Paper 539 Oral presentations
Main theme: Educational research
Secondary theme: Innovating teaching formats

Conversations with graduates: reflections on learning mathematics

Leigh Wood, University of Technology, Sydney, Australia. Leigh.wood@uts.edu.au
and
Anna Reid, Macquarie University, Australia. Anna.reid@mq.edu.au

Abstract This study examines the transition to professional work of 18 recent graduates after gaining a degree in the mathematical sciences. This paper reports on their reflections of learning at university and what they gained from their degrees by analysing their stories gathered using in-depth interviews.

The graduates' work situations taxed their resilience, many changed careers and others were frustrated with their circumstances. Most believed that university changed them and their work expectations, as David states: *It made me appreciate the bigger picture. It sort of opened up avenues of my career that I never would have ever imagined could have existed.* Knowledge of graduates' transition experiences, and how mathematical work is engaged with in the workplace, can inform curriculum review and development.

1 Introduction

This paper examines graduates' transition to professional work after gaining a degree in the mathematical sciences. We examine influences that helped graduates' adjustment to the workplace and their reflections on their learning. The aim of the study is to inform curriculum change for tertiary mathematics educators.

Mathematics has a high attrition rate from first to final year of university study. Consider the University of Sydney, Australia as an example; Taylor [1] reported that there are more than 2500 students studying mathematical sciences in first year, 200 completed mathematics or statistics majors and 25 studied a fourth year of honours. What happens to these few graduates who gain a major or honours in the mathematical sciences?

Graduates' transition experiences have rarely been studied. In tertiary mathematics education, the research effort is focussed on the transition to tertiary study and teaching and learning issues at that level [2]. There has been investigation of the mathematical needs of various disciplines, such as nursing [3] and engineering [4]. The UK Institute for Learning has surveyed employers about the mathematics needs of industry and the Mathematics Association of America has published a summary of research in the area [5]. Burton [6] investigated university and research mathematicians using in-depth interviews.

There is a dearth of research literature on graduate employment from the graduates' perspective. Johnston [7] argues that there is a need for research focussing on experiences of graduates in early employment; including relationships between higher education and work, working conditions, work expectations and satisfaction. This study aims to fill that gap for mathematics graduates.

2 Participants

The participants for this study were recruited from advertisements sent to graduates who had finished their studies in the previous five years. They had a range of employment situations, age, ethnicity and academic backgrounds. Some graduates had laboured through their degrees with many failures and 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. Their majors and job descriptions are listed in Table 1.

ID	Sex	Majors	Job description	Work area
Angie	F	Maths, Finance	Loan advisor	Banking
Boris	M	Pure, applied	Cryptographer	Security research
Christine	F	Pure, applied	Police officer	Police
David	M	Maths, Finance	Dealer bank treasury	Banking
Evan	M	Maths, Finance	IT	Banking
Fredrik	M	Maths, Physics	Technical officer	Hospital research
Gavin	M	Applied	Climate modelling	University
Heloise	F	Stats, OR	Logistics analyst	Industrial
James	M	Maths, Finance	Corporate treasury	Insurance
Kay	F	Statistics	Statistician, tutor	University
Leah	F	Statistics	Clerk	Government
Melanie	F	Applied	Musician	Entertainment
Nathan	M	Applied, IT	IT development	Self-employed, Industry
Paul	M	Maths, Finance	Trading risk management	Banking
Roger	M	Pure, applied	Modeller, programmer	Geological survey
Sally	F	Statistics	Statistician	Insurance
Thi	F	Engineering, Maths	Loan support	Self-employed, bank services
William	M	Actuarial	Instructional designer	University

Table 1: Description of participants

The participants were interviewed using a semi-structured protocol for about one hour each. The transcribed interviews were analysed using a phenomenographic paradigm [8]. The process of finding and settling into employment has been reported elsewhere [9] and we showed the difficulties that graduates experienced with gaining appropriate employment. We also illustrated the importance of the graduates' manager and colleagues in assisting with the transition to work.

3 Results: Focusing on the professional domain

How did learning mathematics at university prepare these participants for professional work? Their responses can be summarised into three categories:

- Specific skills
- Generic capabilities
- Personal growth

3.1 Specific skills

Graduates learnt specific skills to get them the job! They particularly mentioned technical skills or the piece of paper, which showed they had met the requirements for a degree.

Nathan: But what I did learn at uni which I couldn't have really got elsewhere was that the skills set where I could sort of lay a foundation and, you know, put my foot out in the door and, sort of go into the workplace and move from there.

Heloise: Well it got me the job for starters!

3.2 Generic capabilities

The participants described how they had learnt ways of solving problems and ways of thinking that they used in their working and, in some cases, personal lives. Their university education taught them to think analytically and abstractly, to define the edges of a problem, to look for more optimal solutions and to model problems in a mathematical way. The term 'problem solving' was used in a particularly mathematical way, that is, it was mostly applied to technical problems in their workplace. Ways of thinking and logic were seen as more general and widely applicable to life in general.

Fredrik: without that grounding [university], you don't approach problems, the best way, to being able to solve them. It's not the most or the optimal way to solve a problem. …it's [university] taught me that, there's an easy way to do something, and there's a hard way to do something. And sometimes the two aren't easy to, well there can be many options, sometimes it's not easy figuring out which one, which road to take. But you know that you're there, and you start looking for a simple way or an easy way to do it.

Melanie: Problem solving and just thinking about a problem logically is, you know, transferable to anything.

James: I think it helps me out for the future roles that I want to take, not because necessarily you go to a particular class and you've learnt how to do a particular thing but just the different way of thinking about problems.

3.3 Personal growth

Participants experienced a huge confidence boost and felt great pride in finishing their degrees. University study had broadened their horizons and helped them to push for more responsibility. It changed their mindset and helped with confidence in tackling different types of problems.

Paul: Well, a. it gives you a background in something and a confidence in your background so you know that you've got confidence in yourself and it gets you into a problem solving mindset where you want to take on a problem 'oh this is interesting' and its stretching my mind a little bit so you want to take on that kind of work.

Roger: It is a kind of confidence and experience that you don't feel bound by rules

Angie: Well, I think it gives … finishing a course like Mathematics and Finance gives you a great boost in confidence and a big edge.

Graduates suggested that finishing a degree in mathematics demonstrated their determination and their ability to apply themselves to complete difficult programs. Participants stated that university had taught them to work hard to achieve what they wanted and that this had been good preparation for work. The following quote by Christine shows how important failure was to her. It defined her experience of university and changed her attitude to learning. Failure can be a crucial event and excellent motivation.

Christine: I probably wouldn't say that going to university helped me as far as work is concerned, it was more failing for the first year that really hit home that I had to work for what I wanted, so that, that helped me. But the fact that mathematics is not the sort of subject you can just, you know, figure it out in the last week of semester, read a book and you'll be right, because of the type of subject it is, you need to be working throughout the whole thing, so by the time I eventually finished my degree, I suppose that sort of taught me … I had to work for what I was getting. So, that … university in general could have taught me that, but because I was doing mathematics it was more, more of an effort, so …

4 Results: Focusing on university learning and teaching

Participants made suggestions to change university programs that could have assisted their transition to the workplace. There were suggestions about content, computer skills and personal skills. Some ideas were the obvious domain of academics (that is academic content) and other suggestions were concerned actually getting a job such as; interview skills and knowledge of the employment market. There was appreciation of the diversity of jobs that universities are preparing students for and that the role of universities is not necessarily vocational; that the broad aim is learning. Nevertheless there was robust criticism of teaching and the way content is delivered at university, in particular the lack of overall coherence and a failure to link areas of knowledge. Especially strong was the perceived failure to link areas of knowledge to real situations. Good teaching, they suggested, made a difference. When Gavin talked about why he studied mathematics he said: *It was a good lecturer. And I wasn't doing as well in maths as I was doing in physics, but, a good teacher makes it much more exciting.*

4.1 Changes to technical content

There were suggestions about technical content. The majority of these were to do with specific computer products, such as Excel, Visual Basic or SAS (a statistical package). The following quote was typical.

James: As far as transition for work, everywhere uses standard products like Excel, and if you come out of a maths degree, I wasn't really taught to use Excel all that much here [at university] and I think it's really a tool of the trade.

In general, graduates felt that they knew far more mathematics than was needed for their jobs. This was not always seen as a negative as Roger says: *It is always much better to know a great deal more than what you actually use*. Others were frustrated about having so much knowledge that they were not using. No one suggested that they required extra mathematical content for their jobs, though some needed to revise content they had covered in their courses when needed on the job.

4.2 Changes to teaching

The criticism of mathematics learning and teaching at university level was disappointing given the work done by mathematics educators over the past 20 years. However research on mathematics teaching and learning at university level has increased in the past 10 years (see, for example, the ICMI study on University Teaching and Learning, [10]) and it takes time for developments to filter through to the chalk face. Burton [6] too, considers the lack of action on learning and teaching mathematics at all levels. Indeed her book finishes with a plea for changes in the teaching and learning of mathematics.

Group tasks were strongly recommended by graduates as an important way to prepare for the workforce. Graduates who had studied in other disciplines where a greater range of teaching methods were used felt that this was an advantage in the workplace. Thi (and others) believe

that you really learn a topic if you teach others and they recommended that opportunities for teaching be incorporated into learning tasks. This resonates with the work done on peer teaching by Ken Houston at the University of Ulster [11] and many studies on collaborative learning, summarised in D'Souza and Wood [12].

> *Nathan: …the maths studies that I did were a lot more, what's the word, individualized. So you get a project or an assignment and you work on it on your own, pretty much, and that's it and then you do your exams and you pass or you fail. So, it's very much an individual's sport, if you like. Whereas, doing something like psychology or business studies is a bit more of a team sport.*
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> *Kay: I think that the more group-work that we're doing we're forcing people to learn to communicate*

Many of the changes suggested by graduates were structural. Some believed that the lecture situation is not conducive to learning, others suggested formal work experience as part of their degree and James suggested a third year subject on transition. Laboratory learning for statistics and computing received positive commendations.

There was a constant theme about subjects not being related to each other and students having to make connections themselves. In joint programs, such as mathematics and finance (which is a set degree with half mathematics and half finance) students expected integration between the subject areas but this did not happen. Even for those who did straight mathematics degrees, the graduates perceived that the subjects were not linked or put in the wider context of mathematics as a discipline. What is clear from this study is that, for this group of graduates, links between subject areas were not made explicit.

> *Gavin: That's the problem with most university courses is that you're not introduced to the philosophy of the course, you know, you're not introduced to the motivation of the course, you just go straight onto the content.*
>
> *Boris: Actually, I'm take [?] it for courses a bit more integrated with each other …. In my honours year, there were honours subjects and in the beginning you get the idea that they are starting to deal with each other, and at the end of him it's actually have idea why they have something to do with each other, I think that in the middle of the next semester you actually realise why they have actually something to do with each other.*
>
> *Melanie: […] this is a left field idea as well, but like if the very first lecture of any course was given by somebody who wasn't actually going to be the lecturer of that course, but just somebody who had good communication skills and could actually put the whole course in context.*

Students are often isolated in mathematics classes. Graduates requested more interaction in class and less content driven curriculum.

Christine: the classes aren't big, you've got maybe 20 students in a class, but I couldn't have told you a single name of someone in some of those classes. I've just, there was no interaction with other students, for a lot of the time, … so perhaps if you start up with a bit of the touchy-feely stuff, and just getting to know everyone, and I don't know if other people do that sort of thing, but that perhaps would have been a bit nicer. Just to make, encourage more discussion in the class, cos I think there's so much to get through in the course that it's just, Day 1, right, this is my name, this is my contact details and all that sort of thing, right let's begin. And then it's just scrambling through it for the rest of the semester.

Graduates wanted more exposure to real world situations as part of their learning.

Nathan: I think that you could probably, if you had a lot more exposure to the 'real world' as part of your learning process, I think you can't go wrong.

Several participants believed that they should have taken a more vocational degree after surveying the job prospects on graduation. If gradates are finding it difficult to gain employment using their statistics and mathematics degrees, universities will find it more difficult to recruit students to those programs. The majority of graduates do not move into higher degree studies and most will want to use their qualifications to secure employment.

5 Conclusion

Graduates learnt technical skills, generic skills, in particular problem solving and logic, and they gained confidence from their mathematics learning at university. University study opened their eyes to broader horizons, encouraged them to assume more responsibility and taught them that they needed to work for their goals.

The study revealed serious areas of under preparedness for the workforce. Graduates were unprepared for the office environment or to deal with colleagues and managers. Their first experience, particularly with their manager, set the scene for their adjustment. Many of the mathematicians were alone with their area of expertise and had to adjust to the language of those around them – with no training for this from university. This particular finding is startling. Participants in this study attended institutions that had focused on the development of generic skills intended to enable students to become work ready. However the graduates themselves did not perceive the universities' efforts in the same way. The teaching of generic skills was not sufficiently explicit for the students to develop the skills needed. Most were unprepared for the job seeking process itself and had to educate employers on their skill set.

Reflecting on university teaching, many graduates were disappointed with their mathematics teachers, in particular the inability of their lecturers (and by implication the curriculum designers) to place their studies in a discipline context. This included linking subject areas (for example, a pure mathematics graduate had no idea about applied mathematics or statistics) and making broader connections to the outside world. Graduates asked for more group work, more realistic problems and a more personal approach from their lecturers.

Many of these problems could be alleviated by changes in curriculum that would be cheap and effective to implement. Firstly, course designers and lecturers should make connections between subject areas explicit – explicit to the students. Group work in subjects is relatively easy to implement and will not add cost to the course. Other teaching and learning suggestions should be seriously considered. A well designed third year *Transition to the Workforce* subject could lead to the study of a project, consulting or peer teaching and develop many of the generic team and communication skills needed for the workforce as well as consolidating mathematical skills. This could be complemented by smaller 'real' projects

in previous subjects. Universities can coordinate opportunities for work experience in the university vacations. There is need for all agencies of the universities to work together to assist in the transition to the workforce.

Given that graduates are not using all the mathematics that they learnt at university, there is opportunity to reduce the amount of content and increase the development of generic capabilities and general learning skills. After all, mathematics is changing in complexity, scope and application and graduates will need the skills to be able to learn new areas that are not in current degree programs.

Mathematics graduates require a broad range of skills to succeed in the marketplace. Graduates also suggest that employers should be made aware of the range of mathematical and professional skills that graduates can offer to the workplace. There is a need for curriculum reform to assist with transition to the workforce in technical areas so that we do not squander people who have learnt technical skills, but not job seeking and generic skills that will help them secure employment and thrive in their careers.

6 References

[1] Taylor, D. Firmness, commodity and delight. *Gazette of the Australian Mathematics Society*. *32*, 5. 2005. pages 298-301.

[2] Wood, L.N. University Teaching and Learning. *MERGA Review of Research in Australia 2000-2003*. 2004. pages 219-242

[3] Hoyles, C., Noss, R., & Pozzi, S. Proportional Reasoning in Nursing Practice, *Journal for Research in Mathematics Education* 32,1. 2001. pages 4-27.

[4] Kent & Noss, R. *Mathematics in the university education of engineers*. Ove Arup Foundation Report, Ove Arup Foundation, London. 2003. Retrieved 28 June 2005 from http://k1.ioe.ac.uk/rnoss/REMIT/Kent-Noss-report.pdf

[5] Selden, A. & Selden, J. Examining how mathematics is used in the workplace. *Mathematics Association of America*. 2001. [accessed 9 February 2006] http://www.maa.org/t_and_l/sampler/rs_6.html

[6] Burton, L. *Mathematicians as enquirers: Learning about learning mathematics*. 2004. Dordrecht:Kluwer.

[7] Johnston, B. The shape of research in the field of higher education and graduate employment: some issues. *Studies in Higher Education, 28*, 4. 2003. pages 414 –426.

[8] Marton, F. & Booth, S. *Learning and Awareness*. 1997. Laurence Erlbaum, UK.

[9] Wood, L.N. & Reid, A. Graduates' initial experiences of work. *Proceedings of the Australian Association for Educational Research*. 2005. [Online].

[10] Holton, D. *ICMI Study on Teaching and Learning of Mathematics at University Level*. 2001. Kluwer, Dordrecht.

[11] Houston, S.K. & Lazenbatt, A. Peer Tutoring in a Modelling Course, *Innovations in Education and Training International*, 36. 1999. pages 71-79.

[12] D'Souza, S.M. & Wood, L.N. Tertiary students' views of group work in first year. *Proceedings of the Australian Association for Educational Research*. 2003.[Online].