges for curriculum design, since universities need to ensure that learning outcomes for a three-year Bachelor's degree still satisfy the Australian Qualifications Framework (AQF) standards. For students, the necessity of studying additional mathematics units may result in limited degree pathways and majors since they need to devote much more space in their degrees to mathematics.

In addition to this, there is evidence suggesting that changes to entry standards have had a negative effect on the number of students studying intermediate and advanced mathematics in the final years of secondary school, due to the perception that these subjects are not required for further university study. Students believe that maximizing the Australian Tertiary Admissions Rank (ATAR)[4] score is a more important consideration [14–16] and so, driven by this imperative, students capable of studying intermediate mathematics in senior secondary school often choose lower level mathematics subjects or alternative subjects, that they believe they will score highly in, postponing their study of mathematics until they enter university. However, this decision may mean that students never improve their mathematical skills and knowledge, as some science degrees do not require students to study mathematics subjects. This means that some students may not advance past a year 10 level in mathematics and will struggle to develop the necessary quantitative skills for applying mathematics within a range of scientific contexts. The resulting drop in learning standards 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.[7,17,18]

3. Literature review

We reviewed the research conducted in recent years on first-year mathematics teaching and student transition in Australian universities. The studies were broadly concerned with identifying the impact of students' mathematical background on their learning outcomes and evaluating the impact of participation in university bridging programmes, learning support and specific teaching interventions. Studies can be categorized as addressing different types of gaps in students' mathematical background.

- Gaps in knowledge of key mathematical principles and ideas
- Gaps in student thinking and approaches to mathematical problem solving
- Gaps in experience and applying mathematics

Several studies have focused on the gap between students' actual mathematical background and the background required to succeed in both mathematics subjects and subjects that apply mathematical skills. In the earliest Australian study concerned with diversity of student mathematical background, Rylands and Coady identified that first-year students' mathematical background was a better indicator of success in mathematics at university than their tertiary entrance score was.[4] While Varsavsky considered a different student cohort, she found that students without intermediate mathematics had the same chance of success as those who had studied the subject, but those studying intermediate mathematics did make it more likely that they continued studying mathematics into second year.[11] A study of chemistry students also identified that students' prior mathematics study and their confidence in using mathematics were the key determinants in their success in chemistry.[19]

Other studies confirm that the specific choice by students not to take intermediate or advanced mathematics subjects seemed to have a negative effect on their success in first-year mathematics.[3,20,21]

For students commencing tertiary study, diagnostic testing is one effective way of identifying if gaps in knowledge are present and thereby providing the appropriate enrolment advice and support. A number of studies highlight the value of these tests to inform students of their level of mathematical ability, to establish criteria for entry to specific first-year subjects and to direct students to appropriate mathematics support if needed.[22,23] Other studies found that the process of identifying the quantitative skills needed for a particular discipline, in order to develop a test, was valuable in determining the appropriate entry standards for that study.[5]

Two studies were concerned with the gap in cognitive development as students adapt to more independent learning, and, specifically within mathematics, to the different level of conceptual thinking required between school and university mathematics.[24,25] These studies found that this gap was exacerbated by the mismatch between what students are expected to have in terms of knowledge and skills (outlined in entry standards statements of assumed knowledge or subject prerequisites) and their actual mathematical background. The studies indicate that using the secondary school mathematics subject content and ATAR scores as a measure of mathematical knowledge was not effective, as factors like students' retention of previously learned material, and variations in school curricula also needed to be considered.

While none of these studies specifically addresses the impact of assumed knowledge entry standards on outcomes for students, it is clear that the change to entry standards has significantly increased the range of ability levels of first-year mathematics students. The lower the level of mathematical preparation (both in terms of grades and in level of mathematics studied), the more difficulty students have in studying undergraduate mathematics and applying this in a scientific context.[20,26]

4. Methodology

One of the key aims of the FYiMaths project was to identify the issues and challenges academics face in teaching first-year mathematics, with a view to facilitating strategies to address these challenges at the departmental, institutional and national level. The project used a phenomenological approach to collecting qualitative data on the experiences of 40 academics teaching and coordinating first-year mathematics programmes at 26 Australian and New Zealand universities. The data were collected through semi-structured interviews, conducted in person and by telephone, which were recorded and transcribed.

All interviews were conducted by two members of the project team with the majority conducted by the authors, who were the project leader and project manager. The project leader, a mathematician, with extensive experience in undergraduate teaching, is active in the scholarship of teaching and learning and was the Director of First Year Studies at her institution for seven years. The project manager, a librarian, has a background in higher education research and experience in conducting interviews. The combination of these skills and knowledge enabled the interviewers to build rapport with the interviewees and encourage them to discuss their roles and responsibilities from a variety of different perspectives.

Each interview ranged from 60 to 90 minutes in length, and all but two interviews were conducted face to face (the other two being conducted by telephone due to time constraints). One interview was conducted as a focus group, as six members of the mathematics department at one institution were keen to participate but time did not allow for individual interviews. The interview questions covered the following topics:

(1) Details of the mathematics programme
(2) Defining the role of first-year coordinator (programme and subject coordinator)
(3) Job satisfaction, workload and morale
(4) Professional development and career options
(5) Pedagogy and models of teaching
(6) Strengths and weaknesses of the role of coordinator

The full texts of all interviews were analyzed and coded using Nvivo to identify the key themes that emerged and to build a detailed picture of the role of first-year coordinators and the mathematics programmes from their institutions.

The data were validated through four interviews with Heads of Schools of Mathematics together with feedback collected from participants at three project workshops, which provided additional information on the types of challenges across the sector and measures currently in use being used to address them. These events included the 'National Forum on Assumed Knowledge in Maths: its broad impact on tertiary STEM programmes',[5] which involved presentations, and, in some cases, subsequent peer-reviewed articles,[6] on local research into the impact of assumed knowledge.[26] This validation involved comparing opinions on specific issues, building a wide picture from the experiences of others in the sector and gaining an understanding of the broader context of mathematics education and higher education policy.

5. Interviews

Analysis of the interviews identified major themes in relation to the role of first-year mathematics coordinators and the teaching of mathematics to first-year students. The major themes were identified and grouped into two broad categories:

(1) Defining coordinators roles, responsibilities and workload
(2) Teaching, curriculum and structure of the mathematics programme
(a) Challenges
  (i) Assumed knowledge entry standards that allow students to enrol without the expected background in mathematics
  (ii) Difficulty in adapting teaching to meet the increasingly diverse range of student abilities with limited time and resources.
  (iii) High student failure rates.
  (iv) Poor student engagement.
(b) Adaptations
  (i) Reviewing and developing curriculum
  (ii) Innovations in teaching

This article is concerned with the findings in the second category of teaching, curriculum and structure of mathematics programmes (the findings of the first category will be reported in a forthcoming publication). The major themes that emerged within teaching, curriculum and mathematics programmes were mapped across all interviews to identify the extent to which these experiences were shared and to identify any inter-relationships (see Table 1). The themes broadly reflect the challenges academics stated as being significant to their work and the approaches taken to address them.

The most common challenge identified was in teaching students who lacked the required assumed knowledge (Table 2). This was experienced by 77% of interviewees from institutions in all States and in all types of university.[7] Of the six interviewees who did not identify this as a particular challenge, three were from institutions that still had intermediate mathematics as a prerequisite and the remaining three were from institutions that had developed a range of first-year mathematics subjects that catered to different backgrounds. The impact of this lack of assumed knowledge was described in terms of the wide range of first-year student's mathematical preparation, particularly the level of mathematics they had completed at school, the student's ability and confidence to absorb new ideas and their

Table 1. Issues identified in interviews with first-year mathematics coordinators.

Type of university^	Go8	N	N	Reg	Go8	ATN	Reg	ATN	Go8	Go8	N	Go8	N	IRU	ATN	N	Go8	Reg	IRU	IRU	IRU	IRU	IRU	N	Go8	Go8
University ID code	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Teaching																										
Reviewing and developing curriculum			√	√	√	√	√	√		√			√	√	√	√	√	√	√	√	√	√	√	√	√	√
Students without assumed knowledge		√		√		√	√	√	√	√		√	√	√		√	√	√	√	√	√	√	√	√	√	
Difficulties in adapting to student diversity		√	√	√		√	√	√	√			√	√	√		√	√	√	√			√	√	√	√	
Innovations in teaching	√		√	√				√			√		√	√	√		√			√					√	√
Poor student engagement				√			√		√	√			√	√		√	√	√			√	√		√		
High student failure rates			√	√				√	√				√	√		√			√					√		√
Mathematics programme																										
Prerequisite mathematics subjects	√	√							√										√ ♦	√ ♦	√					√
Provide mathematics support	√	√	√	√	√	√		√	√	√	√	√		√	√	√					√				√	
Subjects for different backgrounds				√	√	√		√	√	√	√			√			√	√	√	√	√				√	√
Bridging programmes*			√	√	√		√	√	√	√			√	√			√	√	√	√	√		√	√	√	√

Note: ^University types – Go8 = Group of Eight, ATN = Australian Technology Universities, Reg = Regional Universities, IRU = Innovation Research Universities and N = Non-aligned Universities.

♦Intermediate mathematics is a prerequisite for some courses at this university, but not others.

*Bridging programmes covering secondary school mathematics curriculum required for later subjects. These were mainly subjects that counted towards the degree, but at two universities, they were short courses studied prior to commencing first-year subjects and did not count towards the degree.

Table 2. Challenges and adaptations in first-year teaching.

	Number of universities	
	$n = 26$	%
Students without assumed knowledge	20	77
Difficulties in adapting to student diversity	18	69
High student failure rates	10	38
Subjects catering to different backgrounds	15	58
Bridging programmes	18	69

level of engagement and interest in the subject. The majority of interviewees felt that the assumed knowledge entry standards had created significant problems for both students and universities, by allowing many students to enrol who did not have the capacity to cope with the level of mathematics being taught. Their interview responses clearly identified a mismatch between the mathematics background stated in course documentation available on institutions' websites, which formed the baseline for the curriculum taught in first-year subjects and the actual background of the students who enrolled. The interviewees had formed their opinions through years of experience in teaching first-year subjects, but felt frustrated that the 'anecdotal' nature of their evidence held little weight in attempts to address the problems.

One of the main reasons given for this mismatch was that assumed knowledge entry standards were largely misunderstood or even ignored by students. Interviewees felt that information on assumed knowledge entry requirements did not adequately explain what mathematical background was necessary or indicate the level of ability required.

> we need to inform students, what assumed knowledge means and that if they do come in without the assumed knowledge they are going to struggle (University R).

Interviewees also felt frustrated that universities' enrolment procedures allowed students to enrol in subjects without understanding the consequences that an inadequate background may have on their chances of success. Some expressed their frustration and sense of guilt over high failure rates, but were powerless to effect change in their institutions, while others were in institutions that had attempted to address the problems with diagnostic tests and foundation units for students to complete prior to commencing their degree programmes.

Many interviewees felt that the change to assumed knowledge entry standards sent an incorrect message to students and secondary school teachers, that intermediate mathematics subjects were not required for a particular course of study. They cited feedback from many students who had reported choosing lower level mathematics believing they could achieve higher grades in order to maximize their ATAR. A number of interviewees made comments that indicated advice from schools also influenced these decisions,

> some schools actually encourage students to do the maths that will give them the higher marks. . ..so they actually discourage students from doing the harder maths (University T).

We found that 69% of interviewees had difficulty in adapting their teaching (as did their colleagues) to cater for the diversity of student needs. Interviewees found teaching very difficult when students' skills and knowledge in classes could range from year 10 to year 12 intermediate mathematics level, with insufficient time to adequately support these students. This range of student mathematical background coupled with the normal expected diversity in student ability, and the inherent complexities of service teaching, resulted in dissatisfaction for both teachers and students alike. The comments by interviewees indicated that while the assumed knowledge entry standards were intended to provide a baseline from which the curriculum could be built, in reality, they had to start at a much lower level to address the needs of the many students who enrolled without the assumed knowledge.

> The hardest thing is meeting the needs of the diverse cohort and the fact that we struggle to work out what to do with that diverse cohort (University S).

Just over a third of academics we interviewed reported high failure rates of up to 40% in first-year subjects. Interviewees believed that this was due to students' lack of required assumed knowledge, students' not retaining material from school, low levels of achievement in earlier subjects and low levels of confidence. The issue of high failure rates was a sensitive topic with some interviewees indicating that pass grades were being lowered to maintain student progression rates. Others were conscious that high failure rates reflected poorly on their teaching ability or on the reputation of their department, even though the main cause of difficulty was out of their control. Most interviewees used diagnostic tests or formative assessments in their subjects to help them gauge student background. They indicated that they had become more direct in their advice to students who were at risk of failing.

> I've become a bit blunter over the years. . .I really don't think it's helpful for a student to think that they know more mathematics or think that they're better prepared than they actually are (University N).

> We get called to account. We're told that we're teaching poorly when I know we're trying pretty hard to actually meet the needs of the students (University S).

Interviewees reported that many students lacked more basic mathematical skills and knowledge, usually taught in pre-senior secondary subjects, such as basic algebra, factorizing and fractions, which they felt may be related to surface learning styles focused on assessment rather than understanding. Some felt that this could also be due to variations in senior mathematics curricula, which focused on particular skills and topics or covered a wide range of topics in insufficient depth.

> And those basic skills are really lacking (University P).

> a lot of our students who come in, they can actually grasp the calculus concepts and things like that, but they can't do the simple manipulation accurately, but their higher level stuff is fine. It's just that the school level stuff, they haven't practiced enough at school, they're not confident with it (University W).

Requiring senior secondary intermediate mathematics as an entry benchmark for knowledge and skills can cause other problems. Several interviewees found that students did not have the option of studying intermediate mathematics because their school did not have qualified teachers to offer the subjects, so they had studied the only mathematics that was available. For these students, university bridging subjects are the only option.

> not all schools can offer high school maths program (University A).

> It depends really what school they came from, which part of (their state), and whether, I would get more often than not, "My school did not offer this because they didn't have the teacher" (University L).

A number of interviewees commented on the effectiveness of bridging and foundation subjects, questioning if they could provide students with deep learning opportunities that subjects of longer duration could. Some bridging subjects are highly compressed, taught in intensive classes and cover a large amount of content in a number of days. Others are offered over a semester and combine on campus classes, with assessment and online resources. These semester-long subjects usually count as credit towards degrees. Interviewees from institutions with assumed knowledge entry standards felt that these subjects had become a common alternative to studying secondary mathematics for many students to take the pressure off the ATAR scores as advanced mathematics was seen to be too hard. While some interviewees portrayed this as 'dumbing down' the first-year mathematics content, others saw it as important in providing alternative pathways to students unable to complete secondary mathematics study.

> the bridging courses are too much, in too little time and too late (University H).

> Somehow we're supposed to produce a comparable product with an input which is substantially less prepared than what it used to be (with prerequisites) in terms of background. I think background is the big issue and also their understanding of what it is to be a student (University P).

Several interviewees reported that their institutions were reviewing their first-year mathematics subjects and developing new short courses and support programmes that would address the perceived difficulties in dealing with lack of assumed knowledge. Some universities had introduced diagnostic testing and found that it was an effective tool in identifying what mathematical knowledge and skills students did have, regardless of what they had studied in senior secondary school. In some universities, the test results were used to guide or direct students enrolment in subjects that were appropriate for their background and could provide them with the necessary skills to pursue their intended degree programme. Interviewees felt that testing was very useful in providing students with clear information about their level of mathematics and how this related to the course requirements. The data also assisted academics in redeveloping curriculum and courses to adequately address student needs. Several interviewees had recently developed or adapted entry testing in response to high failure rates due to students enrolling without the required mathematical background.

> We've done testing that suggests to students instead of going into this unit you should go into that unit, so we've done pathways. . .if they don't pass the test they are obliged to do foundation mathematics (University C).

> at the same time doing well in that test gives confidence to the kids we know are in the right place and they've got the right knowledge for first year maths (University C).

Many interviewees reported that institutions had increased academic support services for mathematics through help centres, mentoring programmes, online resources and additional tutorials, which had been effective in supporting students who did not have the required background. However, for many recent programmes, it was too early to assess the long-term impact on student outcomes.

Interviewees expressed concern and frustration at the current system, which was resulting in large numbers of students struggling in first-year subjects with bridging subjects not adequately filling gaps in background. Most had analyzed student records and could identify that the key indicators for students' success in first-year mathematics were above average grades in the assumed knowledge mathematics requirements and good basic mathematical skills. However, sensitivities about student enrolment numbers and institutional reputation meant that they were unable to publish or document their concerns and findings.

6. Discussion

The interviewee responses revealed that there are different interpretations of the meaning of assumed knowledge by students, by academics and by university administration. This inconsistency has had a number of unintended and often publicly unacknowledged consequences.

- Many more students are struggling with first-year mathematics resulting in high failure rates, consequently requiring students to repeat subjects,
- Increased workload and responsibilities for academics in supporting underprepared students,
- Increased cost to universities in resourcing support for students, including providing bridging subjects, and
- Disincentives to secondary school students to study intermediate mathematics.

Our research has identified that while these problems are evident in almost every mathematics department in Australia, individuals are largely unaware that their problems are sector-wide and often feel thwarted in their efforts to draw attention to them.

The academics we interviewed all had a deep commitment to teaching mathematics and were concerned for the welfare of their students. While interviewees reported that their Heads of School were supportive, it was evident that influencing the wider institutional process of student enrolment and entry requirements was not within their power.

While many interviewees acknowledged the financial imperative for universities to grow enrolments, it was clear that they thought the current system was not giving students accurate information about their chances of success. The current approaches in many institutions were not successful in addressing the gaps in the mathematical background of some students, and some interviewees felt that much more structured and foundational subjects were needed. The increased resource costs to universities (in staffing) and to students (in course fees and degree length), however, could be substantial and needed to be considered in any redevelopment.

The dilemma for institutions, whether or not to reintroduce prerequisites, has no easy answer. However it is absolutely clear that provision of information about the mathematics background, whether required or assumed, needs to be made clearer, with reference to the consequences for progression, limitation of pathways and extra fees if students choose not to follow advice. Universities need to identify the mathematical knowledge and skills students need on entering university in order to achieve the necessary learning outcomes in degree programmes. These requirements need to be mapped to secondary mathematics curriculum and clear entry requirements developed.

The reality of student diversity needs to be recognized by universities in their approaches to first-year mathematics curriculum and pedagogy. This includes resourcing teaching adequately to develop appropriate resources, employing sufficient teaching and support staff, revising curriculum and developing supportive teaching practices. This may require revision of degree programme structures and subject sequences to address the current mismatch between entry requirements and student capabilities in first year.

7. Conclusion and further investigations

This study has provided evidence about the impact of assumed knowledge entry standards for mathematics and reinforces the concerns expressed in the recent literature. While this study has focused on Australia, the authors understand that similar issues may exist in other countries. The authors are planning a more comprehensive study of these issues that will include South Africa and New Zealand. It is clear that the mathematical background of students entering first-year mathematics courses has a significant impact on their ability to learn and apply university-level mathematics. The current entry standards for many degree programmes appear to be insufficient to ensure that students understand what is expected of them and in some cases do not accurately reflect the level of achievement in prior study which is required to succeed in first-year university subjects. This study has also revealed that the challenges of improving mathematics education are cross-sectoral and that entry requirements to degree programmes influence public perceptions of the importance of mathematics.

This study has brought to light the serious concerns of mathematics educators and raised many further questions that require more detailed investigation.

- What are the long-term effects on student learning outcomes of current entry standards, particularly on how students apply mathematics within a scientific, education, business and engineering context?
- What is the impact of the increased time and resources being spent on teaching secondary mathematics curricula, on the teaching programme within institutions?
- What is the impact on the capacity of a three-year Bachelor's degree, to meet stated Threshold Learning Outcomes, when a significant proportion of that degree is devoted to secondary school-level mathematics?

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Notes

1. In this article, bridging subjects are defined as subjects which 'bridge' the gap between a university's entry requirements in mathematics and the actual level that students have achieved.

2. The FYiMaths project was an Australian Government Office for Learning and Teaching funded project investigating the role of first-year coordinators in mathematics and the challenges they faced.
3. There are a number of factors that limit students' opportunity to study advanced mathematics subjects, including, lack of availability at the school or internal school regulations on progression.
4. The ATAR score is a percentile rank derived from students aggregated results in their final senior secondary subjects and is used by universities across Australia to select school leavers for entry to degree programmes.
5. This forum was organized by the FYiMaths project in response to the evidence from early data collection about the level of concern and frustration around the impact of assumed knowledge entry standards on student outcomes in science, technology, engineering and mathematics degree programmes.
6. A special issue of the International Journal of Innovation in Science and Mathematics Education focusing on the impact of assumed knowledge entry standards was published as a result of the National Forum on Assumed Knowledge in Maths: its broad impact on tertiary STEM programs.
7. Group of Eight (Go8), Australian Technology Universities (ATN), Regional Universities (Reg), Innovation Research Universities (IRU) and Non-Aligned Universities.

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