Intervening to create conceptual change

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Abstract*: It is well established in higher education that students arrive at university with existing schema (misconceptions) which can exist alongside new conceptions and are characterised by being personal in nature, counter intuitive, highly resistant to change and/or contradictory (Osborne and Freyberg 1985; Driver and Bell 1986; Fensham 1994; Wandersee, Mintzes and Novak 1994). Current ideas about 'threshold concepts' mirror this early work on science misconceptions in that some core scientific concepts are conceptually difficult, counter intuitive, and linguistically challenging (Meyer and Land 2003). As a result, there is a wealth of information indicating that the learner's developing, imperfect cognition becomes 'troublesome knowledge' (e.g. Perkins 1999; Wandersee, Mintzes and Novak 1994). The resolution of the conflict between a long-held misconception and the 'counter-intuitive', but reasoned scientific idea can be equated with crossing a cognitive threshold and leading to a different way of thinking. Sometimes this occurs quickly, more often torturously slowly, and sometimes never. The challenge for instructors is how to create an 'ah-ha' moment for students and academics, likened in comic strips to a light being turned on (Liljegahl 2005) or by Meyer and Land (2003) as a transformation. One useful strategy is deliberately intervening when it is suspected the new topic could involve a threshold concept, by creating conceptual conflict that students need to resolve using reasoned scientific argument. (Gilbert, De Jong, Justi, Treagust and Van Driel 2002).*

In this paper, we describe a planned strategy of creative and innovative interventions to create transformations in student thinking and learning in Biology at the University of Western Sydney. This teaching methodology has evolved following the stages set out by Biggs (2003); (i) where the student is at (ii) what the teacher does and finally (iii) what the student does. (Ross and Tronson 2004; Ross, Tronson and Ritchi, 2006 and Ross, Tronson and Ritchie. in press). We present results of student evaluations and focus groups to demonstrate the success and limitations of these interventions in creating change in student's conceptual understanding. We also propose a modified model of interconnecting lenses Brookfield (1995) that may help increase the frequency of transformations for learners.

Introduction

Over twenty years ago, the seminal work of Driver (1983), Driver, Guesne and Tiberghien (1985), Osborne and Freyberg (1985) and Driver and Bell (1986) highlighted students' errors in understanding, or alternative conceptions (misconceptions), of fundamental science concepts. These misconceptions, developed from previous learning experiences, can be very stable and highly resistant to change. They are often personal in nature and show incomplete and contradictory understanding (Driver and Bell, 1986; Gabel, 1994). Some teachers and textbook authors may subscribe to the same alternative conceptions and misconceptions as their students, perhaps due to an entrenched culture of similar teaching regimes. These misconceptions often persist and remain intact, despite repeated instruction at successively more advanced levels (Alparsian, Tekkaya and Geban 2003; Mann and Treagust 1998; Seymour and Longdon 1991; Songer and Mintzes 1994; Wandersee, Mintzes and Novak 1994). It may be that, when first introduced to a new exposition of a scientific idea, students have not yet attained as high a level of abstract thinking as the instructors assume (Piaget, 1929). Perhaps instructors provide only part of the concept or a more simplified concept in the belief this will lead students to a better understanding, as sometimes happens when the concept is difficult or known to be troublesome. Such a limited explanation, however, may prevent some students from crossing a cognitive threshold and entering through a door to a higher level of understanding. If the door remains closed, they may cling to their former misconceptions and make inappropriate cognitive links to the new knowledge they are expected to acquire.

Recent investigations into 'threshold concepts' reflect this earlier work on science misconceptions. Many students find some core scientific concepts conceptually difficult and counter-intuitive. They may find them even more alien than instructors realise because of the difficulty created when the specific language developed to describe particular scientific situations becomes confused with the students' natural language form (Meyer and Land 2003 2005). As a result, to the learner, some critical scientific concepts become troublesome knowledge (Perkins 1999) where they get 'stuck' (Meyer and Land 2005). Such liminal or 'stuck' places prevent the learner from undergoing a transformation that could extend their understanding of formal and symbolic language and allow them to make an irreversible and integrative change (Meyer and Land 2005). There are sometimes discrete moments when a cognitive threshold has been crossed, allowing the student to step through an open door within their mind likened to an 'ah-ha' moment or, as in comics, to a light being turned on (Liljegahl 2005). .

Driver and Bell, (1986) suggested that, for students to move out of the liminal or 'stuck' places, they need a 'conceptual conflict' where they are forced to confront their existing schema and realise that those are no longer tenable; they need to do something new in order to resolve the conflict. As educators, we took up the challenge to create and design deliberate intervention strategies using models, analogies and role plays. These all can help students become 'unstuck' (Meyer and Land 2005) and to cross one important threshold – that between the visible (or concrete) and the imagined (or abstract) (Gilbert, DeJong, Justi, Treagust and Van Driel 2002; Ross and Tronson 2004; Ross, Tronson and Ritchie 2006; Ross, Tronson and Ritchie in press). In this we have focussed on 'what the learner is doing', rather than 'what the teacher is doing' (Biggs 2003). We also provide students with a safe environment for meaningful reflection and discussion about these concepts. Ellsworth (1997) has warned against the tendencies to hear only what the student knows and thus to not understand the importance of what the learner does not say.

Brookfield (1995) proposes four lenses through which we can view the student perspective. We suggest that a modified version of this technique can be used effectively to identify troublesome knowledge and the liminal spaces of students. Brookfield's first lens is to see students through our own autobiography as learners, although we need to be careful this is enriching and not limiting! Self-analysis of our own liminal areas may provide us with some insight into our students' 'stuck' places. Similarly, using the second lens, seeing the troublesome knowledge through our students' eyes and listening to both what they say and what they do not say, may allow us to better identify actual student problems. The third lens, viewing through our colleagues' autobiographies as learners, provides a wider view of which concepts may trouble students because they may identify different threshold concepts than those we identify. His final lens can be interpreted as viewing the wider scene of teaching/learning through the rich theoretical literature on misconceptions in science (e.g. Gabel 1994). If we reflect on the results of others' research, we may cross our own thresholds and create new strategies suitable for our own students.

In this paper, we present results from a range of student evaluations that focus on the effectiveness of intervention strategies designed to improve student cognition of selected topics which have been shown to be poorly understood and reported to be difficult to teach (Songer and Mintzes 1994; Wandersee, Mintzes and Novak 1994).

We present a review of consolidated student evaluations that have been previously published over several years (Ross and Tronson 2004; Ross, Tronson and Ritchie 2006; Ross, Tronson and Ritchie in press). We specifically indicate how this reflection about students' own explanation of their cognitive change experiences has enabled us to gain insight into how the older 'misconceptions' literature can be reconciled with the burgeoning theories of 'threshold concepts'. Using this information, we discuss successes in creating change in students' conceptual understanding, some limitations of these teaching/learning techniques and propose ideas for a way forward.

Methods

Between 2000-2005, interactive activities including model making and role-plays were introduced into selected practical classes, lectures and workshops of first year Biology at the University of Western Sydney on particular topics chosen because they are perceived to be ‘difficult’. Subsequent classes on these topics were devoted to revision by more conventional means. Models included the creation of a 3-dimensional playdough cell (with internal organelles), which could be sectioned and compared with real microscope slides; enzyme substrate models, created by cutting a car sponge to mimic a lock and key, and then manipulating the sponge to show flexibility of the protein and a range of substrate reaction types; chloroplasts made from paper plates and other everyday items to represent the differing proteins and chlorophyll pigments within a thylakoid membrane (Ross, Tronson and Ritchie 2006) and pairs of striped socks, representing homologous chromosomes, used to illustrate mitosis and meiosis. Role-plays included interactive dances and staged scenarios to illustrate photosynthesis (Ross and Tronson 2004; Ross, Tronson and Ritchie 2006) as well as glycolysis and the Krebs cycle (Ross, Tronson and Ritchie in press). Throughout these five years we have evaluated the effectiveness of these creative activities in three ways: an open ended question on the regular Students Evaluation of Educational Quality surveys (SEEQ), in-class ‘minute quizzes’ and focus groups. SEEQ and minute paper questionnaires were offered to the whole class and an average of 48% of students returned these surveys in 2004 and 2005 (more than 200 students each year). The focus groups were used to triangulate these responses. With advice from the Teaching Development Unit staff, we designed questions to further explore some of the themes that emerged from the unprompted responses in the ‘open-ended comment’ section of the SEEQ surveys. We were interested in explanations of the students’ comments in order to eliminate guessing on our part about what they actually thought. Students who participated in focus groups were all volunteers, and were from diverse backgrounds. In 2000, the focus groups comprised a total of 40 students from the 2000 cohort; while in 2005, there were 6 focus groups from 2004 and 2005 cohorts, each with an average of six students

Results

Over a period of five years, students have reported that creative activities enhanced their understanding and recall of difficult biological concepts. As a representative example, the combined results from a series of focus interviews in 2000 (Ross and Tronson 2004) showed that 73%; of students attending these focus groups thought that the creative activities in general (described in ‘Methods’) helped them learn biological concepts, while less than a quarter of the students found some specific activities to be a hindrance to their learning. In each of 2004 and 2005, 50% of students responded to the SEEQ evaluations (total of 450 students each year). Overall responses were similar in each year. Due to the timing of the Human Ethics approval, only the 2005 results are reported here in detail. Of the responding students, 96% indicated that these interventions assisted their learning in some way (there was a wide range of questions). In 2004, there were no purely negative comments made and in 2005 there were only four of the students (4%) who indicated they preferred more traditional methods of teaching. The variety of ‘reasons’ given by students became the basis of the ‘themes’ explored in the subsequent focus groups encompassing students from 2004 and 2005. These are summarised in Table 1.

The themes of the focus groups triangulated and confirmed the SEEQ results, that the students perceived that these novel and creative strategies increased their conceptual understanding. The summaries in Table 1 are based on consensus by all the 36 students who participated in the focus groups that they were able to explain to non-scientists some of known difficult concepts such as the Krebs cycle and photosynthesis. They were excited about not having to ‘look it up’, and ascribed their high level of understanding to the intervention and interactive strategies they had used in class.

It was extremely instructive for us to note that the 2004 cohort students, 18 months after having learnt these concepts, were aware of the difference between this continued cognitive awareness and their lack of understanding of other topics or subjects they had studied at the same time.

Table 1. Main themes identified in focus groups in first year Biology at the University of Western Sydney, July 2005

Theme	Summary of student comments
Effective Delivery Modes	Engagement and passion of the lecturer was seen as a motivating factor
Emotional Investment of Lecturer	Relationship between the teacher and student was seen as positive and important in helping the learning process
Effectiveness of Creative Teaching Strategies	Role play, games, mind maps, model-making, interactive lectures etc., allowed students to build on cognitive foundations. They reported increased understanding of biology (e.g., when reading textbooks for more detail)
Assessment	Aligned assessments, clear expectations, self assessment, and interactive feedback methods were all reported to aid learning of work done in assignments
Time Efficiency	Students stated that interactive teaching strategies helped them gain a cognitive overview, and they were able to use their time more efficiently in Biology during their private study and review for exams (compared with other subjects).

All students in the 2005 focus groups reported having attained Biology 1 examination results as good as, or better than, they expected. More importantly, they all commented enthusiastically on finding their private study of Biology 1 more enjoyable and 'easier' than some of their other subjects.

We also identified some limitations of these creative interactive strategies from student surveys and discussions within the focus groups. These included: inconsistencies in teaching styles between different tutors/demonstrators, not all of which were aligned with the pedagogical approach taken by the lecturer; lack of time in scheduled practical or tutorial classes to fully explore and reflect on how the activities were related to learning the topics; and the inevitable distraction in the class if some students were not committed to this interactive, creative, less formal way of learning.

Discussion

In general, students indicated that the creative activities we described in this paper enhanced understanding, recall, and overview of a topic. Focus group discussion indicated students were motivated to 'fill in the details' themselves by conventional means (such as text books). Many students stated they learnt these topics faster, remembered them better with less effort, and enjoyed studying them more than other topics or subjects taught conventionally. When creative activities are introduced for a limited, particular purpose, we have found that they provide a powerful mechanism for helping students connect the abstract ('submicroscopic') concepts in biology with their familiar 'macroscopic' world. For example, physically dissecting the 3-dimensional playdough cells allows students to better conceptualise why and how the cell under the microscope looks 2-dimensional. Similarly, the enzyme substrate models helped students visualise how enzymes change in conformational shape better than the standardised picture in a text or the most expensive animation. Role play, when successful, also integrates the cognitive and affective dimensions of learning in a powerful way. This has also been observed by Brookfield (1990). However, these activities are time-consuming. Students sometimes see them as irrelevant if presented out of an appropriate conceptual context, or confusing if delivered by an instructor not committed to this type of methodology or pedagogy. In these cases, they may not have the same impact as reported by our particular students. There is also a tendency for these activities to be trivialized by other professional scientists, because they are not regarded as appropriate for the serious pursuit of learning in a Higher Education setting. Sternberg and Williams (1996) observed that innovations, particularly those which are creative, can be rejected because they stand out as unusual, before being shown to be effective in their own right. We, too argue that one can have too much fun, but the enjoyable nature of these creative activities should not detract from the inherent value that we have shown, in intervening to help students emerge out of carefully selected 'stuck' or liminal thought processes. Our students have reported some transformations of conceptual understanding. As with all teaching strategies, we need to remain mindful of the variation between students' learning styles and preferences. We can use our creativity to develop a wide range of activities so that we appeal (at least some of the time) to the greatest possible number of students in our classes. Many of these creative activities have focused on 'what the learner is doing', rather than 'what the teacher is doing' (Biggs 2003) and follow-up revision lessons are designed to listen to what the student knows as well as what the learner does not say.

Reflecting on our own learning experiences helps us to imagine our students' conceptual difficulties, as Brookfield (1995) advocates. His four lenses for viewing teaching practice can be used to identify liminal or stuck places and subsequently teaching and learning strategies developed from this identification may open conceptual doors for students. We have found that interactive interventions have helped our students transform their thinking in selected topics, and cross the thresholds of these newly opened doors.

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