Classroom notes

The transition to professional work

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A couple of years ago I did an in-depth study of graduates of mathematical sciences and asked them about their roles as mathematicians in the workplace. These graduates suggested changes to content, learning methods and structure of university programs to assist with their transition to the workplace. Kent *et al.* [1] studied employer needs for mathematics in a range of disciplines and found an increase in the requirement for mathematical literacy amongst employers and for skills of mathematical communication in the workforce.

There are several ways that we could enhance the learning of mathematics at university in order to prepare students for professional work.

You can introduce a *Transition to the Workplace* subject, generally completed in the final year as done by UNSW [2], or a first-year subject to develop an orientation to mathematical work right from the beginning of a degree as done by UTS or you can build in opportunities to develop professional skills and attitudes throughout the degree. Depending on the circumstances it may be sensible to do all three!

There is a growing realisation that a majority of students learn better if they can see the relevance of their studies [3]. In these interviews with undergraduate students, we showed that many of them have little knowledge of what it would be like to work as a mathematician. Consider the following quote (Elly, third year, statistics major):

> A lot of people say to me 'oh well you are doing a maths degree, you going to be a mathematician or something?' and I'll say, 'I don't know, what does a mathematician do?' When I hear the word mathematician I think of, you know, Pythagoras, you know, someone who is sitting in a closed room proving theories and discovering things.

If students don't know what it will be like to work as a mathematician/statistician it is perhaps no wonder that it is difficult to encourage more students to study higher-level mathematics. Other factors which suggest the incorporation of professional skills into mathematics teaching include university policy about students developing graduate attributes and the changing nature of work, which nowadays requires less emphasis on content and more on generic skills.

While it is important that graduates are able to perform mathematical and computing techniques and know the relevant jargon and notations, it is essential that they are able to communicate their knowledge in a variety of circumstances and work in multidisciplinary teams in the workplace. The graduates who do well in

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the workplace are able to align their knowledge with the goals of their organisation. In academia the goal of mathematics research is often beauty and simplicity whereas the goal of industry and business is to make money. The goal of graduates is to get a good job.

Assessment ideas

Here are a few examples of assessment tasks that can be adapted to different topic areas across the mathematics curriculum.

1. Teaching as learning

The first example considers teaching as learning. Many of the graduates I interviewed spend some of their time teaching others how to do technical processes. This opens ideas for assessment tasks that develop these teaching skills. Also, as many of us know, in order to explain an idea you really need to understand it. Example 1 looks at wavelets and asks students to write a handout to teach others in the class about the topic. Any topic can be substituted for wavelets. I have used this and similar assignments with engineering mathematics classes of 400 and smaller Linear Algebra classes. There are few issues of plagiarism as it is clear if copying has occurred. I also explain to students that this is important preparation for tasks in the workplace. The best examples can be posted on the Internet. This idea of teaching as learning is further developed in an article I wrote with Narelle Smith [4].

Example 1. Developing teaching skills

Please hand in your assignment in groups of 1 or 2 students.

Only hand in one assignment per group.

This assignment deals with WAVELETS. Wavelets are used in image processing and other areas. You will need to define terms used in your work. For example, if you find an example that uses a *sparse* matrix you would need to define what a sparse matrix is. You need to reference any material you have found on the Internet or in books — including definitions.

Question 1 (12 marks)

(a) What is a wavelet?
(b) Find an article that uses wavelets in an area that is interesting to you. Write a 500-word summary of the article. Hand in the summary and the article.
(c) Answer questions 1–7 in the attached handout. (Not attached here. These were mathematical exercises using matrices, including the process of finding wavelets.)

Question 2 (8 marks) (Bonus marks may be awarded for exceptional work)

Imagine you are the tutor teaching our class about wavelets. In about 2–4 pages, design a handout to teach this topic to the class. Consider your fellow students to be the audience for this handout.

2. Not teaching as learning

Another task mathematics graduates had to do soon after they graduated was learn new material, without the benefit of our teaching. They were required to use different mathematics or apply mathematics in a different way to how they had learnt it at university. One very successful assessment idea is *not* to teach a topic in the curriculum and either set an assignment, similar to Example 1 or, particularly if there is a good exposition of the topic in a textbook, to just state clearly that there will be a question on that topic in the final examination. We all know that what we teach is not necessarily learnt so why not go one step further and not even lecture it? Again, I always explain that we are preparing students for the workplace where they will have to learn by themselves. In the workplace students will have to learn without our teaching so it is good practice to help them along the way. The embarrassment is that students often perform best in this question on the examination!

3. Mathematics in context

A few years ago in Denmark, I attended a lecture by Gilbert Strang from MIT not long after Mary Donaldson married a certain Danish prince. Gilbert was introduced by Professor John Donaldson — Mary's father — much to the delight of the audience and Gilbert himself.

Gilbert said he often used tridiagonal matrices as examples for students because they had so many applications. This got me thinking, so I spent the next couple of lectures playing around with the following problem shown in Example 2 to make an assignment. Students also enjoy playing with this problem. It illustrates many of the properties of mathematics: the idea of definition, looking for patterns, conjecture and proof (a nice example of strong induction). Students then find an application, so putting the mathematics into a context and explaining the application in a form suitable for their colleagues. The process of mathematics is explored, put in context and communicated.

Example 2. Placing mathematics in context

Question 1 (10 marks)

(a) Define a tridiagonal matrix (reference your sources).
(b) Define a symmetric matrix.
(c) Define an upper triangular matrix.
(d) Consider the matrix $\begin{pmatrix} 2 & -1 \\ -1 & 2 \end{pmatrix}$.
- Find the determinant.
- Row reduce the matrix to upper triangular form and then find the determinant.

(e) Consider the matrix $\begin{pmatrix} 2 & -1 & 0 \\ -1 & 2 & -1 \\ 0 & -1 & 2 \end{pmatrix}$.
- Find the determinant.
- Row reduce the matrix to upper triangular form and then find the determinant.

(f) Consider the matrix $\begin{pmatrix} 2 & -1 & 0 & 0 \\ -1 & 2 & -1 & 0 \\ 0 & -1 & 2 & -1 \\ 0 & 0 & -1 & 2 \end{pmatrix}$.

- Find the determinant.
- Row reduce the matrix to upper triangular form and then find the determinant.

(g) Consider the $n \times n$ matrix $\begin{pmatrix} 2 & -1 & 0 & \cdots & \cdots & 0 \\ -1 & 2 & -1 & 0 & 0 & \vdots \\ 0 & -1 & \ddots & \ddots & 0 & \vdots \\ \vdots & 0 & \ddots & \ddots & -1 & 0 \\ \vdots & 0 & 0 & -1 & 2 & -1 \\ 0 & \cdots & \cdots & 0 & -1 & 2 \end{pmatrix}$.

- Find the value of the determinant.
- Prove your answer.

Question 2 (10 marks)

Search the Web and the library to find an application of a tridiagonal matrix. You may need to look at a few sources before you find one that you can understand.

(a) In about two A4 pages, summarise the application. You can use diagrams, mathematics and words. Consider that your classmates are the audience.
(b) Include references to the material you have used.

4. Mathematical communication as a graduate attribute

Being able to communicate mathematical ideas in the workplace is a critical graduate attribute for success. This not only requires general communication skills but the ability to communicate mathematically with those who are not mathematicians. We cannot leave this critical area to communication teachers; we need to integrate mathematical communication into the curriculum because the skills required are discipline specific.

Language teachers talk about the four macro skills of language: speaking, listening, reading and writing. Mathematics at university often emphasises listening and reading (receptive skills) rather than speaking and writing whereas in the workplace the opposite is needed. Clearly, all these skills are linked and in many cases should be taught in a linked manner. Nevertheless it is worth considering each separately and make suggestions for links between activities. The activities of the graduates will be used as examples of types of discourse to be modelled.

Speaking. Presentation of ideas:

- Miniconference. This task requires students to take given materials (such as a popular science book) and change the form of the material to make it suitable for a given audience. They then present the material as a miniconference to their peers and staff. This is generally a group work task with individual components.

- Miniconference (own materials). This is similar to the above except that students find their own materials for the conference. For example, they may be studying regression analysis so they will need to find data, analyse them and present their findings in a miniconference. This has been implemented at UTS for third-year regression students.
- Poster sessions. Similar to the above but presenting their findings in poster form.

Negotiating and selling ideas: One of the communication needs that is often mentioned by graduates is the need to sell ideas to a non-mathematical audience. Indeed one of the problems with even getting employment in the first place was the need to sell the degree to employers. Ways to deal with this range from debates (for example, 'Why is calculus essential in engineering?') to interview practice (How would your mathematics training add value to our organisation?; How would you use your mathematics in the Department of Defence?). These are real questions graduates were asked at interview.

Listening. Formal listening skills are developed in mathematics learning at university by attending lectures and tutorials. These are particular types of skills. Graduates in the workplace also need to be able to perform a broader range of listening behaviours, such as listening and then asking appropriate questions. Formal listening tasks could include:

- writing a summary of a talk and drafting suitable questions that could be asked;
- writing down the three main points after listening to a lecture.

Informal listening skills are also required and these are bound up with listening cues such as body language. It may be useful for lecturers to get in a guest lecturer for a session to discuss body language and other cues with final-year students. It may increase their success in gaining employment and succeeding when they are there.

Writing. Writing is an important part of professional life. For graduates in industry it is not as critical as Burton [5] found it to be for academic mathematicians; nevertheless, many graduates will be judged in part on their written work. Reports are commonly required as are writing manuals, help files and directions for others to follow.

A key area for graduates is the need to write quotes and responses to tenders. This is an area that has rarely been incorporated into mathematics teaching and learning and has outstanding potential for assessment tasks. It brings together ideas about the worth of mathematical knowledge, and project and time management and has a real connection with the workplace. In Example 3, I have shown an Excel spreadsheet of a simplified response to a tender. This was developed for the design of a questionnaire but could be adapted for a variety of situations. Ideally students could find an appropriate tender in the press and write a proposal for fulfilling the tender.

In a similar fashion, grant writing and ethics applications are good ways to show students that their mathematical knowledge has a value in the workplace.

Example 3. The value of mathematical work

Task	Hours	Hourly rate	Cost
Stage I: Survey design			
Literature search	24	$50.00	$1 200.00
Study design	8	$100.00	$800.00
Questionnaire design	12	$100.00	$1 200.00
Liaison	8	$100.00	$800.00
Stage II: Data collection			
Literature review/secondary	50	$50.00	$2 500.00
Phone questionnaire survey (based on four per hour)	100	$25.00	$2 500.00
In-depth interviews (5)	10	$50.00	$500.00
Training and supervision	30	$50.00	$1 500.00
Liaison	6	$100.00	$600.00
Stage III: Data analysis			
Data entry	50	$25.00	$1,250.00
Coding of questionnaires	16	$25.00	$400.00
Data processing (SPSS)	5	$25.00	$125.00
Analysis	16	$50.00	$800.00
Transcripts	20	$25.00	$500.00
Liaison	5	$150.00	$750.00
Stage IV: Report			
Recreational facilities review	16	$50.00	$800.00
Needs analysis	16	$50.00	$800.00
Draft report	16	$50.00	$800.00
Final report	12	$50.00	$600.00
Liaison	4	$100.00	$400.00
Supervision	4	$100.00	$400.00
Total hours	428		
Miscellaneous costs			
Printing (pages)	1200	$0.05	$60.00
Phone (number of calls)	1 700	$0.20	$340.00
Car (km)	250	$0.50	$125.00
Subtotal			**$19 750.00**
GST 10% flat rate			$1 975.00
Total cost			**$21 725.00**

Reading. Graduates require high-level reading skills. Firstly they need to be able to comprehend the materials and translate them into other forms, or summarise. Other critical reading requires graduates to be able to find appropriate reference materials for their purposes. In addition there is a need to distinguish between good and bad writing for a particular purpose. Appropriate learning tasks include comparing textbooks. This is a good task for first year students as it gets them to read different accounts of a topic and consider how they themselves learn.

Conclusion

Graduates require varied skills and knowledge to thrive in the workplace. We can make their transition easier by designing assessment tasks that develop graduate attributes. More than this, clever design of curriculum will also help with learning and the appreciation of mathematical ideas. Treating students as colleagues and initiating them to the delights of mathematics may encourage some of them to become part of our community of professional mathematicians.

References

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