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Graduate attributes: teaching as learning

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Recent graduates of degrees in the mathematical sciences were interviewed in depth about their work and the skills required to perform those tasks. One common undertaking could be described as teaching: demonstrating to colleagues, training their assistants or explaining mathematics to their managers. The paper describes how this understanding of teaching in the workplace can inform curriculum design at university level to better prepare graduates for work. Examples of assessment activities that lecturers can adapt for use in their classes in the mathematical sciences are presented.

1. Introduction

We report on an investigation of mathematics graduates in industry and their descriptions of mathematical practice in their workplaces. One significant feature that emerged from the study was the need for graduates to 'teach'. This took several forms, such as explaining methods to colleagues, taking new mathematical material and presenting it to colleagues and turning information into an understandable form for their managers.

Most students who study mathematics at university do not proceed to gain a major in the mathematical sciences. In Australia, the number of students who study mathematics in some form at university is around 18,000 per year [1] and the number of honours graduates in the mathematical sciences is around 150 per year [2]. So very few who study mathematics go on to become academic mathematicians. The mathematical sciences are a broad range of mathematical areas, such as statistics, operations research, applied and pure mathematics.

This paper reports on the investigation of graduates who had studied at least a major (3 years) in the mathematical sciences and who were working in a range of occupations. We found that graduates required a wider range of skills than they perceived they had been taught. Mathematics learning and teaching at university are not preparing this majority of students for professional life after university because they have not been taught how to communicate mathematically. Studies of employers have emphasized the need for graduates to have mathematical

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communication skills. For example, the UK Institute for Learning [3] has surveyed employers about the mathematics needs of industry and:

> A key finding of the study was that although the ubiquitous use of information technology in all sectors has changed the nature of the mathematical skills required, it has not reduced the need for mathematics. The authors of the report refer to these mathematical skills and competencies, framed by the work situation and practice and the use of IT tools, as 'mathematical literacy'. The term partly reflects the skills needed by individuals in relation to business goals, but also reflects the need to communicate mathematically expressed decisions and judgements to others. [4]

The Mathematics Association of America has published a summary of research in the area [5] and found similar needs to the UK study. Industry in Australia is also asking for different skills from mathematics graduates. Rubinstein [6] was involved in the 2006 national review of the mathematical sciences in Australia and makes the point that:

> As part of the national review, we are hearing that employers want more mathematics and statistics graduates with better skills in communication, team and project work and numerical and computational methods.

There is need for curriculum change in mathematics at university level and we present practical examples to assist with curriculum design in section 5. Very few studies are done from the point of view of graduates [7] and here we address this lack of information for the mathematical sciences.

2. The study

Our study involved 18 graduate participants who were within five years of graduation with majors in the mathematical sciences. We undertook in-depth interviews focusing on the participants' experience of their transition to work. Those experiences were analysed using phenomenography and examples of their work-related texts were analysed using discourse analysis.

The aim was to interview mathematics graduates who were working in diverse jobs, preferably in business and industry. Phenomenography is a methodology that examines the variation of experiences in a particular situation [8].

Participation in the study was by invitation, issued through two university databases of graduates (University of Technology, Sydney and Macquarie University), the email listing of the Society of Young Statisticians and through word of mouth. Participants were selected on the basis of their proximity and their work. As Sydney is a large cosmopolitan city of five million people with five universities, we were able to interview a large range of participants within the city. None of the participants were employed at the same workplace.

As a consequence, the variety of the respondents was high. There was a range of employment, work situations, age, ethnic background and academic background. Some graduates had laboured through their degrees with many failures while others had high grades. Some had done well (by their own reckoning) in the workplace; others had struggled. Participants had graduated from five universities and had a range of degrees with mathematics majors. Most of the participants were

in their early- to mid-twenties. There were three people who had studied mathematics as their second degree and one had come to university as a mature-aged student. There were ten males and eight females, and eight spoke languages other than English as their home language.

The interviews showed that many graduates found it difficult to get work. Many were not prepared for the process of getting a job or coping with the work environment. Several had moved from mathematics into other fields. Those who stayed in fields that relied on mathematics were often the only mathematicians in their area, which provided challenges for them personally and in terms of their work-related communication. The participants' initial work experiences were important influences on the successful transition to the workplace, especially where they had the support of their manager [9]. Employers did not seem to be aware of the benefits that mathematicians could bring to their organisations. As one participant said:

> It's actually really easy to see areas in industry where you think you could make a difference; it's extraordinarily difficult to get past that recruitment filter and to actually find yourself in one of those jobs.

In this paper we focus on the types of discourse used in the workplace. Discourse practices are the ways that people communicate, mathematically and generally. Discourse in the broad sense is a 'communicative event', including conversational interaction, written text, as well as associated gestures, facework, typographical layout, images and any other 'semiotic' or multimedia dimensions of signification [10]. Here, we observed discourse in the workplace from the viewpoint of the participants and we concentrated on the use of teaching.

3. Teaching in the workplace

Graduates found they needed to modify their language and ideas depending on whom they were working with.

As David (working in a bank treasury) says about his manager:

> And he's an intelligent man, but he's not, he doesn't have, his background's not quantitative, but he's quite comfortable with quantitative ideas. But I don't think I'd be able to take him to the . . . calculus, that's not his cup of tea.

Presenting seminars and discussing new ideas with colleagues. In this case, graduates are in a work situation where there is an exchange of mathematical ideas. The graduates are combining the skills of listening and speaking in a semi-formal situation. In the following quote from Boris the group has been given an article to discuss, so reading skills are implied. Also of interest in the following quote is the reliance on the whiteboard in mathematical discussions:

> Boris (working in cryptography research): We basically have um, each week we have a seminar basically, and actually not a seminar, it's more a discussion group, then somebody just said, I want to talk about something, and you have an article or something that you hand it out beforehand, and it is actually the one that is supposed to be the most prepared. And you just go over talk to the . . . and we talk about what we don't understand, and how it affects you. But otherwise um, I can, I can always stand up, go to somebody['s] office and

> start talking about the mathematical ideas when we write on the whiteboard basically.
>
> Thi (self-employed as a mortgage consultant): Talking to colleagues we can go into a more technical discussion about our field and they'll understand the lingo. Predominantly, it's the lingo . . . whereas; if I was to start an in-depth conversation with a client I'd have to explain to them what every word meant first.

Instructing team members. Graduates talked about instructing their peers, junior staff or students:

> Heloise (working in a logistics company): Yeah, and then I'll go, 'OK sorry', and then I'll just re-word and then it might be a matter of just getting on to the whiteboard, just jotting a few things down to say, 'OK, say this, this, that, that,' and she'll go, 'oh, OK,' which really helps.
>
> Evan (working as an IT developer of mathematical products for a bank): Yeah, I guess . . . you've really gotta determine how much you need to let someone know. There's, there's, I guess there's a difference between giving someone all the information they need, and giving someone enough information for them to get what they need to do done. And that's probably the hardest thing to differentiate. You could go through the whole theory of it, but sometimes it's easier just to get them to the end goal.

Talking with colleagues and management. These interviews were done just after a scandal around foreign exchange losses in a major Australian bank and while no-one from that specific bank was interviewed, those at other banks were expressing their concern. In particular the risk operations of the banks were under scrutiny. James has implied, in the following quote, that the mathematics person is on the line and must be able to explain what is going on to management:

> James (working in a bank treasury): For example if you work in a bank, if you look at the issues right at the moment that are around its losses, if you have someone who is an expert in that field, they are going to be a maths person no doubt, I'm sure everyone in management is asking, 'what's going on here?' You need to be able to communicate in general and in jargon.

Sally worked with a range of people and adapted her language for each person:

> Sally (working for an insurance company): You can't expect a mathematician to speak and the other person to understand,'cause you really need to go back to an average person's level and explain what your thing is.

Paul developed the following method to modify his discourse when working with non-technical colleagues.

> Paul (working in a finance area for a bank): I have a hard time explaining things without being technical but it's probably partly my nature as much as my background. I think that the majority of ideas, if you sit there and think, 'how would I explain this (and this is how I think about it) to my brother,' then

> usually if you can work out how to explain it then it will work with my work colleagues.

Roger gives a clear description of how he modifies his discourse for mathematicians as against non-mathematicians:

> Roger (working in remote sensing for geological surveys): Well, fortunately there [at my workplace] both of the bosses were PhDs in maths themselves so they understood. So you could just leave everything in the mathematical form, you didn't have to first interpret it back into some hand-waving thing, you could just leave the equations, and then they could understand that. . . . If we had to give reports to the non-mathematical people, then we would use um, we would do examples, we would have our, all our own equations in the background but then we would [show] certain examples, like: If the mountain looked like that, for example, then this is what it would give. So in this way we would teach by example, almost, with lots of pictures to show the comparison, that was the easiest. It would have to be quite simple. And mostly examples with pictures, no, as few equations as possible for the general people. But for the, for our mathematician bosses then we could just say exactly what it was without trying to interpret it further.

Negotiating and selling ideas. Paul is talking about selling ideas to management and how he has to do it differently to how he would have proved it to a mathematical audience:

> Paul: In both my previous roles since uni, one was in structured finance and that one I was the only maths person, everyone else was finance, accounting something along those lines, and weren't maths literate so if I came up with ideas or something like that I'd have to dumb down the way I was explaining it because . . . if you try and sell an idea which is, like, here's a proof, and then prove something to them they are just going to look at it and go, well, 'so what? It doesn't mean anything to me'. You've got to actually sell the idea as an idea.

Both Paul and Roger, with the use of the words *dumb down* and *hand waving*, are expressing some attributes of being part of a mathematical community, which has its own symbols and discourse and is only open to those in the know. It is almost arrogance. They both feel more comfortable with the mathematics and dealing with those who are mathematicians.

Explaining to clients. Thi needs to work with clients who are not mathematically literate. These clients are borrowing money and Thi wants to be sure that they understand what they are getting into. This is partly due to legislative requirements associated with loans.

> Thi: Imparting the knowledge that you already know so that clients feel that what they're getting into is not above their head.

Teaching/explaining. Kay works as an associate lecturer at a university. She teaches statistics to students who are not statistics majors, so they often do not have specialist mathematical knowledge and may be mainly interested in statistics as applied to their subject area. She also works as a consultant statistician with colleagues. She likens the process of consultation to teaching as she tries to involve

the clients in the process of making meaning with statistics. She is educating her colleagues about the statistical process:

> Kay: So colleagues . . . I actually . . . I'll do it the same way [as teaching], pretty much, I just don't make it quite as simple so they don't feel like I'm treating them like a student but basically that's what I do. . . . I'll advise them and work through with them what's a good analysis approach, why's it a good analysis approach, what assumptions do we need to make and what sort of data do you have and what do you actually want to say from the . . . Like, that's probably the biggest is actually at the beginning, figure out what they did, why did they do it and what they want to know and half the time they don't even know what they want to know. So, that is the best . . . I love that' cause that's just like problem solving right there.

Writing

While the graduates talked to a large extent about oral communication, there were several instances where it was possible to describe their position on written communication as well, for example, [Heloise] *I'll just re-word and then it might be a matter of just getting on to the whiteboard.* This is an instance of informal writing but the whiteboard was an essential component of communication. Boris also talks about going to colleagues' offices and writing on the whiteboard. Informal writing is a powerful element of mathematical communication. Graphs, often demonstrated on computer, are a part of communication with less mathematical colleagues and clients.

Many participants worked with computer programs. They modified, constructed and applied programs. The development was often in a team environment and required planning and an obligation to meet the needs of the organization and clients. These participants had to convert mathematical and commercial ideas to computing solutions that were implemented in their workplaces.

Reports (for boss, for client, for management). The following quote from James shows that he struggles with the need for accuracy and writing for the audience. He has thought about how to do this and has worked out a way to present information without too much detail:

> James: Actually I try, it's a hard balance to be honest, for example I wrote a paper on the stability of the portfolio of deposits that we have and it's pure stats as far as standard deviation 99 and 95% confidence intervals for a report paper for example. So I'm using the maths in that but I wouldn't give them the spreadsheet with all the formulas on it. I'd just say 'using data back for the last 18 months I can be 99% confident that the portfolio won't be more than 3 or 5 million dollars in a day'. So I'm using the maths to get my answer that I'm trying to put it in a form where I just state that I'm 95% confident of this. If you want the details I'm happy to provide it. So that's, it's a fine balance because you have got to get the information there but you don't kill them with the detail. So I do use the stats to get the results but then how much of that do I use to explain the result? It depends on the audience.

Paul writes reports on the bank's risk position three times a week and has longer-term writing projects to research areas of interest to the bank. This would be more in the form of a report than an academic journal article. James is moving into a more legal financial area and expressed the need to develop his formal writing skills.

Listening

Participants attended meetings, negotiated with clients and colleagues and received instruction from others, particularly their managers. In both speaking and writing, graduates showed that they were sensitive to the need to consider their audience: *It's usually that glaze-over effect! When they start glazing over it's time to stop!* [Evan]. This implies that they are listening, at least to the body language of their colleagues. Graduates through their mathematical training have learnt to listen, but not to promote themselves or mathematics.

4. Peer teaching

Peer tutoring is defined as students taking on the role of a teacher to other students of either the same academic level or lower. There are three (not mutually exclusive) reasons why peer teaching is advocated:

- To improve the supply and quality of tutors for mathematics subjects [11]
- To improve the learning of those who are doing the peer teaching [12]
- To prepare students for teaching situations in the workplace (current paper)

4.1. *Improve the supply and quality of tutors*

Oates *et al*. [11] were unable to find sufficient numbers of qualified tutors for their first year mathematics subjects and so instituted a pedagogy subject in the second year of a mathematics degree. Students were taught how to learn and teach mathematics. They observed classes, wrote materials and reflected on their experiences. Students were then paid to conduct tutorials in their third year. The results were positive and the experience also showed that the peer teachers improved their own learning as is discussed in the next section.

4.2. *Improve learning*

Most of the work looking at the benefits of peer education has looked at the positive effects of reciprocal peer tutoring on various educational levels [13]. They found that peer tutoring is effective at increasing student achievement for both the tutor and the tutee, where often the tutor benefits even more than the tutee. Peer tutoring schemes have been implemented in a variety of subjects and educational levels. Carroll [14] discusses the effectiveness of senior medical students acting as co-tutors working in tandem with the academic tutor for first year biology students and Bush [15] describes a peer tutoring programme used for introductory accounting courses as a possible suitable substitute for laboratory classes. In both of these studies the senior students were paid as academic tutors and were able to relieve full time academic staff while at the same time providing quality tuition to first year tertiary students.

Peer tutoring has benefits not only for the tutee but also for the tutor as a means to promoting educational and personal development. Both Hopkin [16] and Houston and Lazenbatt [17] investigate the use of reciprocal peer tutoring within a class environment at a tertiary level where each student (or group of students) in the class is responsible for a particular topic and then takes on the role of the tutor, teaching that particular topic to the other students in the class. This type of peer tutoring

fostered independent and responsible learning, promoted greater levels of communication, student participation and a deeper understanding of the work involved (mathematics in Houston and Lazenbatt [17] and education in Hopkin [16]).

4.3. *To prepare for the workplace*

Preparing students for teaching as a graduate has some of the same characteristics as preparing them for teaching other students. One essential difference is that the audiences in the workplace are more diverse so the students need to be given diverse learning situations that reflect this. In the next section, we offer four examples of learning tasks that can be adapted for mathematics students to assist with their preparation for teaching situations in the workplace. Note this will also help their learning of the content area.

5. Examples of assessment tasks

We present four examples of assessment tasks to illustrate how this idea of teaching can be incorporated into mathematical tasks. Both are scalable and work equally well in small or large classes. As the tasks require some creativity, there is little risk of plagiarism that can be the bane of university teaching. Each assessment task focuses on a particular type of discourse that students will meet in the workplace. We have presented marking schemes that make marking and feedback effective and efficient.

5.1. *Written presentation of new ideas*

This assignment focuses on the skills required in describing and discussing new ideas with colleagues in the workplace. The target audience is fellow mathematics students.

Assignment 1: written presentation of ideas

Linear Algebra: Assignment 1
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

(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 Bonus marks may be awarded for exceptional work

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

Marking scheme
Question 1 (12 marks)

(a)	0	1	2				Correct definition
(b)	0	1	2	3	4	5	Good summary
	0	1	2	3			Good choice of article
(c)	0	1	2				Correct answers (total 14 marks)

Question 2 (16 marks)

0	1	2			Choice of material
0	1	2	3	4	Clear description of situation
0	1	2	3	4	Appropriate use of mathematics, diagrams, examples
0	1	2			Appropriate for the audience
0	1	2	3	4	Good teaching technique

Here is an unsolicited comment from one of the students who completed this task:

> One of the things that I find interesting about wavelets is the fact that they are such a recent notion. Although Alfred Haar discovered what is now recognized as the first wavelets in 1909 (and many other rediscoveries have been made since), wavelets have only really been used and developed since the 1980s. As a math student, I am used to hearing about functions and formulas that came into existence hundreds of years ago, so the idea that wavelets came into use within my lifetime was a nice change.

5.2. *Writing for management*

This assignment focuses on the skills required in talking with colleagues and management, and explaining to clients. The assignment specifically asks the student to imagine they are the only statistician in their workplace, and their target audience is management.

Assignment 2: writing for management

Seminar Statistics: Assignment 2
Please hand in your assignment in groups of 1 or 2 students.
Only hand in one assignment per group.

For this assignment you are asked to imagine that you are the only statistician working for StudyWell, a firm producing study guides for high school students. The firm has commissioned some market research in NSW and Queensland to estimate what proportion of final year students in each of these states will purchase the StudyWell brand of study guide. The market research company has given a quote based on a sample size of 200 students for each of NSW and Queensland, with a margin of error of 7%.

The manager of StudyWell asks you to explain what this means, and how the figure of 200 for each state has been reached. In particular, he can't understand why the sample size is the same for the two states when the population size of NSW is much greater than that of Queensland; and he wants to know what 'margin of error' means.

Write a memo explaining to your manager these concepts in non-technical language that is appropriate for a non-statistician. Consider using examples to assist your explanation.

Marking scheme

Assignment 2 (10 marks)

0	1	2	3	4	Correct statistics
0	1	2			Appropriate for the audience
0	1	2	3	4	Good teaching technique

5.3. *Oral presentation of ideas to non-mathematicians*

This assignment focuses on the skills required in interpreting mathematics for non-mathematical colleagues in the workplace. While it has been written to use an article, this task is flexible and students could be asked to give a presentation of how to show their staff how to implement an algorithm or change a mathematical idea into a numerical solution. It would be particularly good with developing programming solutions.

Assignment 3: critical reading skills and oral presentation

Aim: To develop skills in interpreting and disseminating information from mathematical writing in an appropriate form for a specified audience.

Section 1: For this task you may be given an article by your lecturer or you may choose one from an appropriate journal in your discipline area.

(a) Read the title, abstract (if any) and the first and last paragraph. Write down the aim of the article in one sentence.
(b) Now skim-read the article. Write down the three main points of the article in three dot points.
(c) Now read the article in detail. Write a summary of the article for yourself in about 100 words.

Section 2: Using the same article, this task requires you to prepare for an oral presentation of information.

(a) You are to deliver a 5 minute talk that interprets the article for your peers. List the points you would make and design appropriate aids, such as PowerPoint slides, to accompany the talk.
(b) Again, you are to deliver a 5 minute talk but this time it is to final year high school students. Here the emphasis is on how to present the material in a way that the students will grasp the ideas. Write down how you would deliver the talk, what you would say.

Section 3: Present the information to an appropriate audience.

Marking: Sections 1 and 2

0	1					1(a)	The aim is correct
0	1	2				1(b)	The three dot points summarise the content accurately
0	1	2	3	4		1(c)	The content and language of the summary are accurate and clear.
0	1	2	3	4		2(a)	Your content and overhead transparencies show accurate, clear and appropriate preparation for the required audience
0	1	2	3	4	5	2(b)	Your method of presentation, content and handout show accurate, clear and appropriate preparation for the required audience

Marking: Section 3

0	1			Your presentation is within the set time limits
0	1	2		Your presentation shows careful preparation
0	1	2	3	Your presentation is appropriate for the audience
0	1	2		Use of equipment is appropriate
0	1	2		Good use of eye contact and body language
0	1			Aids are readable
0	1			Voice is audible
0	1	2	3	Your mathematics is correct
0	1	2	3	Your presentation is effective
0	1	2		Your presentation is entertaining

5.4. *Report writing*

This assignment focuses on the skills required in writing a summary report of a large scale statistical analysis. A suggested format, which is typical of that required in the workplace, is given. This also builds the skill of following instructions on presentation. The assignment should be preceded by some examples of papers and how much is expected to be written, with some discussion of what should go in Methods, Results and Appendices.

Assignment 4: report writing

Seminar Statistics: Assignment 4

The Royal Botanic Gardens occupy one of Sydney's most spectacular locations, and are a popular destination for local, interstate and international visitors. As with many other tourist sites, it is important to keep aware of who is visiting the Gardens, the reasons for their visit, and the impressions that they take away with them. To this end, researchers at the Centre for Tourism and Leisure Studies, led by Simon Darcy, carried out a 'Visitor Use and Attitude Survey' in 1994–95, interviewing over 1500 users of the Gardens. (Students are given the data file.)

Analyse the data from the Royal Botanic Gardens Survey and write the results in a report suitable for submission to the management of the Gardens. Your report should take the following format:
Executive Summary. This should be less than one page in length and should highlight any major findings and recommendations.

Introduction. This should briefly summarize the survey method, number of respondents and type of questions asked.
Method. Also a brief section. Outline the statistical techniques you used to analyse the data with a short explanation in words of why each technique was appropriate.
Results. This will be the longest section. You need to report on all your investigations of the data, striving to present in as succinct a fashion as possible.

Conclusions and Recommendations. In this section you need to draw together the results that will be of most interest to management, e.g. the main characteristics of visitors; any areas which clearly need attention based on levels of visitor satisfaction; any particular insights that have arisen from your investigations. This section should give more detail to the points raised in your executive summary.
Appendix. Any tables or other output which you feel were too cumbersome to put in the Results section can be placed in an Appendix.

Marking scheme

Assignment 4 (20 marks)

0	1				Executive summary-clearly written
0	1				Introduction-clearly written
0	1	2			Method-clearly written
0	1	2	3	4	Method-correct statistical methods chosen
0	1	2	3	4	Results- correct statistics (including Appendix)
0	1	2			Results- clear and succinct presentation
0	1	2	3	4	Conclusion-insight and judgement
0	1	2			Conclusion-clearly written

6. Conclusions

Graduates use their mathematical knowledge in a variety of ways in the workplace. One significant way is in the communication of that knowledge to others; clients, managers, peers and junior staff. We recommend that students in undergraduate mathematics degrees develop these communication skills by using targeted learning tasks. Not only will they develop needed graduate skills but will improve their own learning in mathematics at the same time.

We have presented four tasks which will develop these skills. They can be adapted to different tasks and different groups of students.

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