Enhancing the transition into first year chemistry through modular, self-regulated, formative assessment

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Abstract

It is becoming increasingly important that the preparedness of students for tertiary studies in a disciplinary context is measured, to enable both a response to issues in diversity in conceptual models possessed by students, and to inform benchmarking of student achievements as they progress through their tertiary program. Concept inventories are extensively used for diagnostic and summative purposes; however, they have not been used to improve student learning through formative practices.

This project aims to develop modular, formative learning objects to be administered in class and virtually in first-year chemistry courses. The learning objects address key missing and mis-conceptions possessed by incoming students, who form a large and diverse cohort of students. Use of these learning objects by students and academics will help change the culture of formative assessment within the tertiary context and also embed the expectation for self-regulated learning.

Background

There have been significant advances in the last five years in recognizing the role of the first year experience (FYE) in student engagement and retention (Kift, 2009 and references cited therein). Students enter tertiary studies with preconceived expectations of the tertiary learning environment, possibly holding a perception that this is a new ‘chapter’ in their studies. The reality is that they are required to build on their prior knowledge, self-manage their studies and schedules, develop new social relationships, master new concepts and skills and demonstrate independent thinking. The new learning environments are very different to the secondary context in terms of space, facilities, learning material delivery, expectations and instructors. In response to recommendations (Kift, 2009), 1st year course coordinators are responding by addressing social and cognitive diversity through the introduction of more learner-centered environments.

A typical Australian tertiary 1st year chemistry cohort is characterized by large classes (300-2000) of students who represent a diverse range in academic abilities, interests, and motivations for learning (students are enrolled in around forty possible programs of study that require some chemistry, for example, engineering, medicine, pharmacy, dentistry and other health sciences). All students are recommended to have completed senior chemistry (though many attempt the course without this preparation). In 2008, a new secondary chemistry syllabus was implemented in Queensland, which increased the diversity in student secondary chemistry experiences as a result of increased specification of inquiry based learning and experimental investigations. In 2014, the introduction of the national curriculum for senior chemistry (ACARA, 2011, QSA 2011) will amplify this situation further. The diversity in
chemistry conceptions possessed by students as they enter tertiary chemistry provides us with a unique opportunity to research and develop mechanisms to differentiate learning support for students at risk of failing chemistry.

A significant body of research exists around identifying student conceptions, misconceptions and missing conceptions, and a number of instruments has been developed to characterise the range of conceptions held (Mulford & Robinson, 2002; Potgetier et al., 2008; Pavelich et al., 2004). One interesting application of the data arising from concept inventories is as a diagnostic to identify students at risk of poor achievement or failure in tertiary chemistry studies (Potgeiter & Davidowitz, 2010; Potgeiter et al., 2011; Bell, 2011). Having identified students that are at risk in a cohort, an intervention is required, which does not place additional load on the students. One option is to offer optional tutorials or peer led study sessions which focus on key ideas; however, it is difficult to engage the specific students who require this support (Regan et al., 2011). A versatile, non-resource intensive intervention is required, which can be readily translated by chemistry academics into their contexts; for example, collaborative self-directed activities (Sandi-Urena et al., 2010). Our strategy aims to enable students to self-diagnose and address their incorrect conceptual models through interactive modules, which provide feedback and generate cognitive conflict based on the nature of their misconception. Little attention has been paid to this approach to address student diversity in conceptions in chemistry in the literature to date.

The overarching goal of this project is to enhance student learning outcomes by improving the transition between the secondary and tertiary contexts. This is being addressed by:

- Designing learning modules which represent a computer-assisted intervention, challenging students’ misconceptions and enabling reflection based on feedback. These modules are self-contained, enabling an academic to select ‘off-the-shelf’ and implement in any of a range of learning environments (lab, lecture, tutorials, self-directed study) according to course context.
- Changing the culture in first-year chemistry courses; in particular, the role of formative assessment and feedback in enhancing the transition from secondary.

Our approach addresses diversity in students’ conceptual models and chemical literacy in first-year chemistry through formative feedback. Feedback is known to be a critical component in improving student learning outcomes (Hattie, 2009) but is especially problematic in the large class settings, such as those in the first-year sciences. While the traditional classroom relies on face-to-face student–teacher communication for the feedback process and this is impossible in current large class settings. Our solution involves a mixed-methods approach that utilize communication technologies to carry out the formative assessment and deliver strategic learning experiences for self and peer-assisted learning, leaving teaching staff to deliver the high stakes personal assistance and feedback.

In the transition into first year, feedback is particularly important because students are struggling with the change of system, expectations, teaching approaches and types of assessment. In this context, Hattie and Timperley’s three questions (Hattie & Timperley, 2007) are particularly apposite: “Where am I going?” (goals), “How am I going?” and “Where to next?” Formative assessment is critical to the: “How am I going?” question and feedback from the assessment is just as important for the teacher as for the students because it makes synchronization of teaching and learning possible. Assessment is carried out at the start of the course is particularly useful from this point of view. Our project is using concept

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inventories (Mulford & Robinson, 2002) to give this feedback and building responses to the other two questions into the in-course tutorials (Wright et al., 2000).

The efficacy of matching diagnostic assessment with a post-test intervention is well established in chemical education research (Treagust et al., 2011). However, the large class setting provides a particular challenge. In part this is because the large numbers make it imperative to develop student’s ability to self-regulate their learning. Useful guidelines for the use of feedback to promote self regulation have been analysed (Nicol & Macfarlane-Dick, 2006) and are being used for the tutorial development. This includes the clarification of good performance, facilitation of self-assessment and encouraging feedback and dialogue.

Despite the published outcomes in terms for common misconceptions, there are few learning tools that a teacher can apply as an intervention for students with incorrect or naive mental models (Regan et al., 2011). Our strategy enables students to self-diagnose and address their incorrect conceptual models through interactive modules, which provide feedback and generate cognitive conflict based on the nature of their misconception. Useful guidelines for the use of feedback to promote self regulation have been analysed (Nicol & Macfarlane-Dick, 2006) and are being used for the tutorial development. This includes the clarification of good performance, facilitation of self-assessment and encouraging feedback and dialogue.

**Context**

A typical Australian tertiary 1st year chemistry cohort is characterized by large classes (300-2000). To maximise the effectiveness of the proposed project, we have assembled a collaborative team involving key stakeholders across the secondary-tertiary transition:

- Chemistry academics at two major tertiary institutions in Queensland (QUT and UQ) who are involved in delivery of 1st year general chemistry;
- Chemical education academics at these institutions responsible for preservice chemistry teacher education and chemical education research;
- Secondary educators involved in curriculum development.

Active learning environments are most effective when the learner and teacher possess shared understanding of the existing conceptual models that learners possess, to enable them to extend and apply these models. As students engage in these new learning environments it is important to assist them maximise the effectiveness of their learning and this requires assessment and feedback relating to their existing conceptual understanding. One of the challenges in teaching chemistry is to encourage students to first recognise their existing knowledge and conceptual understanding and then to apply it in new learning situations (Schraw et al., 2006). A variety of concept inventory instruments for chemistry has been developed in the last decade which profile the range and level of concepts students are able to understand (Mulford & Robinson, 2002; Treagust et al., 2011 (see above)). However, there has been little attempt to apply such instruments to inform transitional curriculum reform. The template for the new National Curriculum does not identify core concepts that enable constructive learning; rather, all concepts that are deemed significant across all aspects of chemistry are addressed.

**Value/need for this project**

This project aligns with and builds on recommendations for enhancement of the first year experience from previous ALTC initiatives (Kift, 2009; Nelson et al., 2006). The outcomes of this project include: Enhancing the transition into first year chemistry through modular, self-regulated, formative assessment. Nuts and bolts session, FYHE 2012, Schultz, Lawrie & Wright.
of this project in enhancing the student transition to tertiary education and developing benchmarks for learning are also aligned with the new ALTC initiatives in developing Learning and Teaching Academic Standards (LTAS) for each discipline.

- Kift (2009) called for ‘transition pedagogy’ to enhance engagement, success and retention of 1st year students. This project represents a disciplinary model for curriculum alignment across the transition which will reduce the level of anxiety in learning in ‘Year 13’. It also examines academics’ changing practice to address the transitional issues.
- Implementation of the National Curriculum is imminent, and this project represents forward-thinking preparation for change which will deliver strategies for instructors and students that can be translated into parallel contexts across the country. Knowing what students should be bringing on entry to the tertiary environment enables better benchmarking of threshold learning outcomes on graduation and each level in between.

By placing a spotlight on articulation between the secondary and tertiary contexts, this project addresses these principles by developing a mechanism for tertiary academics to differentiate instruction and provide learning support in the form of interactive modules. Students benefit through engagement in reflection and self-evaluation through the feedback they receive.

Concept inventories and related diagnostic assessment tools are particularly suitable for the formative assessment role in subjects such as chemistry because there has been a substantial amount of work developing such tests in the conventional summative setting that that evaluated (Mulford & Robinson, 2002) and the results benchmarked internationally. The project is using these resources in combination with those from recent studies in Queensland universities (Schultz & Lawrie, 2011) to develop tests that are focused on feedback. Recent work on the application of concept inventories to the formative assessment role has demonstrated that attention to the type of questions asked and the analysis of results can increase the level and utility of the feedback that the assessment provides (Wright et al., 2009). This project is using an iterative approach of successive assessment-intervention-assessment episodes that provide students with support.

**Key questions for discussion at nuts and bolts session**

This interactive session will report on the first stages of this project: identification of key concepts to be addressed through, and development of, pilot modules for formative feedback through a learning management system. These concepts have been identified through data collected from entering first-year chemistry cohorts across two Queensland institutions in 2011 and 2012. The session will include examples of cognitive dissonance and how the project team aims to apply this in the activities designed to address misconceptions. This will stimulate discussion, and attendees in this FYHE “nuts and bolts” session will be asked to assist the project team identify mechanisms to help students step through formative activities.

Questions will include:

- What are the inherent challenges in engaging students in formative assessment?
- To what extent can students’ shared ideas, through collaborative problem-solving, adjust individual misconceptions?
- What strategies can we use to generate cognitive dissonance in self-regulated learning environments for key chemistry misconceptions?
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Nuts and Bolts Session Plan

Activity 1 (10 mins): Concept inventories ... orientation
- Introduction to project: need and value
- Engage participants in very short concept inventory (science).
- Share common related misconceptions.
- Current use of diagnostics.
- Discussion Q: What are the inherent challenges in engaging students in formative assessment?

Activity 2 (10 mins): Shifting responsibility for learning
- Strategies to increase student self-regulation in learning - shifting the construct of the learning community.
- Discussion Q: To what extent can students’ shared ideas, through collaborative problem-solving, adjust individual misconceptions?

Activity 3 (10 mins): Cognitive dissonance
- Activity to engage participants in the idea of cognitive dissonance.
- Discussion Q: What strategies can we use to generate cognitive dissonance in self-regulated learning environments for key chemistry misconceptions?
Dr Madeleine Schultz is the director of the ALTC-funded Chemistry Discipline Network. Within this role, she is engaged with tertiary chemistry educators around Australia. She is also active in teaching and learning within her academic position at QUT, and has implemented multiple strategic changes to improve student learning in both the laboratory and lecture environments. She has been awarded two Faculty Learning and Teaching Grants at QUT and is currently involved in the development of the new BSc degree.

Dr. Gwen Lawrie holds a 2012 UQ Teaching Fellowship and is current Chair of the RACI Queensland Branch Chemical Education Group. She has successfully completed multiple UQ and Faculty of Science funded teaching and learning projects addressing the diversity and engagement of students through collaborative inquiry tasks and the implementation of undergraduate research experiences. She recently co-led and completed an ALTC Competitive grant (CG9-1112), which enabled implementation and evaluation of collaborative active learning environments in large first-year STEM courses.

Dr Tony Wright is a lecturer in science education in the School of Education at the University of Queensland. He has worked as a journalist, a research chemist and has taught in high schools and universities in England and New Zealand as well as Australia. His current research involves topics that relate to science education and examine student learning in science, assessment in science education, teacher professional learning in both school and university settings and the use of information and communication technologies to support learning. Tony is a leader in the implementation of conceptual diagnostic assessment and evaluation of student outcomes.