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Different Disciplines, Different Transitions

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There is not just one mathematics taught at university level, nor is there one group of students. Mathematics is taught differently depending on the discipline and the perceived background of the student. There is engineering mathematics for the students heading towards engineering degrees, life science mathematics for those heading towards biology degrees and so on. This paper considers the phases of transitions that students experience as they embark on a course of study and then go on to professional life. We make inferences about the ways the curriculum should be designed to alleviate the difficulties of these phases as well as to take account of the capabilities that graduates will require in the workplace. It is not only where students are coming from that affects their learning but where they are heading to, in combination with their perceptions of that destination.

There have been numerous studies on the transition from secondary school to university mathematics study (international summarised in Wood, 2001, and Australasian in Wood, 2004). There are also general studies of graduates and requisite graduate attributes, such as Scott (2003). The transition to university and its challenges are well recognised (DEST, 2006). What is less understood is the transition from university to professional work; how people change from being students to developing a professional identity and professional skills and attitudes. This paper considers the transition from school, to and through university in the light of the preparation of professionals who use mathematics in their study and professional work.

We contend that the connection between what is learnt and professional work is not clear to students. Learning mathematics as a service subject as part of a degree programme in engineering, life science, optometry and so on can make the connection even more tenuous. Our hypothesis is that a clear understanding of professional capabilities, needs, and transitional phases will encourage a deeper and more personally relevant engagement with the subject matter. There are multiple transitions that begin at school and are significant in the transition to university and beyond.

We start with a brief literature review and move on to discuss transitions and graduate capabilities, then conclude with student experiences.

Background

Mathematics curriculum content in Europe has been influenced by the Bologna Declaration (Ministry of Science, Technology and Innovation [Denmark], 2005) where there has been discussion of the mathematics and statistics taught at various levels and types of degree programmes (Bringslid, Rodriguez, & de la Villa, 2007). The Bologna Declaration attempts to standardise levels of education across members of the European Union. For example, Bringslid et al., (2007) give lists of topic areas and learning suggestions and believe that mathematics learning must take the changes in technology into account and that mathematics therefore cannot be taught as it was 50 years ago.

In Australasia, Wood (2004) identified 111 articles dealing with teaching and learning of university mathematics for the period 2000 to 2003. Many were studies on first year and bridging mathematics showing that this continues to be a fertile area for innovation in learning and teaching. There were attempts to “hook” first year students into mathematics; for example Varsavsky (2002), who found that 60% of science students do not finish their degrees and so need some incentive to connect with their studies. Kirkup, Wood, Mather, and Logan (2002) discussed the ad hoc nature of service teaching and difficulties of communication across disciplinary boundaries. There were very few articles on graduates or the skills they need for the transition to the workplace. Recently Franklin (2005) described a subject he has introduced (as a requirement of his university) on ethics to assist mathematics majors in the transition to the workplace.

In a large study of mathematics use in industry in the UK, Hoyles, Wolf, Kent, and Molyneux-Hodgson (2002) found that their case studies suggested that at all levels of the workforce:

- Mathematical literacy can contribute to business success in an increasingly competitive and technological based world-wide economy.
- There is an inter-dependency of mathematical literacy and the use of IT in the workplace but that this is not always appreciated.
- The findings have implications for adopting a more systematic approach to business success in terms of appreciating the critical part played by employee’s mathematical skills and knowledge. (Hoyles et al., 2002, p. 4)

As part of the Hoyles research, Kent and Noss (2003) studied engineering workplaces and found that they made extensive use of mathematical modelling and higher-order mathematical concepts. Whilst they made wide-ranging use of computing tools, the engineers made no use of calculus or routine mathematical manipulation and needed better skills in explaining mathematical ideas.

In Australia, Wood (2006) interviewed 18 mathematical science graduates and found that they did not use some of the mathematics taught, but had to learn other mathematics post-graduation in order to meet workplace demands. They also needed more computing, both mathematical and general, and better communication skills, and particularly mathematical communication.

Several studies have pointed to the difficulty for undergraduate students in envisaging what working as a professional will be like. The study by Reid et al. (2005) used phenomenographical analysis of in-depth interviews to show that students who had a good idea of professional work were able to better focus on studies at university. In this study, students were also asked about how they would use their knowledge and skills in the workplace. All of the students were studying for a B.Sc. in mathematics with majors in statistics or operations research. For this group of students, their future role was not clear at all and we quote student responses to demonstrate this. The students were asked what they thought it would be like to work as a qualified mathematician.

> Gabrielle (3rd year, statistics major): Um, I have no idea. Um I don’t know, because I don’t know what the industry is, as I say, I haven’t really investigated anything much, I went to some careers fairs, I went to the careers fair this year, and that was the first attempt that I’ve made to have a look into anything that’s to do with the industry at all.

> Hsu-Ming (2nd Year, statistics or operations research major): Don’t know, don’t know, don’t know, no, I’m not really sure. … Who knows, I certainly don’t, I don’t know what I want to do.

> Candy (3rd Year, statistics major): Well actually, a lot of people ask me what degree I'm doing and I tell them I'm doing a mathematics degree and then they go, "Oh, what's that going to get you to do in the real world?" And, I'm not exactly sure myself, so I can't really imagine what it will be like to work as a mathematician, or be recognised as a mathematician until I graduate, and a lot of people wouldn't even realise, they will be probably thinking, "What can a mathematician offer me?"… It's not like an accountant, lawyer, like that's just straight away, "Oh I need one of those," but like with a mathematician, "What can I do with a mathematician, what do I need one for?" you know. So I'm not exactly sure, because right now that's what I think as well, I think it will become clearer to me once I probably maybe start going to interviews, applying for jobs, then I will probably realise what people are looking for, and what people see mathematicians as, because at the moment I'm not very clear either on that.

> Elly (3rd Year, statistics major): That's funny because 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.

It is clear from these student quotes that they have little idea of the type of work they could be doing in their chosen profession. Moreover, this ambivalence or lack of awareness for what mathematics is and how it can be applied cannot be a consequence only wrought through tertiary education. The students quoted above appear to have no clear idea of their progression from school to tertiary continuation and on into employment. The procedural chain of orientation and experience that leads to being a professional mathematician appears to be weak. School mathematics has not helped them to visualise what it would be like to work as a mathematician but neither has university. It appears that the transition form school to university has not altered the students' ideas.

It is interesting that, despite the cost and time commitment required to complete a degree, many students do not seem to have a good idea about professional work. It is possible that the families of many of these students are not professionals themselves. Reid, Wood, Petocz, and Smith (2005) did not ask participants about the status of their parents or communities.

We believe that these students need assistance in developing an identity as a professional and that one of the roles of the transition from school to university is also to foreshadow the future transition to professional work.

Transitions

Purnell (2002) portrays the stages of transition into university as being preparation, encounter, adjustment, and stabilisation. On preparing for and entering university preparation-encounter-adjustment-stabilisation phases occur as students negotiate the sometimes traumatic separation from school and pre-university status and the methods of working associated with it, before re-establishing themselves within a new university social community. According to Purnell (2002), models of transition are useful process tools that help us to understand where we can invest time and effort in supporting students through the various transitions they undergo. Taylor et al. (2007) have adapted Bridges' (2003) phase of transition to develop a model of transitions, described as 'A Student's Learning Journey', in Figure 1. This has three rather than four stages as in Purnell's scheme, and perhaps better captures the journey from pre-enrolment to graduation and work. The three stages are separation, transition, and reincorporation.

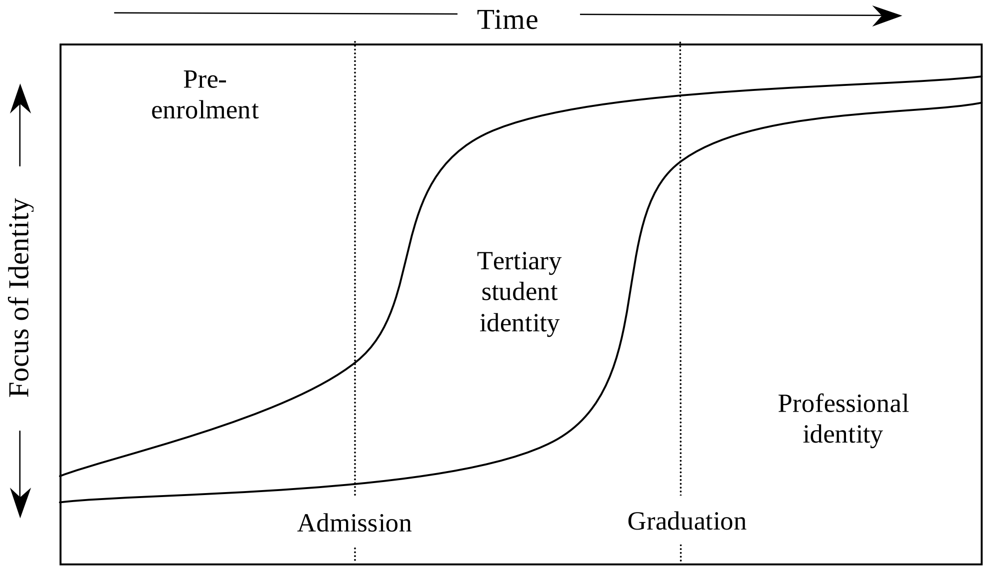

Figure 1. A student's learning journey (Taylor et al., 2007, p. 2).

It is implicit in this model that the pre-enrolment identity includes a view toward employment, which comes increasingly into focus as they approach the point of graduation, the transition into work and the adoption of a professional identity. How realistic that initial view is, or even if it is present at all may be a moot point, especially when one considers that students leaving school may have a relatively immature understanding of what mathematics can offer beyond calculation. The idea that mathematics might lead to applications and work in a variety of professional domains is relatively unformed in the mind of the school leaver (Petocz et al., 2007).

Of course these phases of transition are not final and the student will not experience them in "unambiguous finality"; moreover, the authors state that the model suggests that:

> …the focus of identity work—*the ongoing achievement wrought out of emotional and epistemological labour in the context of actual daily work*—changes over the period from pre-enrolment to post-graduation. It acknowledges that, even before enrolment, students necessarily have begun the transition to both the tertiary student identity, and their anticipated professional identity. (Taylor et al., 2007, p. 3, emphasis in original)

This model has implications for what we expect of mathematics students, suggesting that we need to look at both where they have come from, as school and pre-university students, and their induction into being university students, and towards where they anticipate being, or will be, professionally. As a consequence we must accept that some of the academic discourse and learning demands we place on students may be at odds with both the community of practice and the perception of students. Following our earlier comments about the chain of transition from school to university to the professions, perhaps there should be more time given to the rigorous orientation university pre-entry and entry students to the creative *and* vocational nature of mathematics at university and beyond. This would be through the use of authentic tasks and experiences rather than more superficial or adjunct activities.

Transitions are inherently challenging, as illuminated by the separation-transition-reincorporation phases identified by Bridges (2003). Separation is the move away from established beliefs and values; transition is the in-between, liminal stage where ambiguity may be experienced; and reincorporation is the stage where the individual becomes accepting of and accepted by the new context of being. Given the nature of each stage it is hardly surprising that transition involves emotional challenges. Reid and Solomonides (2007, p. 31) described students moving through "cognitive and emotional borders" as students focused their attention on different parts of their anticipated professional and internal life, depending on whether they focused on some future profession, being a learner, or being a student at university, and so on.

Meyer and Land (2005) promote the idea of *liminality*, which is the transitional phase one has to get through before some form of personally meaningful engagement is reached, rather than mimicked. This implies there is a threshold that has to be approached and negotiated on the way to "epistemological transitions, and ontological transformations" (Meyer & Land, 2005, p. 386). It is reasonable to ask therefore how these transitions are experienced and managed by students with varying professional intentions. Whatever the transitional status of students, we can conceptualise the points of transitions as "risk management points", or stages at which there is a danger of either alienation (especially on entering university) or rejection (especially on entering work).

By considering the various transitions that students have to negotiate, we can start to build a picture of the student experience. We expect students to make the transition from school and into the academic discourse of university study and then more broadly to the professional discourse specific to their discipline. On entering university students are expected to learn in ways they may not be familiar with, which may be imposed on them by the curriculum, assessment and conceptions of teaching and learning held by university tutors. The school leaver also has to develop an undergraduate student identity involving attitudinal and social constructs that on the one hand may involve 'learning the rules' of being a student and, on the other hand, may include fitting into the social scene and dealing with new-found freedoms and opportunities. As regards movement to professional identity, the transition can be characterised as taking on the role and status of the professional and all that that entails from gaining workplace acceptance through to behaving in a professional and industrious manner. These various transitions are summarised in Table 1.

Given the various transitions and inevitable expectations placed on students by the curriculum and academic staff, clearly there are opportunities for things to go wrong. Taking a risk management approach we can begin to suggest some techniques for managing student perception and thereby minimising risk. Later we will consider the expectations of academic staff but for now we will consider the student position.

Table 1
Student Transitions and Contexts

Transitions and Contexts	School	University	Professional
Discourse	Limited academic	Academic	Discipline-specific
Identity	School student	University Student	Professional
Learning	Very structured	Structured	Self-directed
Mathematics	Disconnected calculations	Structure, abstract and modelling	Flexible application in context

In Australia, all students who have completed degrees are invited to respond to a Course Experience Questionnaire (Graduate Careers Australia, 2006) that includes open-ended questions. In a study of the very extensive open-ended responses, Scott (2005) identified a number of key implications for learning in higher education. To foster productive learning, he established that the total experience at university is critical and that this encompasses appropriate and consistent combinations of course design (responsive, flexible, relevant, and so on); capable, committed and responsive staff; efficient and responsive support systems; and relevant assessment. Scott (2005) re-affirms that what counts in the success of students is their perception that life at university is:

> relevant (e.g. to any one or a mix of the following: their career, further study plans, their general interests and a range of social as well as intellectual needs); desirable (e.g. consistent with their general values); distinctive (e.g. has potential to give them 'the edge' in a highly competitive market); and, most importantly: achievable (that is, they can feasibly manage what is being asked of them, given other life demands and their particular background, abilities and experience). (p. xiii)

Encapsulated in this view is the potential for mismatch between what is expected by academic staff and what is achievable or willing to be provided by students. Empirical studies by Solomonides and Martin (in press) point toward the different conceptions academic staff and students hold in relation to *student engagement*.

Student engagement is seen as a commitment to learning, or the time, energy and resources students devote to learning activities (Krause, 2005). Student engagement can be considered as an holistic concept relating to the full experience and practices of being a student and of learning. Fostering student engagement may in part be achieved by enhancing the transition experience of students into and through university. Engagement is significantly affected by the experience students have of these transitions. (DEST, 1999; Kift, 2004; Rhodes & Nevill, 2004; Krause et al., 2005). Krause (2005, p. 12) provides "ten working principles for enhancing student engagement", whilst Kift (2004, p. 6) describes broad principles to enhance engagement including:

> Develop the curriculum and align it for coherence, sequence, and cumulative development of higher order thinking and academic skills.
>
> Realise that students need to make personal meaning of their learning context by constructing rather than acquiring knowledge.
>
> Reform the curriculum based on 'contemporary realities' (who our students are,

their 'fears, preconceptions and stressors, acceptance of their multiple roles') in the support of professional development and life-long learning.

In particular, the last point raises some important issues regarding how best to incorporate the realities and needs of school leavers and their relationship with university education.

To illustrate briefly the nature of student engagement, consider the following from a study of 47 undergraduate students by Solomonides and Martin (in press) that focussed on students' descriptions of engagement with their design studies. In the excerpts below, students are reflecting on the relevance of study material against their developing identities:

> Craig (3rd Year, Design) So if you just learn the material you are so focussed on the course and you don't know how to apply it, you don't know where it fits in … you think, 'Why am I learning this, where is it going to be applied?' so you really need to know if you can understand and see how it fits in, then you will probably be more interested.

The student is describing a desire to develop a personal identity and sense of relevance whilst still in the undergraduate context. This sense of self and enjoying being a 'mathematician' or an engineer or any other professional identity seems important to many, for example:

> Bryan (4th Year, Engineering) Being able to enjoy the work I do is so important to me, it's almost like playing a sport for a profession; professional sportsmen and women training and playing their sport for a good salary (or average salary, the pay is not important, doing something I love for a living is enough for me) … using my skills and rationalism to provide solutions for a living is a dream come true … I love having the problems to solve.

Equally students can focus on the utility of activity:

> Nick (4th Year, Engineering) Anything that you can relate to your studies can help to engage you. If I am fully involved in a project, I feel happy and confident about what I am doing and most importantly I am enjoying it. It is relevant or useful.

Besides these student descriptions of engagement, the study (Solomonides and Martin, in press) also collected data describing academic staff conceptions of engagement. When compared with the students' descriptions it became clear that staff tended to have an expectation of student engagement based in cognitive and conative frameworks. Students on the other hand had a strong emotive or affective perspective. As a debate emerges into *styles* of engagement (Coates, 2006) then we must consider the interplay between what academics think student engagement is and how students themselves see this engagement. Mismatches in style between tutors and student may have significant if not disastrous effects on sense of engagement and learning outcomes. This phenomenon is described by Bryson and Hand (2007) who suggest that:

> staff generally desire to pitch the level of interaction with students at a relatively high 'academic' level. ... [this] entails that… students are not perceived as working hard enough or being diligent about study and teachers feel powerless to do much about this … This mismatch of expectations between the two parties is not only problematic for staff but is likely to lead to rather less meaningful experiences for students. (p. 11)

Thus academic staff need to be keenly aware of the discourse, identity and learning that they promote and that they expect students to strive for. Based on studies into conceptions of teaching, it is argued that academic staff can be seen to hold a range of conceptions about what is most appropriate in the teaching of transitional students (see for example Prosser & Trigwell, 1999, pp. 134-163). Surveys of teaching conception and philosophy have emerged such as the Approaches to Teaching Inventory (pp. 176-179) and the Teaching Perspectives Inventory (Pratt & Collins, 2001) with an assumption that these should be the focus of efforts to improve teaching although this is disputed elsewhere (Devlin, 2006). As academic staff we can fall into the trap of placing greater emphasis on student background and perceived deficits, rather than focusing on where our students are heading—there is little real evidence to suggest that students must master at school, the whole gamut of serialistic or prerequisite mathematics skills in order to be able to work with mathematical ideas at a higher level in their university studies. Even if students do not possess such skills on entry to university, they tend to acquire them later as long as they perceive them to be necessary. Indeed, some graduates have to self-augment their mathematics and applications in order to meet work demands (Wood & Reid, 2005). Our concern is with the perception of the student rather than the perception of the academic member of staff, since it is the student's perception that will have the greatest influence on their degree of success, in university or in the workplace. This is confirmed through the work of Scott (2005) and the notion of relevance as described earlier.

The Studies

In this section we expand our argument based on the results from two studies that Wood has been involved with, which serve to illustrate the transitions made by undergraduates and graduates. One study involved 18 graduate participants who were within five years of graduation with majors in the mathematical sciences. Graduates were invited to participate in the study by the alumni associations of Macquarie University and the University of Technology, Sydney. There were 10 males and 8 females and 8 spoke languages other than English as their home language.

The other study was an international investigation of almost 1200 students studying mathematics as part of various degrees at five universities in Northern Ireland, South Africa, Brunei, Canada and Australia.

For the first study, Wood (2006) undertook in-depth interviews focusing on the participants' experience of their transition to work. Those interviews were analysed using a phenomenographic methodology. The interviews showed that many graduates were not prepared for the process of getting a job and they found it difficult to get work. 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.

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 success of the transition to the workplace, which was eased where they had the support of their manager (Wood & Reid, 2005).

The second source of data is from an international study of undergraduate students (Wood et al., 2006; Petocz et al., 2007). In order to elicit the range of opinions, three open-ended questions were developed:

> Question 1. What is mathematics?
>
> Question 2. What part do you think mathematics will play in your future studies?
>
> Question 3. What part do you think mathematics will play in your future career?

The analysis of responses to the first question, "What is mathematics?" has been reported in Petocz et al. (2007) who found that these students' conceptions of mathematics ranged from a narrow view of mathematics as calculations, through the idea that mathematics has a modelling or abstract structure, to a broad view of mathematics as an approach to life and a way of thinking. Later year students showed significantly broader conceptions of mathematics showing students conceptions had broadened through their degree. The conceptions held early in the degree (the surveys were done in the first weeks of first year) reflect the students' conceptions from secondary school. Already, at the beginning of first year some students had broad conceptions of mathematics but most had a narrow view of mathematics as calculations, tools or operations. There was also a hint that students in service mathematics courses had narrower conceptions of mathematics. This link between discipline and conception of mathematics is currently being investigated with a closed form questionnaire.

Analysis of the third question, "What part do you think mathematics will play in your future career?" reveals that undergraduates hold a range of ideas and positions relative to the transition journey. These appear to align with the phases of separation, transition and reincorporation as described by Taylor et al. (2007, p. 3) described earlier.

Some students in our study showed ambiguity in their ideas about how useful mathematics would be in their future profession, and were very unsure about how the mathematics they were studying would be used:

> Dunno, get back to me in about 10 years.
>
> I don't know what career I am going to pursue so I do not know.
>
> I have no idea what my future career is going to be.

This is consistent with the first phase of the student learning journey—separation—where there is a perceived loss of control and a clear sense that they do not know how to respond to the new situation.

Other students appeared to be seeking some clarification of the role of mathematics and as such demonstrate liminality. This is a true transitional phase, as suggested by these quotes:

> I don't think it will play a big part in my career as I am not too fond of the subject and I would hope to get a job in the computer industry.
>
> If I become an engineer I think it will help me make better decisions based on mathematical processes.
>
> Most of the maths we will learn will probably be totally irrelevant in my future career, so I think we should only learn what is needed!!! Apart from the irrelevant stuff – it should help at some stage in my career—hopefully!!!

> I'm not really sure that it will play a big part. Most of this seems pretty useless.

> To be honest I'm not entirely sure. Originally I thought it would have minimal, since I thought I would concentrate on the IT part of my studies. But I'm now open to any job opportunities math may open for me.

These students appear to be uncertain and somewhat ambiguous about mathematics in their careers. This ambiguity is consistent with the second phase of the journey – transition. Students in this liminal phase are at a significant point in their development where on the one hand there is an opportunity to reach a more personally meaningful position, or on the other, regress to the former position. Here the notion of risk management is critical if the latter situation is to be avoided. Nevertheless, there is a valuable opportunity to capitalise on the opportunities here:

> In a profound sense, this phase provides an opportunity for learning, as each individual struggles to achieve a new identity based on their understandings of the "identity resources" available in the new social and cultural context, and the 'identity resources' they bring from their former experiences. (Taylor et al., 2007, p. 3)

A third group had made the transition and were in the reincorporation phase where there is a clear sense of recognition of the professional identity to which their mathematics will contribute (or not):

> Statistics in particular, differential equations, calculus, these will all be of use in my actuarial career with regard to probability functions and stochastic/deterministic variables.

> Mathematics will help quantify scientific data that will be the main focus of my career as a physician. The understanding and application of mathematics will be an essential part of medicine.

> A great deal since I plan to be an airline pilot. It will help me be a better thinker. I will probably find solutions to problems in a faster and more efficient way.

> I think that mathematics will play a major part in my future career also due to the large number of calculations that must be carried out during a civil engineer's project.

> Maths will play no part in my future career as I don't like it and it is boring to me.

> The most important thing math will help me in my future career will be with the ability to think logically.

> Career wise, I believe I will be well equipped and extremely sought after because of my mathematical intuition and knowledge, and understanding and appreciating the must-have knowledge of a very sought-after study. It's a privilege to be mathematically blessed!!

What characterises the above students is that they have (or made a conscious decision not to) made the commitment to mathematics as either a generic or specific skill set and consequently can place it within their self-directed, professional identity. For some vocationally orientated students it is evident in that they can articulate how they can apply the study of mathematics to their professional degrees. This transition appears to have been a positive experience and the students are showing no signs of being lost. Within this group are students who have made the conscious decision that mathematics is not for them and that they want no further part of it in their careers. They may be sadly mistaken, but they have a clear view as they move towards professional work.

Finally, there is another group of conceptions (possibly a sub-set of the reincorporation phase for whom mathematics is clearly important) who are concerned much less with the need to work from first principles and are much more focussed on applications and mathematical tools:

> But, I am convinced that using softwares (such as Excel) to do numerical calculations will occur more often. Courses in numerical analysis should therefore be more present in the curriculum.

> I will likely end up doing population studies, which rely on a bit of calculus. Most math in the life sciences is already done for you by statisticians and mathematicians. All we need to do is punch in the variables.

> Computer programmes will do all the work and applications for you.

This last group of quotes is an interesting one, not least because it hints at the contemporary realities of higher education as well as the changing nature of mathematical processing. The quotes show that the realities of professional work as revealed in the study by Hoyles et al. (2002) and Wood (2006) have filtered down to some students in undergraduate degrees. As this situation continues to evolve, it may become increasingly difficult to justify teaching pen-and-paper mathematics to students in a range of applied degrees.

The transition process described here as the transition to professional work is mirrored at the transition to university from school. Some will find the separation form school and their school student identity, learning and ideas of mathematics painful and may reject university or the degree they are enrolled in – or perhaps just the discipline area. Others will be confused and others will develop the identity of a university student with the accompanying skills. Knowledge of these different phases of transition can assist with the development of support for students in the transition process whether it is from school to university or university to professional life.

Need for Relevance in University Studies

One of the transitions is the transition in learning style and its associated discourse. As a student moves from school to university and towards graduation and employment, we help the student towards more self-directed learning. In this section we look at how the graduates in Wood's (2006) study saw the transition to the workplace and what could have been improved in their university education to help their learning. A particularly interesting feature is how well many of these graduates are able to articulate the importance of the perceived end-point of their knowledge is in motivating them to engage with the mathematics while at university.

Graduates felt that it was important to understand the purpose of what they were learning at university (Wood, 2006). Evan (developing IT products for a large bank) commented:

> I need a purpose to what I'm doing. I can't learn something for the sake of it. A

> good example is probably stochastic processes, all very useful stuff, wasn't quite tied enough to why we're doing it, maybe if we inverted the subject and said, this is what you need, let's work through the semester to get to that point, that might've been better.

Gavin (climate modelling) and Melanie (part-time university tutor) also felt the need for more explicit motivation in the presentation of the course:

> 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.

> 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. … Cos there's a lot of people who just want to know what's this useful for, you know, what can I use this for, so just like, different applications of this subject.

This need to see the purpose of the course was reflected in the desire for realistic and authentic assessment tasks to prepare students for the workplace:

> William (IT course developer): And I think it's the way that education's heading by engaging in more realistic tasks in more realistic settings, as a technique for training or educating at university.

> Nathan: I started working for a relatively small company where I had close interaction with the two directors and one of them, he's sort of the sales director, has a sales background and I've learnt an awful lot from him in terms of how the whole sales side of things works in an IT company, or just generally in business how you negotiate with other suppliers or customers, in all those sort of things that, you know, form part of the business cycle. I think I would have been in a better position if I'd done, maybe, a course or, you know, half a subject focused a bit on that. I did do [a subject] and that sort of looked at things like that but it wasn't really hands-on and it was more of an overall, broad, general type subject. You need something a bit more specific.

A particular aspect that the graduates felt their studies had not prepared them for was the professional level, discipline-specific, mathematical discourse – how to communicate mathematically at different levels in the workplace. In the following quote, the interviewer asked Roger how he negotiated with clients. Roger works in geophysical modelling, using statistical techniques to assess anomalies in the Earth's crust in order to find minerals.

> Roger: The difficult thing is to judge how much money you should get, because they do not realise how difficult it is, because to them mathematics consists of arithmetic, maybe there's an equation with an x in it that must be solved, but that's about as far as, because they obviously only know their own, everything they have done which is school maths.

> Nathan (IT services): Pretty much once a week I'd write some sort of a … it might be a quote, it might be a tender response, it might be a progress report. In the degree that I did, they don't teach you how to write those sort of reports. … I think we had to do a couple towards the end, but that's not the way to do it. It's something you've got to learn a lot earlier in the degree.

We have demonstrated here that undergraduate students are not sure of how they will use their studies, and that graduates are often unprepared in terms of the skills and knowledge required for the workplace. Graduates would have liked more employment-focused tasks in their degree programmes, which they believe would have assisted their learning. These tasks will help the transition to university as students strive to develop their early identities in joining a professional group. Why not use this idea to further the learning of undergraduates and help them with deep, personally meaningful or vocationally useful learning in their studies?

As an example of how this can be done in a first year engineering class, Barry and Webb (2006) took a multi-disciplinary approach to teaching numerical methods by running the course jointly with three separate disciplines, with each putting their own professional perspective on the course, such as how they would approach problems. “A typical lecture delivery would start with a description of the engineering problem to be solved by the engineer, followed by descriptions of the mathematical background including the relevant MATLAB functions, programmeming techniques and numerical issues.” (p. C220). They note that, “The deep learning happens in the computer laboratories where the students tackle the assignments under supervision.” (p. C220).

Wood and Smith (2007) found that graduates often play the role of teacher in the workplace in the form of, “explaining methods to colleagues, taking new mathematical material and presenting it to colleagues and turning information into an understandable form for their managers.” (p. 1). This led them to develop learning tasks that required students to explain to different audiences. The lecturers were able to teach large classes of mixed disciplines but could allow their students to find a context that was in their discipline area by searching internet and library resources.

Enabling Effective Transitions

There are three broad opportunities for enabling effective transitions. One is the development of graduate capabilities founded on professional realities; another is the teaching and learning activities that have authentic contextual meaning; and the last is centred on the management of these transitions.

Graduate Capabilities

All degree programmes have graduate capabilities or similar listed as an endpoint of a degree programme. Some universities have university-wide capabilities (or graduate attributes, graduate skills, generic skills) listed. How many of these are based in the realities of graduates in the workplace? For our graduates, we contend that more research is needed so that the graduate capabilities for different degree programmes are based, as far as possible, on the realities of graduates in the workplace. It should not just be a wish list from employers, but rather be based on what graduates actually need to make a successful transition to the workplace. This would require different capabilities for different end points.

For example, in a study of mathematics graduates, Wood and Reid (2005) found that two of the capabilities that graduates discovered to be most important related to the accuracy of the mathematics, and to the ethical nature of their mathematical applications. That is, they felt that they were most valued for their ability to:

- Justify the mathematics in an appropriate context so that the audience will understand the consequences of the mathematics.
- Present ideas ethically and correctly.

How did the graduates help their audience to understand? Here we move into mathematical discourse and the discipline-specific mathematical communication that is needed at work. Mathematical discourse techniques used at work that the graduates identified were to:

- Avoid technical terms and repeat yourself in different ways—observing the response of your audience;
- Dumb down ideas, use "hand waving" and pictures;
- Inspire and sell ideas instead of explaining;
- Use mathematics and mathematical discourse in a flexible way as the situation requires. Check for accuracy and correctness.

These techniques are not necessarily the best that could be used but they were the ones that graduates had developed themselves to survive in the workplace. Not one of the graduates who were interviewed believed they had been taught mathematical communication at university.

Contextual Meaning

Most students studying an undergraduate degree wish to see the purpose for what they are studying and how the material might be used in context. The adoption of context-based problems and exposure to professional realities can reap benefits and are likely to lead to easier transitions into the workplace. Crebert et al. (2004) found that:

> Graduates and employers felt strongly that industry involvement in all aspects of the undergraduate curriculum was beneficial, particularly because it exposed students to 'real-world' problems and gave them experience in meeting deadlines and managing their time. Stronger linkages between curriculum content and 'real-world' examples and applications were repeatedly mentioned by graduates as a means of developing generic skills in the university context. (p. 17)

Industry involvement can provide opportunities for students to engage with authentic tasks and to develop some skills explicitly valued by employers, which in itself should facilitate a smoother transition into the professional context. Another corollary to be drawn is that industry involvement in the curriculum and in assessment would raise awareness in both students and academic tutors of the realities of the workplace, the type of problems encountered, the discipline-specific and generic skills required to operate successfully, as well as a greater understanding of broader graduate capabilities such as ethical and professional conduct. The implication is that to develop a curriculum that fosters transitional success requires those that execute the curriculum to have a broad conception of learning and professional work within their discipline.

Students and academic staff tend to have a range of different ways in which they conceptualise teaching, learning and professional work. If these conceptions are relatively narrow then the focus of teaching and learning activities is likely to be on discrete and atomistic elements. If the conceptions and views are more open it is likely that academic staff and students will engage in teaching and learning tasks that encourage critical and reflective attitudes towards work and the discipline. Conversely, to encourage the open rather than narrow view, curriculum developers must engage in some research into "real world" capabilities whilst individual academic tutors need to critically reflect on the conceptions of teaching they hold and value and revise them if necessary.

There is a broader implication when seeing the curriculum as a holistic entity, which suggests that lecturers should be aware of all aspects of the curriculum and be involved in its development; at the very least a team-based approach can help to dissolve the artificial and problematic boundaries between discipline and subject 'silos'. Capabilities are not developed discretely within specific units but must be developed within and be incorporated throughout the curriculum as a whole. It is therefore incumbent on academic staff to embed capability development and assessment throughout the curriculum. This kind of holistic approach can only be achieved through sharing teaching values and principles, which is probably best fostered through regular discussion and other community-of-practice based activities that encourage academic staff to operate as a team rather than as a collection of individuals. Given the tendency for employers to focus on skills rather than capabilities, and teams rather than individuals, there also needs to be some engagement of employers in a dialogue that encourages a more open and expansive view of the type described above.

Management of the Transition

When it comes to the management of transition above and beyond a contextualised curriculum, it is important that there is a continuing dialogue to encourage students to talk about the various transitions they experience or anticipate experiencing. It is here where the models of transition become most useful. Once we identify transition as having a separation phase, then preparations can be made for dealing with separation and the inevitable feelings of anxiety and loss that accompany it. "Separation challenges individuals to identify and acknowledge aspects of their identity" (Taylor et al., 2007, p. 2), a process that can be both demanding and emotional but one that offers opportunity as a new identity is established. Academic staff can provide activities that raise awareness of the transition and feelings associated with it. The induction into university life and the building of a robust student identity demands a number of ritualistic and formative experiences that afford the chance for students to achieve closure of separation from school and acceptance of the transition to university. Much of this would be based on orientation toward the programme of study, introduction and socialisation with the members of staff, facilitation of support networks, an introduction to the language of academia, and the development of an inquiry-based approach to learning.

Programmes for work-integrated learning are an optimal solution, but if these are not feasible then in later years of study activities might involve work-place visits or presentations by employers and recent graduates that explicitly expose students to the professional identity. Extending this activity backwards through the curriculum would involve sessional or adjunct staff relating and discussing professional experiences, inclusion of industry case studies and projects and general exposure to the professional application of mathematics. The underlying issue in any of these proposals is that transition implies a journey from somewhere, to somewhere. Thinking in those terms is important and, as suggested by Taylor et al. (2007), re-focuses the lens toward the experience of students:

> … [the] literature tends to focus on "student adjustment to" rather than any acknowledgment that the change is both *from* as well as *to*. Because of its focus on this specific set of experiences, it tends not to connect those experiences to broader conceptualisation of transitions … (p.7)

As we have discussed before, mathematics academics tend to concentrate on the *from* and look for deficits in students making the transition to university rather than the *to*, where students are developing a mathematical and professional identity.

Conclusion

The transition through life, from school to university, is multifaceted. It is a process that, if successful, includes the later transition to professional work, while potentially inspiring deep learning along the journey. When preparing students for the transition to university, we need to place less emphasis in the curriculum on where students are coming from and their possible lack of skills (deficit model). Instead, there should be greater emphasis on where they are heading. Real graduate capabilities/attributes must be the focus, linking what students have learnt with professional work, integrating technology with learning, encouraging learning to learn, integrating discipline-specific discourse and creating a professional identity.

This does not imply that we teach less mathematics or teach only vocational mathematics. We know that mathematics evolves over time and new tools are developed. Teaching only what will be useful now does not induct students into the discipline of mathematics and may not help them with learning new mathematics when they become professionals. We have given several examples of ways to incorporate different discipline approaches into learning mathematics at university.

These examples show that it is possible to tailor university mathematics learning to assist with the change from a school identity to a professional identity without loss of mathematical content – one could even suggest that content learning is enhanced and deepened by taking account of the transitions that a student is moving through.

The challenge for mathematics educators is to create a dynamic curriculum that inspires students to engage deeply with mathematical ideas. A clear understanding of where they are heading can inspire this deeper engagement, by both academics and students.

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