Mathematics and Ocean Swimming

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Mathematics is often taught in first year as a service subject. It is important that mathematics academics provide a good service to those whose students they teach. The income of many mathematics groups in universities in Australia largely depends on this teaching. At times mathematics academics are seen as not succeeding in this teaching and are blamed for the lack of skills of the students taught, or blamed for not being able to pass more students.

It is claimed here that mathematicians are often given a very difficult task, that learning mathematics has some aspects of what has been called “complex learning” and that some mathematics students are involuntary learners. It is up to mathematicians to educate those whom we serve about the challenges faced and about what is realistic for their students. An analogy which might assist in this is presented.

1 Introduction and background

Mathematics[1] is considered important for many students. There is agreement that mathematical knowledge is necessary in engineering [1] and science [2, p. 6],[3], including the life sciences [4, 5, 6, 7, 8, 9]. The importance of mathematics in ensuring the continued prosperity of Australia is clearly stated in [10, p. 4]. Mathematics is usually a compulsory part of any bachelors degree focussing on business, economics, science, management, IT and marketing to name a few. Yet more students in Australia are dropping mathematics in the final years of secondary school, and of those who study mathematics, the proportion choosing the lower level options is increasing [11, p. 6,19,20], [2, p. 3,5]. This has even been noted in the Australian national media [12].

Australian industry groups have shown concern over the lack of mathematical and other skills, as can be seen in The Industry Skills Councils’ report on language, literacy and numeracy skills [13, p. 6]: “Australia is also unique among all participating countries in that students with an immigrant background in Australia now outperform students without an immigrant background.” Similarly, in the UK “37.6% of employers reported numeracy problems in the current workforce.” [14, Exhibit 13].

Because of the importance of mathematics in many areas, at university many students study mathematics as part of a degree that is not a mathematics degree. Consequently, much service teaching is done by mathematics staff and considerable income is gained from this for the mathematics school or department. As 60% of Australian Government research and development funding goes to Australian universities and most of that is influenced by what undergraduate students study [15], mathematics undergraduate teaching, which is largely service teaching at some universities, supports a significant amount of the mathematics research in Australia.

[1] “Mathematics” here means “mathematics and statistics”.

1.1 Mathematics as a complex learning outcome

It is sometimes said that "mathematics is hard". In one sense it is; for someone who knows no mathematics at all it takes some time to get to university level. Children start learning about numbers when they begin school; 12 years later some come to university to continue their study of mathematics. Mathematics takes time to learn. Taylor writes [16, p. 298]: "This aspect of mathematics is reflected in its hierarchical nature and its long history. This in turn contributes to the fact that the study of mathematics, like the study of foreign languages, is inherently difficult."

Mathematical knowledge has some of the characteristics of what Yorke and Knight [17] call a "complex outcome", though their focus was very different (employability). They use "complex learning" to refer both to the outcomes and the processes that promote them. Complex learning has four characteristics (p. 569–570). Of these, two clearly apply to mathematics:

> (1) It is advanced, in the sense that it involves mastery of large amounts of abstract … material, and the discarding of primitive understandings in favour of more sophisticated understandings ….
>
> (2) It takes a long time and sustained practice.

Yorke and Knight continue (p. 571) "More broadly, the promotion of complex learning involves students being exposed to learning experiences of progressively increasing complexity, with cognitive 'scaffolding' … being removed as the students' expertise and their metacognitive capacity develop." This certainly applies to mathematics.

1.2 Two challenges

The complex and long term nature of learning mathematics presents challenges. Cockroft [18, p. 100] writes:

> It therefore seems that there is a 'seven year difference' in achieving an understanding of place value which is sufficient to write down the number which is 1 more than 6399. By this we mean that, whereas an 'average' child can perform this task at age 11 but not at age 10, there are some 14 year olds who cannot do it and some 7 year olds who can.

A seven year difference at age 11 suggests a bigger difference at age 18 when many students come to university. Many universities in Australia have few or no mathematics prerequisites for most degrees, and many take in mature age students who might not have studied mathematics for a decade or more. Unless a university measures the level of mathematical ability of incoming students and streams them in first year mathematics, one has excellent students who have done Advanced[2] mathematics in their final year of secondary school in the same class as students who have little grasp of any secondary school mathematics.

There is evidence that taking lower levels of mathematics in secondary school has a huge effect on performance in a first university mathematics subject. Rylands and Coady [20] give an example of a first year basic tertiary mathematics subject in which all students who had completed Advanced mathematics at secondary school passed the subject, whereas most who had completed Elementary mathematics the year before failed. The difference in achievement and understanding is clearly significant among those who studied mathematics

[2] Advanced, Intermediate and Elementary for Australian secondary school mathematics subjects are defined in Barrington [18, p. 1].

at secondary school the previous year. However, in a first year university subject there will also be those who have not done mathematics for over a decade. This presents a huge challenge for mathematics teachers; coping with near innumerate students in the same class as with mathematically mature students who have excellent skills; it's more than a "seven year difference", it is the "deadly divide".

The fact that many students studying mathematics in first year do not intend to graduate with a mathematics degree and whose priorities are elsewhere can present another challenge. Some students find themselves having to learn some mathematics without wanting to do so; they are involuntary learners. O'Grady and Atkin [21] studied the effects of incentives (financial rewards) and sanctions (possible withdrawal of allowances) on voluntary and involuntary learners enrolled in training programs. A pilot was successfully completed, with involuntary learners responding to the sanctions and incentives, and the government continued with the incentive/sanction scheme. However, the authors note that "making an adult attend a training programme through the use of directions and sanctions does not, for a significant number of attendees, mean full engagement and participation with the programme."

Universities do not offer financial rewards for success in mathematics subjects, nor do they withdraw allowances for failure; universities are more constrained than the government body offering the program studied by O'Grady and Atkin [21]. We thus have the involuntary learner problem on top of the deadly divide.

We could fail many students or we could drop standards. Dropping standards does not serve the good students, those for whom we teach, and society as a whole. If we aim low so that the weak students can succeed, are we being fair to the good students and do we help them to reach their potential? When we fail many students we can be blamed for poor teaching.

1.3 Blame

The challenges of teaching diverse groups of students, poorly prepared students and involuntary learners often lead to high failure rates. Mathematics groups and academics can be blamed for high failure rates; they can be pressured to lower standards and told that they are not good teachers. Examples of those who teach mathematics being blamed when students fail can be found, even though one would expect that most statements blaming teachers are not published.

Middleton and Spanias [22, p. 77,81] cite some studies from the 1980s in which secondary school teachers are blamed: "Students tended to derive satisfaction from a task when they were involved in successful work, and they tended to blame their dissatisfaction on the teachers." From Rooney [23, p. 13] in 1998, again in school: "The blame for negative perceptions focused on the teacher who was described as the main problem". Even recently in Nigeria an article appeared in the Vanguard blaming teachers for failure in mathematics: "Expert blames teachers for failure in Mathematics" [24].

In the US, on the large number of tertiary students having to do remedial mathematics, Kirst [25] writes: "Many blame high schools for a lack of academic rigor . . . ". However, some blame universities, as is seen as Kirst continues ". . . but high schools contend that they are unaware of the content or stakes concerning university placement. Some policymakers contend that high remediation rates are caused by lax admission standards that do not encourage a rigorous college-prep curriculum." A similar claim has been made about the UK [26]: "Some universities do not advertise the level of maths needed to comfortably study particular subjects for fear of hindering applications." That could be the case in

Australia, take for example, Belward et al. [27] on the lack of mathematics prerequisites for entry to a Bachelor of Science in many Australian universities.

It is easy to blame, but what about the challenges, the involuntary learning and the deadly divide, described in the previous section? Surely too much is expected of those teaching mathematics in many circumstances. However, do academics who are not mathematicians, and whose students mathematics academics teach, understand this or are they willing to listen? We claim here that sometimes the answer is no. Academics are good at learning and at succeeding academically. However, not all academics are physically fit or good at sport. Perhaps those non-mathematics academics will see some of the challenges of teaching swimming to unfit non-swimmers who hate water; this can serve as analogy for the problems of teaching mathematics to poorly prepared involuntary learners. Imagine that you are unfit, can't swim and hate water, and that on a cold morning you are standing at the edge of a pool wearing only your swimmers knowing that you have to jump in and swim one kilometre of butterfly.

Let's develop this analogy; maybe non-mathematics academics will listen if we talk about something other than mathematics.

2 The challenges of teaching ocean swimming

The above is rather dry reading, so this section presents the far more interesting fictional challenges of the School of Sun, Sand and Surf, Faculty of Water, Waves & Wishful Thinking, Underwater University, Australia. The purpose is to share my experiences with the subject *Ocean Swimming 101*, and in particular to discuss some of the challenges encountered. The subject is seen by a few students to be "a doddle", but the majority perceive it to be very difficult and so avoid it if they can. The subjects *Basket Weaving for Elephants* and *Tap Dancing for Reindeers* attract many students who would really be better prepared for life in Australia if they chose *Ocean Swimming 101*.

2.1 The purpose of the subject: why various student cohorts take it

Ocean Swimming 101 is core in the programs Bachelor of Fishing (Rock Fishing), the Bachelor of Surfing, the Bachelor of Indigenous studies (Tropical Islanders), the Bachelor of Diving and the Bachelor of Shark Husbandry. It is also a prerequisite for the subjects on Indigenous Fishing, Shark Care and Ocean Rescue, among others. Some students take it because they love swimming.

2.2 Assumed knowledge

We prefer students to have succeeded with at least Intermediate swimming in secondary school. Unfortunately many have only done (and often done poorly) the Elementary subject Swimming with Floaties. We do, however, always get a few students who have done Advanced swimming. These should be a joy to teach, but our attention and curriculum is directed to the majority of very poor swimmers, so the good swimmers are often frustrated by the level of most of the subject.

We find that fewer and fewer students are doing Advanced swimming at school. We have anecdotal evidence that students are being advised that if they are not aiming for the Olympics then they will be better off doing Intermediate swimming or Swimming with Floaties, as it will improve their university entrance score. That the students are at a higher risk of drowning later in life seems not to be a consideration.

We would, of course, prefer to have swimming prerequisites for incoming students. Staff cannot cater for the weaker students; those who did poorly at secondary school can sometimes not swim at all, or can only swim a few metres and will drown if left in deep water. However, like most universities, prerequisites were removed some time ago and there is no prospect of them being reintroduced soon.

2.3 Assessment

The final ocean swim is a mandatory assessment component. Students must pass this in order to pass the subject. Students are dropped one kilometre offshore and are required to swim to shore in under one hour. As readers will be aware, a top swimmer can swim one kilometre in about 10 minutes, so this assessment item should not be difficult.

However, it is this final swim that deters many students. Some of us have overheard conversations much like "Ocean Swimming, that's too hard. I'm doing Basket Weaving for Elephants. It's all essays and I can waffle my way through the assignments, *and* there is no final swim."

2.4 The big problem

Ocean Swimming 101 is not a popular subject, and the failure rate is over 40%. Why is this so? Staff in the School of Sun, Sand and Surf (SSSS) are finding more and more that students are very poor swimmers, and that over time they are getting worse. We all know that early high school students are capable of learning to swim one kilometre in a pool, yet many of our intake have not learnt to do this. They have avoided swimming—"it's too hard". They are not encouraged to put in the time required to become competent swimmers. They are told that it is OK to be a bad swimmer, to be unfit, to be physically weak, and to be afraid of water. Some even proudly boast that they are hopeless swimmers. I recently heard an announcer on the radio say unashamedly that she was a good cricketer, but couldn't swim a length of the pool.

Without basic swimming skills it is not possible to achieve the outcomes of *Ocean Swimming 101*, as they build on the swimming skills that students are assumed to have. It is completely pointless to try to teach someone bilateral breathing or to cope with navigation in a large swell when they can barely swim 20m. In fact, it is worse than pointless as it makes many students feel inadequate and destroys their self-confidence.

Ocean swimming is not just a collection of skills that anyone can master in a week, these skills can only be gained by those who already have a solid base. Bridging courses have been tried as a bandaid measure, however, we all know that unfit students with no muscle tone or aerobic fitness and no technique can at best improve by an infinitesimal amount in one or two weeks.

2.5 Failure rate, the "Drown Rate"

We usually fail around 40% of students. What can be done?

(1) Lower standards. It has been suggested that the final swim be held in a local pool, or replaced by a 50m ocean swim. Both these options lower the level to that of a secondary school subject, and do not prepare students for the degrees containing this subject, nor do they prepare the students for the subjects for which this is a prerequisite. Without something equivalent to the final ocean swim we can't ensure that the subject outcomes have been achieved. The same goes for the suggestion that passing the final swim not be required for a pass in the subject.

(2) Improve our teaching, use innovative teaching methods and flexible learning. This ignores the reality. Many of our students do not get into the water. For some, if they

do they sink because they have very few skills. When it comes to the crunch they put off the necessary work, or they start, and as soon as they find the water cold, or are a little breathless, they give up or put off the work for next week. Those that are weak must develop the stamina, technique and physical ability necessary to swim one kilometre. Many of our students do not have these attributes and will not develop them without much hard work and time over the 13 weeks of semester. It is just impossible to develop these skills in a few days of cramming.

(3) Replace the final swim with a sequence of shorter ocean swims. This has been suggested, but then it was changed to "strongly encouraged" to do this. Staff of SSSS unanimously vetoed this proposal as we all know that the only students who will act on this are the keen ones. The students who need most to swim are the ones most likely to ignore any encouragement. The argument that killed this proposal was "if you are out beyond the breakers and get into trouble, do you want your life to be in the hands of someone who has only been encouraged to swim, or someone who has actually proved that they can swim one kilometre to shore?"

(4) Have several mandatory short and easy swims early in the semester. A pass in these is necessary for a pass in the subject. These were suggested so that students would know if their skills were not enough for the subject. It was hoped that the threat of forced withdrawal would scare some of them into the water for some practice, and so give them a better chance of achieving the subject outcomes. It was then suggested that students be "strongly encouraged" to do these swims. SSSS staff then dropped the whole idea as those who needed it most they said would be the least likely to do anything if only strongly encouraged.

One might at this point think that *Ocean Swimming 101* is a very difficult subject. However, some of our students find it so mind numbingly boring that they do not engage, fail to pick up the few (easy for them) skills necessary to pass the subject, and fail. They know that they can swim one kilometre, but without some work they will not learn bilateral breathing or the other necessary skills, and often lose tone and fitness during the semester.

For a reasonable Advanced swimming student we could, if we could target our teaching at these students, have them achieve all outcomes by midsemester. We do such students a disservice by treating them as though they know nothing of swimming, and giving them work much below their abilities. We are disappointed, but not surprised, when these students disengage and fail the final swim, or are not even aware that it is mandatory.

3 Conclusion

Those who teach mathematics are sometimes blamed for the lack of learning of some of their students. This has been happening for many, many years, in many contexts and at various levels. As Australia increases the proportion of the population with a bachelor's degree this situation will only become worse as the deadly divide becomes wider. Mathematics can be difficult to learn for some, requiring much time and effort, so students who are many years behind will most likely still be many years behind after a semester of mathematics, no matter how engaging the subject and how many innovations used. This challenge is compounded if weak students are in the same class as excellent students.

It is up to those who teach mathematics at various levels to explain to those to whom we provide a service what the challenges are and why, for some students, we can't do what they want in the time given. No one else will defend us. The ocean swimming analogy may be of use in explaining some of our difficulties. Until those outside mathematics understand the current challenges in teaching undergraduate mathematics, discussions on realistic solutions for dealing with poorly prepared students cannot begin. Realistic solutions could include not allowing poorly prepared students entry to bachelor's degrees containing mathematics, or requiring poorly prepared students to enrol in and pass mathematics at a foundation college or similar (perhaps studying for several semesters) before beginning bachelor degree studies.

Two other useful analogies are learning to speak a language and learning to play a musical instrument—how many of us could learn to speak fluent Chinese or learn to play the piano in a semester?

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