Academic numeracy in Life Science learning: challenging perceptions

Dr Rosanne Quinnell  
School Biological Sciences  
University of Sydney  
Sydney NSW 2006 Australia  
rosanne.quinnell@sydney.edu.au

Dr Rachel Thompson  
Faculty of Medicine  
University of New South Wales  
Sydney NSW 2052 Australia  
rachelt@unsw.edu.au

Dr Rebecca LeBard  
School of Biotechnology and Biomolecular Sciences  
University of New South Wales  
Sydney NSW 2052 Australia  
r.lebard@unsw.edu.au

Abstract
While maths can be viewed as enabling learning in science and medicine, in reality we see students are bringing their maths anxiety with them to their studies. Our work focuses on dissecting the maths problem as it relates to teaching and learning in these so-called hard disciplines. We have been challenging the inertia of what we see as a stand off with students taking the view that they are unable to do maths and educators frustrated at their disengagement. We have found that the maths problem resonates with several pedagogical frameworks (e.g. Meyer and Land's Threshold Concepts Framework, Perkins and Simmons' four frames of understanding) and we have found these useful for unpicking where our students become disengaged. We have applied a number of interventions to assist student learning and are now using our findings to inform the design of an online diagnostic to more explicitly address dysfunctional stances that students adopt when asked to manipulate their quantitative data. Given the extent of the maths problem and the move to increase diversity in the Higher Education sector, we discuss how to enable students to shift to a more positive learning disposition.

Keywords
Academic numeracy, transferable skill, biology education, maths anxiety, learning science.
1. Introduction

In science and medicine, numeracy skills are integral to the processes of data handling, statistical tests, data presentation, abstraction (including visualisation), inference and interpretation. While mathematics can be viewed as an enabling discipline, we have observed many students studying science that bring their maths anxiety with them to our domain. Thus maths is a transferable anxiety rather than a transferable skill. In the classroom, this is exemplified by a standoff, where students resist engaging as they can’t see the science for the maths, and teachers become frustrated as they perceive students to be disabled by their numeric abilities, forming an obstacle to learning within the discipline. We have sought to dissect the so-called maths problem, using theoretical frameworks such as the threshold concepts framework (Meyer and Land, 2003), which have helped us to challenge this standoff. This was achieved by first identifying and understanding the underlying dysfunctional stances that students may adopt which preclude them from engaging in our discipline practices, and secondly by challenging our own perceptions as educators and discipline experts (Quinnell and Thompson, 2010). If our objective is to support students along the path from novice to expert, then being more explicit to our students about our discipline practices is critical.

2. Re-viewing academic numeracy in the Life Sciences

2.1 Understanding our discipline

In undertaking this exploration of academic numeracy, it was important for us to clarify what it was that we were asking our students to do in our tutorial and laboratory classes - the place where theory meets practice. While traditional lecture introduce students to content and concepts, it is the practical/ tutorial classes where we have discussions with our students and where we aim to foster enquiry and critical thinking; this is where we can address misconceptions and this is where we expect students to engage with our discipline.

There are many ways disciplines can be mapped, categorised and described. Life Sciences fit in what Biglan (1973) described as the hard (as opposed to soft), pure (as opposed to applied). Biglan’s work was based on examining the practices of academics in a range of disciplines. There is body of work that examines disciplinarity and how this relates to prevailing discipline teaching practices (e.g. Neumann, 2001; Trowler and Wareham, 2008; Fanghanel, 2009) and this has been useful to us in challenging how to best introduce our students to our practice as scientists.
We have developed a model, a signature pedagogy, of how science is taught in our contexts to provide a descriptive map of the likely and expected processing that students will undertake to achieve this usual practice (Figure 1). We have annotated this model to show the points and reasons for student disengagement and poor learning i.e. where we have found students find it difficult to follow the cycle (LeBard et al., 2009) and re-entry arrows where we think our interventions have helped students re-engage with how science is practiced. Looking at our teaching practices in Life Science has alerted us to the complexity of tasks we set our students. This is where we have had our own perceptions challenged in as much as we have had to acknowledge that students are not staying engaged in this process.

Figure 1. Signature pedagogy of science: practice through engagement with authentic process. Some of the obstacles to learning this process are indicated 1. maths anxiety is elicited when students are required to do calculations 2. As novices, students have difficulties with abstracting to represent data according to convention, 3. mindful or critical thinking is required throughout the process, most evident with interpreting patterns and relationships in the results.
2.2 Clarifying how we want students to engage

When students are asked to do an experiment we are essentially asking them to mimic our practice. That is, to learn to make observations like us, to record quantitative (qualitative) information like us, to handle raw data sets, to calculate (add, subtract, multiply, divide, integrate etc., be familiar with prefixes and using SI units), to present data according to conventions, to use ciphers and symbols, to interpret meaning from these data, and to relate their findings to their understanding of the phenomenon being examined. Put simply, students are asked to abstract, or codify, their observations into formats that can be interpreted by others in the field familiar with our epistemology. The final stage shifts focus on to literacy and to students being able to read critically and to decipher data patterns from the published literature. We now acknowledge we expect students to be able to master abstraction, the highest cognitive level according to Biggs (2002), almost immediately and implicitly we expect students to engage in mindfulness (Langer, 1989 - cited Tishman and Andrade 1996) as they work through this process. Tishman and Andrade (1996) offer an excellent review of thinking dispositions as they relate to learning that clarifies how students approach critical practices.

Traditionally, students were assessed by writing a report for each experiment they have completed. Diminishing resources mean that students do not get very many opportunities to practice very many iterations of documenting the experimental process so there are few opportunities for students to develop their observational, numeracy, abstracting, writing and thinking skills. To become an expert and to develop a discipline appropriate thinking disposition requires a lot of exposure to the practices and process of that particular discipline (Perkins and Simmons 1988a). We are currently tracking at a maximum of two reports per semester course, which we estimate is a tenth of the exposure that we had as undergraduates.

In the Life Sciences, we recognise that we do not usually teach much more than aspects of scientific phenomenon in the context of the discipline that is beyond the level of knowledge within what Perkins and Simmons term the content frame (1988b). Perkins and Simmons (1988b) assert that interventions to improve learning have to target levels of knowledge beyond the content frame and the most successful interventions integrate all knowledge levels: the content frame, the problem-solving frame, the epistemic frame and the inquiry frame.
2.3 Student engagement/disengagement

The prior conceptions of a subject that a student holds is important - this is exemplified in Biggs’ 3-P’s model (Biggs 1989) and there are numerous other frameworks that have prior conception as an important factor in student learning. We can reflect on our own conceptions as experts and the conceptions of our students who are novices, and, entering university years after us, are likely to be very different as they have been subjected to different fashions in education, an education system supported by a different funding model and a different socio-economic landscape. For whatever reasons, we know that the mathematical ability of primary and secondary school children in Australia is declining (Organisation for Economic Co-operation and Development (OECD) 2010), so the maths preparedness of students as they come into university is, by extension, declining. But are the levels of mathematics so low that students cannot seem to perform simple arithmetic (divide, multiply, add, subtract) when it is needed in a new context?

We, like Ingleton and O'Regan (1998), believe that there is a paradox when it comes to learning maths. The discipline of mathematics is objective yet it can elicit a lot of negative emotions, including anxiety, from some students. Maths anxiety is a feeling of tension, apprehension or fear that impairs an individual’s mathematical performance (Boyd et al., 1998; Meece et al., 1990; Ashcraft, 2002; Klinger, 2004). The maths anxious hold negative perceptions about their numerical abilities that are often expressed in phrases such as “I can’t do maths”. Exacerbating their situation, they tend to avoid maths wherever possible and studies on cognitive processing demonstrate this anxiety compromises ongoing activity in working memory (Ashcraft and Kirk, 2001).

Maths anxiety and students’ lack of numeric confidence are not the exclusive domain of maths and maths anxiety is evident in science learning. What we thought ought to be low road transfer (Perkins and Salomon 1992), where students used their maths skills automatically in a new, related discipline, is, in fact, not the case for many students. As educators, it did not make sense that our students could not seem to perform simple operations such as multiplication and division and our early work focused on determining whether a lack of confidence was getting in the way of students’ engagement with the discipline – a lack of confidence as an obstacle to learning. That students transfer their maths anxiety rather than their maths skills has implications for how we teach science as we rely on students transferring maths skills to their science studies.
One of our early interventions was a simple tutorial evaluation of the level of confidence our students have when performing simple calculations, the sort usually carried out at the bench while doing an experiment (Quinnell and Wong, 2007). What was important for us with this work was finding out that about half of these biology students lack confidence and that many of these students appreciated knowing that for them, it wasn’t their maths that was the problem – they knew how to do the tasks but they needed to work on their confidence. A simple two by two matrix can help to explain where our thinking on the maths problem in science is at currently (Figure 2). Students already confident and capable should be able to demonstrate low road transfer (Perkins and Salomon, 1992) from maths to science (indicated by the tick). The arrows shown in Figure 2 represent the transitions that students have to make if not already confident and capable with their numeracy skills. These transitions seem to be more or less problematic for students to achieve. The seemingly less complex transition (arrow 1) is the one where most interventions seem to focus - shifting a student to a place where, with more practice, they can automatically complete their calculations. The more difficult transitions (arrows 2) are those requiring reflection, and where students address their confidence as a critical part of their transfer process. For our students, confidence building starts with reflecting on their misalignment between their ability and their confidence (Quinnell and Thompson, 2010).

![Figure 2. Intervention matrix to improve students’ disposition of academic numeracy.](image)

1. Assistance to improve students numeracy skills requires contextual examples of calculations.
2. Assistance to improve student confidence/reduce anxiety requires students to engage in reflection.
3. Conclusion

With our cohort composition becoming increasingly diverse (maths backgrounds, degree programs represented, diverse career aspirations, perceptions of relevance of numeracy), teaching seems to be becoming more difficult. Coupled with increasing student numbers and student:staff ratios it can be difficult to interact with students to sufficiently support them as they gain experience in discipline via the tasks we place before them. We do not have a complete picture of the complexity of what we are asking students to do when learning to engage with our discipline practice. Our work to date offers some strategies to address issues that cause students to disengage e.g. when the maths problem manifests itself in Life Sciences learning. For us, discovering more about the ways students learn, appreciating the learning agendas of our students, and most importantly, identifying the learning obstacles students encounter has re-focused our teaching practices.

4. References


Ingleton C., O'Regan K. (1998), Recounting mathematical experiences: Using Memory-work to explore the development of confidence in mathematics. Paper presented at *Australian*


