Curriculum Redesign to Provide Opportunities for a Diversity of Students

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Abstract

The Faculty decision in 2012 to change the prerequisite for the Bachelor of Science at La Trobe University from Mathematical Methods (intermediate) to "any mathematics" (elementary/intermediate), in conjunction with the introduction of a quantitative literacy requirement in first year, has presented both challenges and opportunities for the Department of Mathematics and Statistics. This paper describes the curriculum redesign undertaken to provide pathways to the mathematics or physics major for any student, whilst also satisfying the constraint that there be no proliferation of subjects or duplication of teaching. This careful redesign has also enabled the closure of a somewhat problematic summer bridging course, and permits mid-year transfer to engineering degrees for students whose subject choice at Year 12 would otherwise leave them ill-prepared for such programs.

Introduction

This paper describes the curriculum redesign undertaken in the core first year mathematics subjects at La Trobe University across the years 2012-2014, in response to the changing preparedness of students entering the Bachelor of Science. *Core* describes the subjects which must be passed in order for students to study mathematics in second year and beyond; these also include electronic and civil engineering students, as well as students in the Bachelor of Teaching (Secondary) who wish to become high school mathematics teachers. Throughout this paper, the terms elementary/intermediate/advanced, as introduced and described by Barrington and Brown (2005) to classify Australian mathematics subjects in the final year of secondary school, will be used to make it more accessible and relevant to all readers. Similarly, no La Trobe specific subject codes will be used.

There are numerous papers describing new teaching initiatives or help centres or diagnostic testing in response to the pressing national issue of some students' lack of mathematical preparedness for the STEM disciplines, particularly in this special issue. Often these are directly relevant at the classroom level, and too frequently describe the efforts and insights of a "first-year team" who may be expected to resolve these issues isolated from, and for the benefit of, those who teach at higher levels. This paper describes an alternative or complementary approach which receives less attention. It has application at the whole-of-department or program level and takes seriously the shifted resource issues (as highlighted in the communiqué from the national forum *Assumed knowledge in maths: Its broad impact on the STEM disciplines*):

> 'Universities currently expend significant resources teaching secondary-school-level mathematics to students who lack the level of mathematics they need for success in

> their university programs…This duplication is a significant and costly inefficiency both in terms of academic and administrative considerations.' (First Year in Maths, 2014)

Although she uses the term *curriculum* more broadly than this paper does, including transition support and co-curricular activities, Kift (2009) identifies the design of intentional sequencing of knowledge as an obvious way to support diversity and widening participation. It is this sequencing that is the focus of this paper. Further, Kift warns that,

> '[c]rucially, safeguards need to be embedded to protect against deficit approaches that seek to blame students for any "preparedness shortfalls'(Kift 2009, p.15).

It is important to remember this, however frustrated one might be that the changing University entrance prerequisites, which at least in part are intended to widen participation, seem to feed the move to senior secondary students taking, or being advised to take, mathematics at the elementary, rather than intermediate or advanced level (Barrington, 2006, 2013). Discussions of the reasons students make the choices they do at Years 11 and 12 can be found in Varsavsky (2010) and Gordon and Nicholas (2013). It seems that they are *not* getting the advice which is a favourite when one does a web search for "maths quotes"

> 'I advise my students to listen carefully the moment they decide to take no more mathematics courses. They might be able to hear the sound of closing doors.' (Caballero 1989, p.2)

This paper demonstrates that by careful redesign of the curriculum, students who have and have not heard such a closing door are catered for, without proliferation or repetition of subjects. In the next section, the challenges and opportunities, both external and internal, that surrounded the redesign of curriculum are outlined; the third section explains the existing and the redesigned curriculum. In the fourth section, benefits to student groups who were not the primary focus of the redesign are explained, and the paper finishes with some very preliminary observations and a short conclusion.

Challenges and Opportunities

External challenges The 2014 prerequisites for entry to the Bachelor of Science (or closest identifiable equivalent) at Victorian universities are shown in Table 1 (VTAC, 2014 & 2013), disregarding bonuses and specific required scores for reading clarity; most of these have been in place for a number of years. Against this background, in 2012 La Trobe's Faculty of Science, Technology and Engineering reviewed its two generalist degrees (Bachelor of Science and Bachelor of Biological Sciences), and among a number of other changes, decided on new prerequisites for the Bachelor of Science from 2013. Widening participation to students who might otherwise choose another university with 'lower' mathematics prerequisite was certainly a factor in this decision.

Table 1: Prerequisites for generalist science degrees in Victoria

University	Prerequisite(s)
Deakin	English
Swinburne, VU, Federation (Ballarat)	English, any mathematics
RMIT La Trobe (pre 2013)	English plus one of Mathematical Methods[1] or Specialist Mathematics[2]
Monash, Federation (Gippsland)	English plus any one of Biology, Chemistry, Geography, Physics, Mathematical Methods, Specialist Mathematics or Psychology
Melbourne	English plus one of Mathematical Methods or Specialist Mathematics, plus one of Biology, Chemistry or Physics, or English plus both Mathematical Methods and Specialist Mathematics
La Trobe (from 2013)	English plus Mathematical Methods or Further Mathematics[3], plus one of Biology, Chemistry, Environmental Science, Physics, Specialist Mathematics or Psychology

[1] Intermediate [2] Advanced [3] Elementary

On the other hand, the degree was redefined as being specifically for students who had demonstrated interest and experience in science through their Year 12 subject choices. However, there was no subject in place at La Trobe for those who had studied only elementary mathematics in Year 12, that could open a pathway for them into the mathematics or physics majors. This had not been required prior to 2013, as all students in the B. Sc. had been required to have done (at least) intermediate mathematics or equivalent. Unless resolved, this lack limited the options available to admitted students; here Kift's (2009) warning against blaming the students for their level of preparedness is pertinent. The number of students in mathematics and physics majors, despite the urgent national requirement for graduates in these areas (Office of the Chief Scientist, 2012), was potentially vulnerable.

Internal challenges and opportunities

Resourcing multiple subjects Of course, as Table 1 shows, La Trobe is not unique in admitting students at multiple entry points, so far as their Year 12 mathematics is concerned. For example, at Monash (Varsavsky, 2010), each of the three sequential pathway subjects is offered in both semesters, so that students can enter at the appropriate point and take one, two or all of them, even repeating any they fail in the next semester, before proceeding to the second year subjects. This is not an option for the Department of Mathematics and Statistics at La Trobe, as multiple teaching of subjects is a critical resource issue, and student numbers are overall smaller. A solution needed to be found to the uneven preparation of students that did not increase the overall number of subjects or duplicate their offering.

Engineering students across two campuses At the same time as the Bachelor Science changed its entry requirements, a number of changes were taking place regarding the engineering degrees offered at La Trobe. In short, alignment of first-year subjects offered at two campuses and mid-year entry were deemed desirable; if they could both be accommodated in the design of new subjects, this would 'kill' a second and third bird with the one stone.

Bridging Program For more than a decade prior to 2012, La Trobe had offered a summer Bridging Program for mature-aged students, the outcomes of which were considered equivalent to Year 12 intermediate maths. This enabled them to be selected for entry to engineering or the Bachelor of Science. As it sat outside the degree structure, the burden of resourcing and organisational issues were borne by the Department; selection alone was time-consuming. It was not timed for school leavers (commencing in October), it did not cater for non-metropolitan students (despite La Trobe being a provider of regional tertiary education), and it required up-front payment from the participants. The hidden, unrecovered costs were high. It was noted that maturity was required to complete successfully as up to two years of school mathematics was being taught across four months, two evenings per week, and that the face-to-face teaching in a small class was important, so minor rescheduling to accommodate numbers of school leavers was not to be considered. On the other hand, this program had delivered great outcomes for some students who went on to post-graduate degrees. Could capturing the strengths of this program while resolving some of its problems be a fourth bird to be hit with the same stone?

Quantitative literacy A great opportunity existed for the Department with the introduction of the ‘new’ Bachelor of Science in 2013. The rules of the degree require all students to take a quantitative subject in their first year; for some students with elementary mathematics this can be a statistics subject, ‘Discrete Mathematics’ or the (non-continuing) ‘Mathematical Applications in Biology’. However, a calculus-based subject at an appropriate level that could satisfy the quantitative literacy requirement but also lead into the core subjects would have a guaranteed enrolment.

Curriculum Redesign

In reviewing the curriculum, the Department was happy with the types and numbers of classes, their focus on active learning (Seaton, King and Sandison, 2014), the amount of formative assessment provided (Seaton, 2013), and the use of diagnostic testing with feedback and associated supportive learning resources. We had also developed ways of extending and deepening the understanding of students who had taken advanced maths in Year 12, without providing them with separate subjects. The key issue to be addressed was how to provide for two cohorts of students (elementary; intermediate/advanced) without duplication of quality teaching. Sequencing of knowledge (Kift, 2009) lay at the heart of the solution.

Prior to 2013, the persistent pattern of the content of the core first year subjects at La Trobe was (for more than twenty years) two streams unfolding *in parallel*, one in each half of the teaching weeks. Tables 2 and 3 show the content in the two streams, in the respective semesters. The prerequisite for taking the first semester subject was either intermediate mathematics at Year 12, or the Bridging Program; in turn the Semester One subject was the sole prerequisite for the Semester Two subject.

Table 2: Core Semester One subject prior to 2013

Calculus Stream (Ca)	*Number Systems Stream (NS)*
Limits and Continuity	*Sets*
Differentiation	*Functions, composition and inverses*
Chain and Product Rules	*Sequences and Series*
Graph Sketching	*Complex Numbers*
Fundamental Theorem of Calculus	*Logic (statements, notation)*
Integration, including 'by parts'	*Proofs*

Table 3: Core Semester Two subject prior to 2013

Differential Equations Stream (DE)	*Linear Algebra Stream (LA)*
First order differential equations	*Vectors*
Separation and integrating factor methods	*Dot and cross products*
Second order constant coefficient DEs	*Matrices, determinants and invertibility*
Structure Theorem	*Lines and Planes*
Taylor's Theorem and Taylor polynomials	*Linear Systems, solution sets*
Approximation methods for DEs	*Gaussian algorithm*

In each table, the calculus-based stream is shown in normal font, while the 'other' stream is in italics. Depicted like this, it seems like a small step to envisage a new first semester subject made up as shown in Table 4, which students with intermediate (or advanced) mathematics are prepared for, that draws one stream from each of the former subjects.

Table 4: Core Semester One subject from 2014

Linear Algebra Stream (LA)	*Number Systems Stream (NS)*
Vectors	*Sets*
Dot and cross products	*Functions, composition and inverses*
Matrices, determinants and invertibility	*Sequences and Series*
Lines and Planes	*Complex Numbers*
Linear Systems, solution sets	*Logic (statements, notation)*
Gaussian algorithm	*Proofs*

Also offered in Semester One is a new subject, Introductory Calculus. Students taking this are school leavers with elementary mathematics, or those mature-aged students who in the past would have come in via the Bridging Program.

Turning to Semester Two, and to calculus, the remaining streams in Tables 2 and 3 clearly do not lend themselves to being unfolded in parallel! A further collective mental step had to be made, that of re-envisaging the existing streams as *sequential blocks* of a single subject, as shown in Table 5. This subject does not have the first semester subject as a prerequisite; rather, *either* Introductory Calculus *or* Year 12 intermediate mathematics are the required preparation.

Table 5: Core Semester Two subject from 2014

Weeks 1 to 6: Calculus (Ca)
Limits and Continuity Differentiation Chain and Product Rules Graph Sketching Fundamental Theorem of Calculus Integration, including 'by parts'
Weeks 7 to 12: Differential Equations (DE)
First order differential equations Separation and integrating factor methods Second order constant coefficient DEs Structure Theorem Taylor's Theorem and Taylor polynomials Approximation methods for DEs

Pathways, open doors and satisfied constraints

So why is this all any more than just re-arranging topics? Table 6 shows the possible pathways made possible for students with different backgrounds. It is informative to compare it with Table 1 of Varsavsky (2010).

Table 6: Redesigned curriculum pathways in Mathematics and STEM

Background	Semester 1	Semester 2	Semester 1	Beyond
Intermediate/Advanced	*NS & LA*	Ca & DE	Year 2	
Elementary	***Introductory Calculus***	Ca & DE	*NS & LA*	Year 2
Mid-year entry		Ca & DE	*NS & LA*	Year 2

The de-coupling of the core first and second semester subjects (i.e., re-structuring knowledge, so that they can be taken in either order) has created pathways to major studies in maths or physics, for students with elementary maths, without duplication of teaching. Each of (*NS & LA*) and (Ca & DE) is taught only once in a year, but students entering mid-year or who pass Introductory Calculus can immediately take a subject in second semester. (Had we only added Introductory Calculus to our first semester offering, there would have been nothing for these two groups of students in second semester.)

The astute reader would notice that Introductory Calculus is new, which does not seem to satisfy the first internal constraint outlined in the second section of this paper. But by discontinuing the Bridging Program (upon which we base Introductory Calculus) and standardising the core subjects across campuses, there is no overall increase in the total number of subjects. Indeed, by making the redesigned core subjects truly multi-campus (with shared resources and responsibilities) staff workload (the point of the subject cap), not just the number of subjects, is lessened.

More pathways For elementary maths students who wish to enter engineering (and some other specialist degrees with no elective freedom), their pathway lies through enrolling in the Bachelor of Science, passing Introductory Calculus, and then seeking a mid-year transfer. Students in the Bachelor of Teaching (Secondary) can accommodate the pathway shown in the second row of Table 6 into their degree.

Note that these two groups were not the intended target of the curriculum redesign flowing from the 2013 Bachelor of Science rule changes. Kift (2009) in citing the UK work of Shaw, Brain, Bridger, Foreman and Reid (2008) points out that measures taken to widen participation for one group of students can benefit other groups as well.

Other beneficiaries include students who are eligible to begin the core subjects, but who, for a variety of reasons (James, Krause and Jennings, 2010) make a rocky transition to University and fail in first semester. Prior to 2013, if they needed or wanted to continue with maths, they would have to sit out second semester (their maths skills dulling with disuse) and re-attempt the first semester subject the following year. With the de-coupling of semesters, they are able to pick themselves up and continue with the second semester subject if they wish.

Finally, we meet [the parents of] a number of students who realise too late that they want a career (engineering or mathematics teacher or astrophysicist) which needs at least intermediate mathematics, but who have made choices at Year 10 which leave them without the mathematics they need at Year 12. They are turning around and banging on those closed doors! Often we meet them at Open Day, and often there are tears (including the parents') involved. We now have a way to re-open the doors for them.

Preliminary reflections Introductory Calculus ran for the first time in Semester One of 2014. As a first year subject with minimal prerequisites, it attracted enrolments from students (across the university) for whom it was not designed, and some of whom had not even taken elementary mathematics in Year 12. Nevertheless, and satisfyingly, in response to the student feedback question *I see the relevance of this subject to my educational goals*, the mean response was 4.5 and the mode and median were 5 (on a five-point Lickert scale, with 5=always and 4=usually). While such voluntary surveys are not well-controlled and the results should be interpreted with caution, this exceeded the faculty, campus and university-wide response to this question (aggregated across all subjects) and suggests that it was indeed needed, to create for students the educational pathways outlined above. The need for a subject pitched at this (secondary-school) level is reflected in the responses to the item *Overall, the level of intellectual challenge in this subject is…*There were *zero* responses at score 2 (low) or 1 (very low). The pass rate for students in this subject who *were* enrolled in STEM degrees was 68%. Again, there are very many factors which should be considered when looking at a single pass rate, in a new, first year, first semester subject, at a university which enrols a significant cohort of first-in-family students. It will also take further time to evaluate how these students perform in the core mathematics subjects, and what take-up there is of the created pathways to physics and engineering.

In the redesigned core subject, the pass rate and student feedback were not noticeably different from previous years. However, the enrolment in the core second semester subject is greatly increased now that the de-coupling with first semester is in place, and mid-year entry and successful students from Introductory Calculus join: it is 60% bigger than in 2013!

Conclusion

In this paper I have described how creatively rethinking the sequencing of knowledge has helped a mid-size University department efficiently provide suitable subjects for students with different level of mathematics preparation for their tertiary STEM studies, within the constraints such a department has. Throughout, we have been careful not to 'blame the student'. It has further been explained that this careful curriculum redesign has benefits for various cohorts of students who need bridges, pathways or doors opened to them.

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