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TEACHING AND LEARNING STANDARDS: WHAT DOES A STANDARD MEAN TO YOU?

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EDITORIAL

Conversations about improving the quality and standards of our students and teachers in primary, secondary and tertiary institutions occur daily, both nationally and globally, in the media, in our institutions and between neighbours. The question that everyone is asking is whether our schools and tertiary institutions are preparing students and graduates for professions and citizenship in the 21st century. Such questions are also being asked in tertiary institutions where concerns of falling standards are coupled with perceptions that the quality of our Science and Mathematics graduates is not what it used to be. We are now well clear of the days when universities were the place where only the brightest received a berth, many to be future scientists on a research track. It is unlikely though that these halcyon days ever existed, where all graduates were of high quality; proficient at learning and understanding and skilled at communication and team-work.

Whether our current graduates will be rigorous, sceptical analysts and learners who question science/mathematics concepts and theories and also have the problem-solving, communication, team-working and creative abilities needed for the 21st century remains uncertain. Our anxiety surrounding such uncertainty has heightened as student participation in tertiary institutions has increased and as we have more explicitly broadened the basis of what we expect our graduates to be able to know and do. These broadened expectations of graduates, once perhaps tacit, are now clearly articulated in the “Threshold Learning Outcomes” for Science and Mathematics (Jones & Yates, 2011).

Now that we have articulated our vision of what we want and need our Science and Mathematics graduates to know and be able to do the question remains can we achieve it? How we will know when we have improved the quality of our Science and Mathematics graduates, especially if we did not know what the standard was before? We are now in a tertiary future where the significant work of academics is to teach this broader, more diverse student base, where we will be asked to provide evidence to certify that our students have reached “standards”. Can we measure the standard we want our students to reach? Our greatest resource and our main leverage to do this lies within ourselves; academics and academic practice.

This proceedings of the Australian Conference for Science and Mathematics Education (ACSME) represents the collective contributions of academics who are committed to ensuring evidence-based practice in improving the quality of learning and teaching in Science and Mathematics within our tertiary institutions. You will read about the work of academics that have passion and energy for their disciplines and a desire to instil the same love of learning in their students so that they are equipped for an uncertain future. It is this approach that makes the challenge of producing quality Science and Mathematics graduates achievable. It is through conferences such as ACSME, where academic practice is shared, collegiality is nurtured and new understandings are reached, that we better understand the strategies needed to create graduates who have critical thinking skills, disciplinary knowledge and flexibility to make a productive contribution to our technologically, complex world.

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Associate Professor Pauline Ross
Chair, Australian Conference for Science and Mathematics Education

The Proceedings of the Australian Conference on Science and Mathematics Education contains three types of papers:

- **Full Refereed Papers** which have been peer reviewed by two independent experts and satisfy the Australian DEST E1 category.
- **Full Written Papers (non-refereed)** which have been subject to editorial assessment and satisfy the Australian DEST E2 category.
- **Abstracts** (extract of paper) which have been subject to editorial assessment and satisfy the Australian DEST E3 category.

We look forward to seeing you at the Australian Conference on Science and Mathematics Education (18th Annual UniServe Science Conference).

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KEYWORDS: capstone projects, graduate attributes, undergraduate research

ABSTRACT

This interactive presentation will explore creative ways in which we can design final year and capstone projects which include a significant element of research and inquiry and deliver key graduate attributes. Some departments have introduced capstone projects in their final year courses which are innovative or creative in the context of their discipline or institution, and may include group, work-oriented and community-based projects. There can also be novel ways of disseminating the findings – via exhibitions, undergraduate research conferences and other forms of public engagement. The key is to develop flexible alternatives which meet the needs of all students while maintaining comparable standards.

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TEACHING AND LEANRING STANDARDS AGENDA IN AUSTRALIAN HIGHER EDUCATION: POLICY AND PRACTICAL IMPLICATIONS

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KEYWORDS: teaching and learning standards, higher education, policy and practical implications

ABSTRACT

This presentation will explore the policy and practical implications of the teaching and learning standards agenda in Australian higher education. It will start with a brief mapping of the academic standards territory nationally and internationally. This will be followed by a comparative analysis of several projects engaged in collegial peer review and verification of standards. We will examine the opportunities offered by a range of methodologies, as well as implications of these approaches for the work of quality assurance and enhancement in tertiary education. The presentation will include consideration of practical implications of the standards agenda for academic staff in disciplinary contexts as well as implications for institutions seeking to enhance the quality of their students' experiences and outcomes.

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TEACHING AND LEARNING STANDARDS

Professor Alan Robson AM, CitWA, BAgrSc *Melb.*, PhD *W.Aust.*, FTSE, FACE, FACEL, FAIAS, Hackett Professor of Agriculture

Chair of the Higher Education Standards Panel

BIOGRAPHY

Professor Alan Robson recently completed eight years as Vice-Chancellor of The University of Western Australia.

He has been Chair of the Group of Eight Universities (2007-2010) and Deputy Chair of Universities Australia (2005-2011); Deputy Chair of the Council of the National Library (1998-2005); a member of the Western Australian Science Council (2003-2009); and the CSIRO Board (2003-2008).

He was awarded the Australian Medal of Agricultural Science. In 2003, he was made a Member of the Order of Australia, and awarded a Centenary Medal. In 2009, Professor Robson was made a Citizen of Western Australia.

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CHANGING THE GAME: THE ACDS CENTRE FOR TEACHING AND LEARNING

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KEYWORDS: national centre, curriculum renewal, network, leadership

ABSTRACT

Faculties teaching science and mathematics need to shift their expectations and support of renewal to achieve broad scale improvement in teaching practice. The sector is developing a rich network of groups and individuals collaborating to develop improved teaching practice including discipline and leadership networks, national projects and national leaders in learning and teaching. Recently, the Australian Council of Deans of Science (ACDS) has begun work towards a National Centre for Teaching and Learning for science and mathematics. The new Centre will be a focal point for effective models for organizational change and curriculum development. It will focus the energies of learning & teaching leaders into change at Faculty level by constructing good practice guides providing distilled advice for teaching and learning. The Centre will draw on the experience of learning & teaching leaders, science faculties and associated discipline groups to offer authoritative advice to Universities and external bodies.

The ACDS Centre will be available to the sector through its website which will also link together the existing groups, projects and leaders. The Centre website will house good practice guides to be commissioned by the Centre and a practice exchange which encourages dissemination of good ideas between disciplines. The ACDS Centre will also provide timely advice for the ACDS on teaching and learning. In this session, attendees will be invited to contribute their ideas and views to make the new ACDS Centre as relevant as possible.

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SCIENTIFIC INQUIRY IN THE UNDERGRADUATE CURRICULUM: CHALLENGES AND BENEFITS IN THE NEW AGE STANDARDS

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KEYWORDS: scientific inquiry, science curriculum, student learning

ABSTRACT

"Traditional 'chalk-and-talk' teaching, copying notes and 'cookbook' practical lessons have offered little challenge or excitement" - from Health of Australian Science, May 2012.

This view, expressed in the 'Health of Australian Science' report by Australia's Chief Scientist, finds oblique affirmation in the Australian Curriculum: Science[1][1] and the recently published Science Threshold Learning Outcomes[2][2]. These documents bring particular emphasis to the processes of scientific inquiry, leading naturally to the instructional strategies described in the Chief Scientist's report being eschewed. This presentation explores the benefits to student learning of developing and embedding scientific inquiry into the science curriculum and brings a focus to the challenges of assessing the attendant learning outcomes.

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DEFINING LEARNING OUTCOMES FOR A CHEMISTRY DEGREE: THE STORY OF A PROCESS

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KEYWORDS: undergraduate degree outcomes, chemistry degree, learning objectives

ABSTRACT

The Department of Chemistry at Purdue University embarked on a process of examining the outcomes of its undergraduate degree program. The Undergraduate Studies Committee for the Department embarked on a 3-year process in which feedback was gathered from faculty members, students, alumni and employers of Purdue graduates. With this feedback the committee developed a report outlining the learning objectives that should define the undergraduate degree in Chemistry at Purdue, and how our courses and curriculum should be restructured to ensure these learning objectives are met. Later, this approach to defining the Chemistry degree through its learning outcomes was instrumental in a state-level process funded by the Lumina Foundation and organized by the Indiana Commission on Higher Education. This approach to defining the learning objectives for the Chemistry Degree was approved by representatives from higher education institutions across the state of Indiana. This presentation will describe the process and the details of the recommendations made in both the Chemistry Department and Lumina project reports about the Chemistry degree.

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ALIGNING AN AGRICULTURAL SCIENCE CURRICULUM WITH THE NATIONAL SCIENCE THRESHOLD LEARNING OUTCOMES

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KEYWORDS: peer to peer learning, multi-disciplinary, vocational knowledge

ABSTRACT

A number of discipline groups have recently published Standard Statements, which contributed to the national regulation and quality assurance framework currently being developed in the higher education sector. In the science discipline, this included a statement describing the nature and extent of science and threshold or minimum levels of achievement (threshold learning outcomes) that can be expected of a bachelor level graduate. The aim of this project was to demonstrate that the nationally agreed Threshold Learning Outcomes (TLOs) for Science can be adapted successfully to the specialist, agricultural science discipline. Here we report on the development of course-level learning outcomes using the process of peer-to-peer professional learning of teaching staff in the School of Agricultural Science and qualitative feedback from a survey of teaching and research staff in the School and more widely in the Tasmanian Institute of Agriculture. Key findings are that a statement on the nature and extent of agricultural science needs to capture its multi-disciplinary nature and that TLOs should also incorporate minimum levels of achievement in vocational knowledge. The process will serve as a model for wider dissemination of TLOs within UTAS and other universities.

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CHEMISTRY TO BIOLOGY KNOWLEDGE TRANSFER: DOES IT WORK? MAPPING OF TLO's BY MULTI-EVALUATION TECHNIQUES

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KEYWORDS: SaMnet action learning project, collaborative learning/teaching, staff attitudes, student engagement, TLO mapping

ABSTRACT

Engaging and collaborative activities along with peer assessment allows students to deepen their discipline knowledge, practice team work and gain experience in judging the work of their peers. Thus these activities provide a rich context in which their learning is multi-faceted and is promoted in both discipline and generic domains, supporting the science threshold learning outcomes[1]. This learning was commenced in first year and then built on in a second year subject. Workshops that were based on active learning principles had previously been developed and used in large first year chemistry subjects[2]. That innovation was implemented in another science discipline, with chemistry and biology teaching staff working collaboratively to introduce workshop sessions into BIOL213, a second year biochemistry subject. BIOL213 is largely a 'service subject' and has a failure rate of concern. The main aims of the teaching innovation were - to support knowledge transfer from one set of science discipline staff to another, to demonstrate proof of concept, to foster sharing of learning design across the faculty of science especially to research focused staff, to promote deeper student learning through active learning and consequently improve student performance. The evaluation of this innovation aimed to determine whether these teaching activities and assessment tasks had been effective in students achieving these learning outcomes, at threshold level or above, and to help map chemistry and biology disciplinary areas against the science TLOs. The project team were supported by advice, peer review, and leadership training from SaMnet action-learning team.

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DEFINING STANDARDS FOR RESEARCH-BASED LEARNING

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KEYWORDS: research-based learning, inquiry-based learning, learning standards, undergraduate research

ABSTRACT
Many science students engage in a variety of research-based learning experiences both within their courses and outside the curriculum in special research experience programs. In the context of a project to develop students' awareness and experiences of research we were recently involved in writing a response to a document prepared by the American Council on undergraduate research “Characteristics of Excellence in Undergraduate Research”. Our response demonstrated the extent to which undergraduate research and inquiry-based learning were being encouraged across our campus. This work provided an opportunity to critically reflect on standards of undergraduate research implementation. It led to a consideration of a set of standards for judging the quality of undergraduates' engagement in research-based activities. In this paper we will outline the characteristics of excellence and then discuss the set of standards we have developed. These are written in the form of levels of achievement that can be applied in a variety of situations within the curriculum and at a range of different levels and subjects.

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OUT OF ONE'S COMFORT ZONE: DEVELOPING A NON-TRADITIONAL FIRST-YEAR UNIVERSITY MATHEMATICS SUBJECT

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KEYWORDS: tertiary mathematics, quantitative thinking, integration, science curricula and contexts

ABSTRACT

Demand for quantitatively literate students in the sciences has significantly increased in recent years as advances in technology dictate industry and business employee capabilities. However, the higher education sector in the sciences is struggling to ensure that its graduates meet these demands as progressively more students are entering science courses with poor mathematical skills and attitudes. Traditional science curricula have tended to meet these standards by including one or two mathematics and/or statistics compulsory subjects to develop quantitative skills in students with varying degrees of contextualisation dependent on the discipline. However, such conventional mathematics and statistics content has not equipped students necessarily with the essential skills to transfer and apply their mathematical knowledge gained in traditional mathematics subjects into scientific contexts. At the University of Western Sydney, a curriculum review created mathematical pathways for student progression to improve quantitative standards including a mathematics subject "Quantitative Thinking", which is integrated and closely linked to first year science subjects. We report here on the concerns, issues, successes and failures as experienced by the academic staff developing this mathematics subject for first year science students. Staff experienced a major pedagogical shift in not only developing the content, but in the method of delivery and assessment tasks used.

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REDUCING SOCIAL ISOLATION AND ENHANCING ENGAGEMENT BY FIRST YEAR STUDENTS

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KEYWORDS: distance, first year, social isolation, online communication

ABSTRACT

Science and maths educators of off campus students often struggle to find the most effective means to demonstrate complex concepts in the same scaffolded manner as achieved in face to face interactions. Our research indicates applying a 'monocle-like' focus on content, particularly in first year classes, may be a contributing factor to high attrition and high failure rates. Drawing upon a 5 year study of a large first year distance education class, and in-depth analysis of the literature, we identify the impact social isolation has on first year students and how it can affect engagement with content, peers and teaching staff. We also identify falsehoods in the assumption that today's students are 'net savvy' or technologically literate to the point of being able to identify and address their interaction needs at least as well within an education space as they may do in social networking spaces. More critically, for conference participants we will present several strategies developed over 5 years of practical reflection and process development that reduced students' perceived social isolation and will provide ample time for the sharing of strategies, practices and experiences to explore possible future research linkages.

Proceedings of the Australian Conference on Science and Mathematics Education, University of Sydney, Sept 26th to Sept 28th, 2012, page 11, ISBN Number 978-0-9871834-1-5.

INITIAL DATA ANALYSIS OF TEACHER AND STUDENT USE OF LAPTOPS IN SCIENCE IN 14 SYDNEY SECONDARY SCHOOLS

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KEYWORDS: 1:1 laptops, Australian schools, Bloom's digital taxonomy, computers in science classroom, digital education revolution, science

ABSTRACT

In Australia, since 2008, 1:1 laptops have been introduced into secondary schools through the Federal Government's Digital Education Revolution. This study examines survey responses from 1245 science students and 47 science teachers from 14 secondary schools in Sydney in 2010. The initial data analysis is in two parts. Firstly, teachers' and students' reported frequencies of use are compared through 'bubble graphs' and a generated 'Misalignment Index'. Results show student and teacher perceptions of use were usually relatively aligned though sometimes very contrasting. Some 30% of teachers were highly aligned, 55% had medium alignment and 15% were substantially misaligned with their respective students (Crook, Sharma, Wilson, & Muller, in press).

Secondly, the types of teacher and student use of laptops are examined. The activities are differentiated from lower- to higher-order using Bloom's Digital Taxonomy. It is found that the modal practice for students is the lower-order paradigm of note-taking and working from textbooks through electronic means by word processing and electronic textbooks, plus simple online searching. Students would like to engage in more higher-order activities such as blogs and video editing but these are not favoured by teachers. Datalogging is a rare experience. Most science teachers appear to use simulations but students do not report the same experience.

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Proceedings of the Australian Conference on Science and Mathematics Education, University of Sydney, Sept 26th to Sept 28th, 2012, page 12, ISBN Number 978-0-9871834-1-5.

A PILOT PROGRAM TO BUILD RESEARCH COMPETENCE IN TEACHING AND LEARNING IN ACADEMICS

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KEYWORDS: educational research, scholarship of teaching and learning

ABSTRACT

As universities moves towards becoming more research intensive while maintaining high standards in teaching and learning it is expected that all academic staff will engage in scholarship of teaching and learning. One aspect of scholarship is research in teaching and learning. Although academics may want to conduct educational research they do not necessarily have the research background to do so. Educational research has its own particular research paradigms, methodologies, data sources and methods of analysis, some of which may be unfamiliar to those from STEM disciplines. In 2011, a curriculum resource and professional learning program was developed to enable academics to engage in educational research in tertiary settings. The curriculum resource includes modules on educational research paradigms, research methodologies, data sources, ethics, data analysis, writing and publishing. In 2012, the program is being piloted with 26 academics. The program has been challenging as academics struggle to understand research methods they are not familiar with and find time within their busy academic lives. Nonetheless, the participants are enthusiastic and most are making steady progress in their research. This presentation will focus on preliminary findings of the experiences of the participants.

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BEST PRACTICES IN THE USE OF LEARNING OUTCOMES IN CHEMISTRY EDUCATION

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KEYWORDS: learning outcomes, benchmarking, chemistry education

ABSTRACT

Learning outcomes driven chemistry education is increasingly practiced, providing new opportunities for international comparisons. The interest in intended learning outcomes and constructive alignment has grown in many parts of the world due to both research in higher education (Biggs & Tang, 2011) and political decisions (*e. g.* the Bologna process in Europe). We will describe our steps towards a method for benchmarking (i.e. learning by sharing and comparing best practice) these outcomes, to enhance learner-centered chemistry education both in the developed and developing world. The project builds on and extends task group members' experiences from national and international projects and draws on the international framework and multicultural competence of IUPAC's Committee on Chemistry Education.

Guiding chemistry education for the future requires the exchange of perspectives on core knowledge, skills and competencies. This project evaluates how learning outcomes for courses and modules are linked to each other and to learning outcomes for educational programs and how the expected learning outcomes can be aligned with learning activities and assessment. The comparison informs guidelines for self-evaluation, which focus on local learning outcomes for chemistry education including courses/modules, compared with national and/or international descriptors and with attention to alignment with learning activities and assessment.

A full electronic report and manual for the benchmarking procedure will be produced at the conclusion of the project, including a collection of examples of good/best practice for dissemination.

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Proceedings of the Australian Conference on Science and Mathematics Education, University of Sydney, Sept 26th to Sept 28th, 2012, page 14, ISBN Number 978-0-9871834-1-5.

SCIENTIFIC INQUIRY SKILLS IN FIRST YEAR BIOLOGY: BUILDING ON PRE-TERTIARY SKILLS OR BACK TO BASICS?

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KEYWORDS: biology, scientific skills, transition, benchmarking

ABSTRACT

With the imminent introduction of the Australian Curriculum, will first-year biology subjects build on and offer further development of the skills and capacities that students will acquire once the curriculum is implemented? The answer to this question has important implications for student transition to, and success at university. Data was collected using university handbook entries from all thirty-nine Australian universities with more detailed information provided by first year biology co-ordinators. The focus of this benchmarking process was inquiry skills taught in first year core biology subjects. Preliminary data will be presented showing that almost all Australian universities offer experiences in multimodal forms of communication, working in teams and undertaking experimental investigations, and are well placed to build on the skills pre-tertiary students bring with them into first year undergraduate studies. Other notable differences and their implications for first year biology courses will be highlighted.

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STUDENT GUIDED TRANSITION ASSISTANCE

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KEYWORDS: transition, strategies, challenges study groups, science,

ABSTRACT

In the Faculty of Science at the University of Melbourne a transition program has been in place for new students entering the Bachelor of Science since 2000. During this time the program has been modified regularly in response to staff and student feedback. However, with the introduction of a new Science degree structure combined with the changing nature of student experiences and expectations, a more extensive review of the current program is being undertaken. The aim of the review is to gather feedback from students, and the student facilitators of study groups, on the program's effectiveness in assisting students. The information collected will be used to develop new strategies to maximize the program's effectiveness. In 2012 we have probed student expectations and provided students with an opportunity to reflect on the challenges of transition. The program has also been reviewed from the perspectives of the first year teaching staff. The data collected will guide modification of the program for 2013 with the objective of targeting the transition program more effectively to assist first year science students' transition from school to University. Our findings will be presented in this paper.

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CROSS-SECTIONAL ANALYSIS OF UNDERGRADUATE NURSING STUDENTS' PERCEPTIONS OF BIOSCIENCE

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KEYWORDS: student perceptions, anxiety, bioscience literacy, nursing

ABSTRACT

Nursing was one of the last health professions to be established in the higher education sector. A lingering challenge is the integration of bioscience into nursing curriculum. Research suggests that students perceive bioscience teaching to be difficult thereby contributing to heightened anxiety. It has been proposed that high content volume, lack of secondary school science, and predominance of science lecturers without clinical practice experience, may lead to a bioscience disconnect with curricula. To ascertain the extent of this problem, we undertook a cross-sectional designed study of commencing, second and third year undergraduate nursing students (*n*=566). They were surveyed about perceptions, knowledge and approaches to bioscience learning. Preliminary analysis revealed similar findings between the three different cohorts. Generally, students' perceived bioscience subjects to be difficult, more challenging and requiring more study hours than clinical nursing subjects. Interestingly, the perception of difficulty and associated anxieties were found in both commencing and existing students. Moreover, students with secondary school biology combined with another science subject perceived bioscience teaching more favourably compared to those who had studied one secondary school science subject. University coursework needs to embed strategies to minimise anxieties about learning bioscience by using innovative deliveries and scaffolded assessments that target the learner's needs.

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DOES OUTREACH INFLUENCE ENROLMENT?

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KEYWORDS: Kickstart, outreach, enrolment

ABSTRACT

Universities often offer a range of programs for high school students as outreach activities. These programs have various objectives amongst which are the implicit intention to recruit. One such outreach program is the Kickstart program run by the School of Physics at The University of Sydney. Historically, survey data for this program was focused on evaluating the performance of the staff involved and content of the program, not the students' engagement or education. This was a useful tool, but once enough data was collected, it was necessary to move to a different focus of student engagement, education and enrolment.

The aim of this project is to evaluate the effectiveness in three domains of the Kickstart program, Education, Engagement and Enrolment. An interest in the project is to gather data on the enrolment aspect of Kickstart or "Does coming to Kickstart encourage enrolment in Sydney University Physics?" To conduct the evaluation of the program, student and teacher surveys gather responses to the program. A survey was designed and iteratively modified, and currently the project has completed the second phase of data collection. The purpose of this second phase was to gain consistent results with previous versions of the survey. The results show clear responses from students regarding engagement and education, and a clear indication that the survey is not appropriate for answering the question regarding enrolment. The data so far has eliminated a number of ways of answering this question. A key issue is whether the question on 'Does outreach influence enrolment?' is answerable and even more importantly, should we attempt to answer this question.

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DON'T DUMB IT DOWN – MIX IT UP! ENGAGING AND ENHANCING METABOLISM STUDENT LEARNING CAPACITY WITHOUT DUMBING DOWN CONTENT OR ASSESSMENT STANDARDS

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KEYWORDS: academic standards, metabolic biochemistry, scaffolded learning, learning capacity

ABSTRACT

Metabolism is a content heavy second year course with which students traditionally struggle and historically suffered from an unacceptably high failure rate (>20%, 2004-2006) in our school. Student perceptions of the difficulty of the course lead to disengagement prior to starting with students not having acquired appropriate study techniques that would enhance their capacity to succeed.

Remodelling of the course in the sequence of information presented (2007) and in presentation style (2009) occurred. Content sequence ensured an understanding of key metabolic pathways followed by regulatory influences and disease states. The new format has a three week cycle that begins with traditional lectures but follows with workshops designed to cement core concepts and develop global cognitive comprehension. The cycle was designed to enable students to approach the study of this subject in a scaffolded manner that promotes engagement with materials and facilitates their overall capacity to learn in a deep manner.

This strategy resulted in consistent reduction in the fail rate of approximately 10% (2008-2011) without compromising standards of assessment. Students were guided to develop better self-efficacy and independent learning skills. Evidence of subject mastery is demonstrated by higher pass rates and also a shift to higher numbers of distinction and high distinctions.

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COMPARING SECOND YEAR STUDENT EXPERIENCES ACROSS THE PACIFIC

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KEYWORDS: sophomore slump, student transition, international comparison

ABSTRACT

Second year students often struggle with personal identity, self-confidence, autonomy and academic commitment (Graunke & Woosley, 2005). We have observed declines in student grade performance, attitude and program satisfaction in our second year science students and these findings appear to share commonality with the *sophomore slump* phenomenon reported at American colleges. To investigate this, 84 third year science (exercise and biomedical) students completed the 2012 online Sophomore Experiences Survey developed to measure academic, social and psychosocial aspects of students' second college year (Schreiner, 2010).

Griffith students reflective responses were compared against 915 sophomore students from seven North American Universities and were found not to differ significantly on the following 6 (high)-point scale student outcome measures (mean GUvsUSA): Engaged Learning Index (4.16vs4.19), Academic Determination (4.29vs4.64), Diverse Citizenship (4.03vs4.35), Positive Perspective (4.32vs4.62), Social Connectedness (4.08vs4.16). However Griffith students report a lower level of being consistently or mostly *thriving* (30vs45%) compared to their USA peers.

More analysis follows but these pilot findings confirm the presence of homogeneous transpacific second year student experiences, thereby justifying further investigation into the successful US sophomore initiatives aimed to improve community, social and academic engagement, student-staff interactions, career exploration and leadership in this forgotten student cohort (Tobolowsky, 2008).

ACKNOWLEDGEMENTS

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STUDENT ATTITUDES AND EXPECTATIONS IN UNDERGRADUATE FORENSIC SCIENCE

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KEYWORDS: forensic science, affective instrument development, student motivation, interdisciplinary education

ABSTRACT

Undergraduate forensic science programs in Australia aim to formally educate students in the philosophies, skills and techniques required of practicing forensic scientists. As forensic science is multi-disciplinary, variations in emphasis and foci can result in differences between the curricula of various programs. In order to determine the differences in attributes that our institutions deemed important for students to possess, we collected information from each institutional partner on: the definition of forensic science; methods used to teach forensic science; important knowledge students should acquire from a forensic science-based unit of study or degree program; and the main factors contributing to the retention of students in a forensic science degree program. This feedback was used to develop an instrument to survey students across the various institutions to measure their: perception of popular media as a motivator to study forensic science; personal interest in forensic science; perspective of forensic science as a science; and perspective of forensic science as a profession. This information can be used to relate the diversity of student attitudes and expectations and examine further matters of importance within forensic science education, such as ensuring graduates from various programs are equipped for a career in forensic science.

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RELATIONSHIPS BETWEEN CONFIDENCE, GENDER, HIGH SCHOOL PERFORMANCE, A CONCEPT INVENTORY, AND SUCCESS IN FIRST YEAR CHEMISTRY

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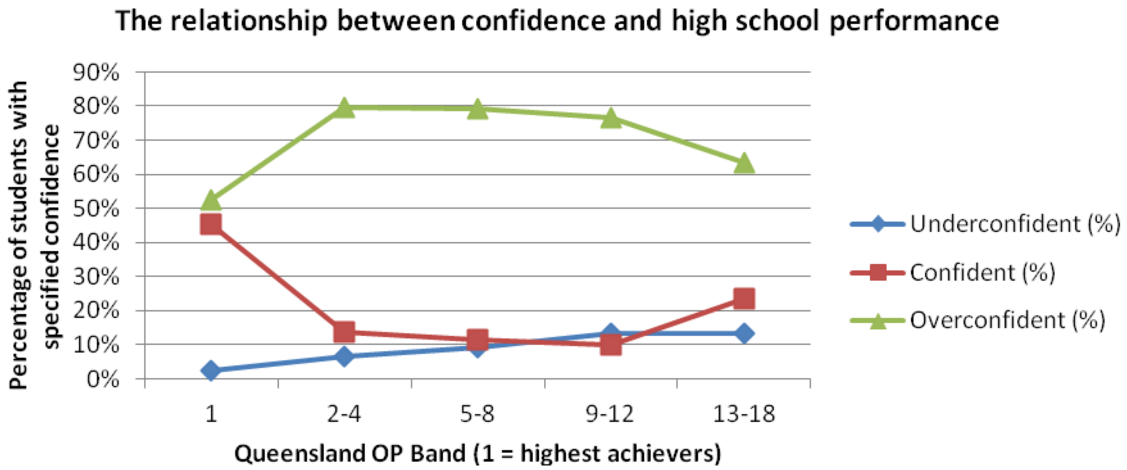
KEYWORDS: first-year experience, concept inventory, confidence, gender effects

ABSTRACT

We have profiled the range of existing conceptual understanding of first-year students entering chemistry at two major research-intensive tertiary institutions in Queensland in 2011 and 2012. Chemical concept inventory items (CCI) have been drawn from across a number of validated literature instruments and delivered in an online questionnaire in week 1 of the first semester of chemistry.

The number of students giving the correct answer for each concept inventory question did not change significantly from 2011 to 2012. High school performance (Queensland OP) was not a significant predictor of performance in the concept inventory. A significant gender difference emerged, with female students (across both institutions) receiving a lower mean score in the concept inventory than males.

In 2012, the students' confidence in their answer to each question was also explored (Potgieter & Davidowitz, 2012). A number of unexpected results emerged that contrast with published findings (Sharma & Bewes, 2011); in particular, females were significantly more likely to be overconfident than males, and the most overconfident students were those in the mid-range band of high school achievement (Queensland OP 2-8) (see Figure). These results will be discussed in terms of factors such as program of study, age and institution, as well as metacognitive factors.



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THE EFFECT OF GRADING MATRIX ASSESSMENT ON STUDENT PERFORMANCE IN A LARGE FIRST YEAR BIOLOGY CLASS

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KEYWORDS: grading matrix, large class, first year biology, graduate attributes

ABSTRACT

In our large first year biology course, 'Cells to Organisms', for 400-900 students per semester, we aimed to provide students with clear links between the course delivery framework and assessment. We wanted the students' grades to reflect higher order learning of key concepts of cellular and tissue biology, achievement of related practical skills, understanding of the nature of evidence and communication of science. In Semester 1 2008, student grades were determined by the traditional weighted average of marks for the assessment tasks. Since Semester 2 2008, the course has been graded with a grading matrix with specified standards for practical reports, practical competencies, communication tasks and knowledge for the grades of 7 (best) to 1 (worst). Analysis of results for the subsequent three semesters showed that 84-90% of students obtained a passing grade, and that 75% of those students achieved 60% or greater in the final examination – a marked improvement compared with about 50% of the students in Semester 1 2008. Also, their knowledge has improved with a 5% increase in the average mark in the final examination. The grading matrix resulted in improved student engagement with and performance in the assessment areas and graduate attributes addressed in the course.

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THE IMPACT OF PREREQUISITES ON STUDENT SUCCESS AND ACADEMIC RIGOUR

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KEYWORDS: prerequisites, academic success, flexibility

ABSTRACT

Discipline specific prerequisite requirements are integral to most course structures and discipline sequences. At Monash University a move to provide increased flexibility in subject choice at the undergraduate level was partially addressed by allowing students choice in pre-requisite requirements. To address concerns of the impact of these changes a study was designed to examine student success in Biochemistry in relation to their prior studies. The study cohort were students undertaking Biochemistry as part of the B.Sc. degree, in which students enrol in Biochemistry as single subjects or as part of required major/minor sequences. Biochemistry studies commence at year 2 and build on previously learned concepts taught by biology/chemistry departments. The relaxation in pre-requisite requirements resulted in students undertaking Biochemistry with prior studies ranging from strong backgrounds in both chemistry and biology to minimal backgrounds in these disciplines. Data was collated on student's prior studies including; final year of school (chemistry/biology), 1st year university (chemistry/biology), 2nd year Biochemistry and 3rd year Biochemistry. Analysis of examination results indicated that prior studies in related subjects correlated with academic success. The issues of how university decisions are made, how we improve student success and the impact on academic content and rigour must be considered.

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QUANTITATIVE SKILLS IN SCIENCE: FINDINGS FROM 13 CASE STUDIES

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KEYWORDS: quantitative skills, science, mathematics, science curricula, curricular models

ABSTRACT

The focus on mathematics and statistics in undergraduate science education is gaining attention as the scientific community calls for higher standards of quantitative skills (QS). An Australian Learning and Teaching Council (now the Office of Learning and Teaching) project explored QS as a graduate learning outcome in science from a whole of program perspective. Using a case study methodology, this paper draws on interview data (n=48) from 13 institutions (11 in Australia and 2 in the United States) exploring how QS are incorporated into the undergraduate science curricula. Framed within a model for large-scale educational change based on the extensive work of Michael Fullan, each case study explored the vision and planning for QS, the implementation of approaches to build science students' QS across the curriculum and evaluation of subsequent QS learning outcomes. The analysis highlights the tremendous variation in the curricular approaches to build QS across the 13 institutions. We offer four QS curricular models to describe how mathematical and statistical knowledge is developed and applied in science units across the undergraduate degree program.

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OUTCOMES OF THE CHEMISTRY DISCIPLINE NETWORK MAPPING EXERCISES

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KEYWORDS: benchmarking, mapping, threshold learning outcomes

ABSTRACT

Standards, threshold learning outcomes and generic graduate outcomes are increasingly important at Australian Universities. The Chemistry Discipline Network has begun developing approaches to these issues and in this paper, we report our experiences and outcomes thus far. We have completed the first snapshot map of all chemistry units of study offered in twelve universities across Australia, including content, delivery and assessment. We report some general patterns found and more possible questions that can be asked of the information base (http://www.chemnet.edu.au/?q=node/39). In addition, we have mapped the first year chemistry and other compulsory science units offered at six universities against the chemistry TLOs (http://www.chemnet.edu.au/sites/default/files/files/Chemistry%20Threshold%20Learning%20Outcomes%20May%202011.pdf). The results, while preliminary, show that in the first year, large gaps are evident. We have also begun identifying exemplar learning activities, objects and related assessments for each TLO. This process establishes possible practices which will enable universities to demonstrate that the subjects and degrees meet TLO and standards audits. The results of the two mapping exercises are proving invaluable as sources of both information and discussion of issues, including what a student must achieve to be awarded a BSc in chemistry, and what sort of diversity should be encouraged between universities with different sub-discipline specialities. Using these results, we plan a good practice guide to help ensure that degrees will pass an audit. In conjunction with this we are working towards possible discipline agreed standards to submit to the standards authority.

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TRANSFORMING THE CLINICAL BACTERIOLOGY CLASSROOM

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KEYWORDS: microbiology, higher-order learning, inquiry learning

ABSTRACT

Traditional microbiology teaching is based on content-driven presentations. To transform how students engage with microbiology, a teaching approach was devised to motivate students and support deeper learning. By creating interactive and supportive atmospheres in both “lectorials” (lecture-tutorial hybrids) and in the laboratory, using higher-order learning activities, students are encouraged to actively engage, thereby influencing their learning. Multiple opportunities are provided for students to apply principles flexibly according to a given situation or context, to adapt methods of inquiry strategically, to go beyond mechanical application of formulaic approaches, and to self-appraise their own thinking and problem solving. The novel approach of commencing (dry) experimental work during lectorials with subsequent follow-up in the wet lab encourages students to better appreciate the critical linkages between theory and practice. Quantitative and qualitative data generated by multiple student evaluations confirm that this approach strongly influences student learning and engagement in the clinical bacteriology classroom. This provides evidence that this teaching practice assists students to learn, and achieve the standards and benchmarks expected at this undergraduate level. Aspects of this model could also be translated to teaching contexts other than microbiology.

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USING TOYS TO INCREASE GRADUATE PRIMARY EDUCATION STUDENTS' CONFIDENCE AND KNOWLEDGE IN SCIENCE AND TECHNOLOGY

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KEYWORDS: scholarship of teaching, collaborative learning, preservice teachers, science, technology

ABSTRACT

A major challenge faced by tertiary science education lecturers is the characteristic lack of confidence and pedagogical content in science of primary preservice teachers. This paper discusses a curriculum based elective unit that was developed to address this problem. The unit was developed as part of a scholarship of teaching project with the goals of enhanced future teaching and learning outcomes by use of student feedback to improve unit design and delivery as well as improved understanding of student needs for developing confidence and expertise in science. Preliminary results at inception provided evidence that perceived confidence towards teaching science and technology was increased along with a moderate increase in background content knowledge. The unit adopts a practical approach in a positive, collaborative learning environment and uses toys as the stimulus for discussion and explanation of underlying science concepts. Examples of toys used will be presented and discussed in the context of university teaching practices capable of supporting preservice teachers developing confidence and expertise for teaching science. Follow up evaluation drawing on student feedback from University Student Experience (USE) questionnaires will be presented as evidence of the continued success of the unit.

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AN EVALUATION AND REDEVELOPMENT OF CURRENT FIRST YEAR LABORATORY PRACTICES

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KEYWORDS: expository learning, inquiry learning, problem based learning, chemistry laboratory, teaching styles

ABSTRACT

Chemical education is an important area of research as it directly impacts upon the production of capable scientists. This study involved evaluation and redevelopment of first year laboratory experiments in Chemistry 1 at the School of Chemistry, UTAS, with respect to the teaching styles implemented. The teaching styles focused on expository, guided inquiry, and problem solving to be applied to two experiments. The aims of this study included the investigation into the engagement and input of both students and demonstrators, the understanding achieved by students through completion of the laboratory experiment, and the enjoyment of participating and completing the laboratory experiment. The underlying goal was the construction of a foundation for further research into the differences between teaching styles when applied to laboratory courses.

The major outcomes of this study found that both problem solving and guided inquiry had greater success than expository in areas such as the engagement of students within the laboratory environment, and the students gaining a deeper understanding of the chemical concepts. In addition, expository and problem solving was found to have more acceptable workloads than guided inquiry. The greatest contribution of this study was the foundation for further study to be continued into this field of research.

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MORE THAN JUST LAB REPORTS – INTRODUCING STUDENTS TO ACADEMIC LITERACIES

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KEYWORDS: academic literacies, academic writing, generic skills

ABSTRACT

The ALTC Learning & Teaching Academic Standards for Science (Jones & Yates, 2011) have been widely endorsed (including by the Australian Council of Deans of Science) after extensive consultation and have the potential to serve as markers for Learning Standards in a more highly regulated environment under TEQSA. The Threshold Learning Outcomes do however present a number of challenges on the 'Understanding Science' and 'Communication' fronts (TLOs 1 & 4) as these outcomes are often not explicitly supported in current curricula. The Bachelor of Science program at The University of Adelaide was reviewed by an external expert panel in 2007. One of the key recommendations that came from this review was the requirement to introduce a common compulsory course in the first year of study focussing on the development of academic literacies. This new course ('Principles & Practice of Science I') was offered for the first time in Semester 1, 2011. The TLOs 1 & 4 of the Science LTAS were key drivers in the development of this course. Students are introduced to the idea of what it means to "be a scientist" through discussion of the broad array of scientific endeavour, the integrated nature of scientific disciplines, the importance of scientific process and critical thinking. Academic writing was used as the key vehicle for assessment of the desired learning outcomes. In this presentation the curriculum constructs and outcomes from the first two cohorts of students will be reviewed.

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WHAT STANDARDS SHOULD BE SET FOR QUALITATIVE RESEARCH CONDUCTED IN A SCIENCE FACULTY: PSYCHOLOGY, RIGOUR AND THE POLITICS OF EVIDENCE

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KEYWORDS: qualitative research, trustworthiness, epistemology

ABSTRACT

While the field of clinical psychology has traditionally relied on empirical research, particularly in the form of randomised control trials, many important questions can also be answered by a wide range of qualitative methods. These methods allow for a closer analysis of therapeutic process, the narrative and interior life of the client, the ways in which meaning is constructed by those in distress and much more. Despite increasing recognition, tensions arise when advocating for, and employing qualitative methods in a science faculty, tensions that can only be alleviated by what Derrida (1997) calls 'An Ethic of Hospitality.' This ethics implies a process of mutual influence between researchers, one which has the potential to both deepen the focus of traditional clinical research and enhance the rigour applied to qualitative work. Ten standards are proposed to ensure trustworthiness in qualitative research, including, including those that support researcher reflexivity and the credibility and dependability of findings. Specific examples of current studies that rely on these standards will be provided.

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WHO'S AFRAID OF THE CHEMISTRY LAB?

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KEYWORDS: chemistry, laboratory, anxiety, preparation

ABSTRACT

First-year University Chemistry students frequently experience significant anxiety in the Chemistry laboratory. This has been ascribed to fears around handling chemicals, unfamiliar equipment and chemical procedures, collecting data, working with other students and time pressures (Bowen, 1999). Use of the Attitude Toward the Subject of Chemistry Inventory v.2 instrument (Xu & Lewis, 2011) in a large enrolment second-semester first-year Chemistry class established that anxiety was inversely correlated with previous chemistry experience. This is surprising as one would assume that greater familiarity would decrease anxiety. A student survey (see Figure 1) revealed that the main factor producing anxiety was time-pressure. Using an information-processing model to inform an intervention, pre-laboratory exercises were expanded, in accordance with Abraham's observation that most learning occurs prior to laboratory classes (Abraham, 2011). Access was also given to *LabSkills* multi-media resources as part of the pre-laboratory preparation. Student responses suggest that these approaches are more effective in ameliorating anxiety for those students already possessing a high degree of self-efficacy.

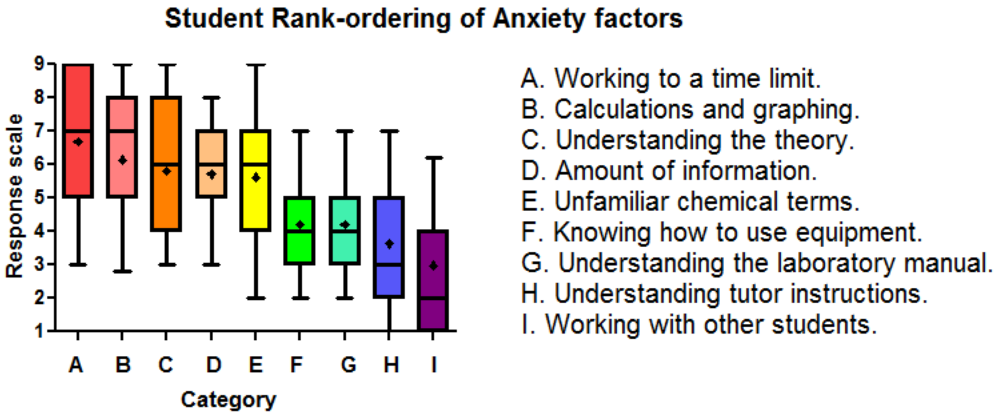

Figure 1: Student rank-ordering of anxiety factors. Boxes represent upper and lower quartiles, with whiskers representing the highest and lowest deciles. Means marked with "+".

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USING THRESHOLD CONCEPTS TO DESIGN A FIRST YEAR BIOLOGY CURRICULUM

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KEYWORDS: threshold Concepts, Laboratory inquiry activities, biology curriculum

ABSTRACT

We used a matrix of threshold concepts, which incorporates a network of discipline ideas/processes (Ross, Taylor, Hughes, Kofod, Whitaker, & Lutze-Mann, 2010) and encapsulates our conceptual understanding of biology, as a useful construct for integrating 'ways of thinking and practicing as a biologist' into curriculum design and delivery (Taylor, 2006, 2008). Our new laboratory program for first year biology students focuses more explicitly on key abstract threshold concepts such as hypothesis testing, and scale, using challenging hands-on investigations and increased levels of student independence. We also integrated into the course, a broad range of activities which address key problems in understanding and help students to monitor their progress (Lawson, 2003; Oh, 2010; Kim, 2011). We used our extensive surveys of students' understanding of concepts such as hypothesis testing, to create a diagnostic survey instrument (Zimbardi, Meyer, Chunduri, Taylor, Ross, Tzioumis & Lluka, 2012), which could be used to track student progress. Similarly our data on student writing of hypotheses and testing protocols (Taylor & Meyer, 2010), which showed a huge variation in understanding of the how and what of testing, led us to design a series of experimental design and interpretive writing activities which allowed students to develop and practice their understanding of the concept.

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Proceedings of the Australian Conference on Science and Mathematics Education, University of Sydney, Sept 26th to Sept 28th, 2012, page 33, ISBN Number 978-0-9871834-1-5.

INTERDISCIPLINARY INTEGRATION OF INQUIRY-ORIENTED LEARNING IN SCIENCE

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KEYWORDS: inquiry, inter-disciplinary learning

ABSTRACT

A substantial body of research has demonstrated the considerable value, across a range of educational domains, of integrating inquiry-oriented learning (IOL) activities in undergraduate science, particularly laboratory- and field-based modalities. These initiatives have often been introduced into single disciplines or at particular year levels by lone but skilled and highly motivated innovators. While praiseworthy, such initiatives may lack the synergies and impact that could be gained through more broad scale integration of IOL both horizontally, across a range of science disciplines, and vertically, through the year levels of a science degree. Such an approach provides considerable potential benefits to students, through articulation of a consistent model and template for laboratory activities, and importantly, through the contextual amplification that can be generated through interdisciplinary, inquiry-oriented learning. It also has the potential to strengthen graduate outcomes through greater resolution of curriculum mapping, and resonates strongly with other initiatives including the Learning and Teaching Academic Standards (LTAS) in the sciences project. The current project has engaged 1st year science educators across a range of disciplines (initially biology, chemistry and physics) to collaborate in the development, implementation and evaluation of meaningful IOL initiatives for students as they progress through their degree.

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SCIENCE LEARNING OUTCOMES: THE STUDENT PERSPECTIVE

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KEYWORDS: learning outcomes, science skills, standards

ABSTRACT

Gathering evidence of the learning outcomes of our graduates constitutes an essential element in the quality assurance and improvement of institutional programs; it has also become the focus of the national standards agenda for higher education. Although the validity of self-reported learning gains is often questioned, they provide an additional dimension to any analysis of learning outcomes.

In this presentation we will report on the findings of a survey administered to graduating science and biomedical sciences students in two research intensive institutions. The Science Student Skills Inventory (SSSI) instrument was used to gauge student perceptions about their learning gains at program level, with respect to both learning scientific content and knowledge in their field of study and development of skills essential to science (communication, writing, quantitative thinking, team work, ethical thinking, and research skills). The report will include (i) an analysis of students' perceptions of the types of class contact and assessment tasks where each of these skills were present, their overall assessment of their learning, and the importance of these skills to their future occupation; and (ii) a comparative analysis between the two degree types, students' backgrounds and future plans.

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DEVELOPMENT OF POGIL-STYLE INTRODUCTORY ORGANIC CHEMISTRY ACTIVITIES

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KEYWORDS: inquiry learning, POGIL, group work

ABSTRACT

Foundations of Chemistry IA (semester 1) and IB (semester 2) courses at the University of Adelaide are undertaken by Level I students pursuing a wide variety of degree programs that require a year of Chemistry study. As a consequence, many students who have never studied Chemistry in high school enrol in these courses. We have rewritten these courses for 2012 to cater to students with little or no Chemistry background, with group-based Process-Oriented Guided Inquiry Learning (POGIL) style activities used to deliver the majority of the course content. Early indications are that POGIL-style learning has been successful in improving student performance.

We have been developing POGIL-style activities for all topics within both courses, but particularly in the area of introductory organic chemistry, for which few activities currently exist. Three organic chemistry activities were developed and subsequently tested in workshops run in November 2011 and April 2012. Student volunteers completed a survey consisting of Likert and open-ended questions related to the activities at the conclusion of each workshop. A focus group was also held at the conclusion of the second workshop. A summary of these responses and how they drove the development and revision process of the activities will be presented.

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ACADEMIC STANDARDS AND PROFESSIONAL ACCREDITATION

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KEYWORDS: chemistry threshold learning outcomes, professional accreditation, academic standards

ABSTRACT

In 2011 a working group chaired by Mark Buntine from the Royal Australian Chemical Institute (RACI) developed an agreed set of Chemistry Threshold Learning Outcomes (TLOs), partly in response to TEQSA. The development of the Chemistry TLOs was also recognition amongst academics and chemical educators that we need to focus more of our thinking on what we expect the complete graduate to look like. What skills and understanding do we think it is important for a chemistry graduate from our Australian universities to have?

In addition to their use in curriculum renewal within universities, the TLOs have the potential to be used in other ways. On a regular basis, the RACI accredits undergraduate degree programs with a major in chemistry. How can the Chemistry TLOs be used to define standards against which a degree can be measured? Is it possible for the Chemistry TLOs to be used in a formal accreditation process? This presentation will address these questions.

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ACADEMIC STANDARDS IN SCIENCE – THE *GOOD PRACTICE GUIDE* FOR THRESHOLD LEARNING OUTCOME 1: UNDERSTANDING SCIENCE

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KEYWORDS: LTAS, threshold learning outcome, understanding science, nature of science

ABSTRACT

With the broadening of participation in Australian Higher Education, it has become increasingly important that tertiary education institutions can provide evidence of the standard of education offered to students to ensure the quality of graduate outcomes. Teaching and Learning Standards are currently being developed by the Tertiary Education Quality and Standards Agency (TEQSA) as part of the Higher Education Standards Framework. To inform this process, The Learning and Teaching Academic Standards (LTAS) Project for Science has developed a list of five Threshold Learning Outcomes (TLOs) for science graduates (Jones, Yates & Kelder, 2011). These TLOs were developed through a period of detailed consultation with the Australian science community and describe what Australian science graduates should know and be able to do by the time they graduate. This paper focuses on the first of these TLOs, *Understanding Science*. The paper explains what this TLO means and why it is important for our undergraduate science students, before suggesting some good practice strategies for teaching and assessing the *Understanding Science* TLO. This information will be made available in the *Good Practice Guide* for TLO 1.

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STANDARDS AND EFFECTIVENESS OF ONLINE LEARNING IN ENGINEERING PHYSICS

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KEYWORDS: MasteringPhysics, online learning, standards, face-to-face tutorials

ABSTRACT

This is a preliminary study. Because of budget constraints and large first year classes there is a move by administrators to get academics to use online learning tools for tutorials rather than face-to-face tutorials. There are a number of on-line tutorial systems (such as, CyberTutor, MasteringPhysics) available for use. We used the MasteringPhysics online tutorial system which is based on the 'Socratic' tutoring style. The software has the capacity to ask questions, provide hints, feedback and other learning devices, such as animations which serve to assist the learning process. The system was trialled with over 100 first year engineering students with various levels of preparation and understanding of concepts and processes in engineering physics to see how effective it was. There were a number of positive outcomes in the introduction of MasteringPhysics. Some of them are as follows: Over 64% of the students agreed that the content of the questions was relevant to their engineering studies while 63% felt that it helped them in their learning and understanding of the subject. As to the question of acquiring analytical skills, over 63% agreed that the program assisted them in solving the problems. About 50% of the students felt that the e-learning resources assisted them in the learning process. Overall, a fairly large proportion (67%) of the students felt that although the MasterPhysics program was useful they would prefer face-to-face tutorials.

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USING ONLINE DISCUSSION FORUMS TO DEVELOP STUDENTS' ANALYTICAL AND REASONING SKILLS IN PHYSIOLOGY COURSES

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KEYWORDS: discussion forum, analytical and reasoning skills, physiology course, collaboration

ABSTRACT

Innovative strategies have been developed to encourage teacher-student interactions and improve the delivery of lectures and practical classes, yet they are often limited to an enclosed learning environment, and the physical presence of students is required in order to receive maximal benefits. An interactive learning environment beyond the classroom, where students can exchange ideas, share information and discuss course content, has not been given much attention to.

This project investigates the use of an online discussion forum (Discussion Board in Blackboard) to assist students in the development of analytical and reasoning skills. The lack of such skills is demonstrated in students' written laboratory reports, where overall performance in data analysis and interpretation is often poor, particularly when students have to deal with complex data sets. A pilot study in Semester 1, 2012 showed that 29 out of 83 students (35% participation rate) posted and/or responded to questions, a majority of which were directly related to data analysis. More importantly, the discussion became student-driven as they progressively developed relevant skills. Preliminary data further suggest that the initial participation and timely input from instructors and being able to post anonymous comments by students are both key to the success of an online discussion forum.

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THE STUMBLING BLOCKS OF INTEGRATING QUANTITATIVE SKILLS IN SCIENCE

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KEYWORDS: quantitative skills, science curricula, integration

ABSTRACT

The Science Higher Education community has acknowledged the essential role of quantitative skills (QS) as a graduate learning outcome. However, efforts to build QS across science degree programs have been meet with a range of obstacles that are inhibiting the development of QS to an appropriate standard. This presentation, drawing on interview data from the ALTC funded QS in Science project which used a case study approach, details the challenges institutions have found in trying to ensure that QS are developed and embraced in science curricula. Interview data (n = 48) from academic staff involved in the case studies revealed several broad categories that significantly impacted on embedding QS effectively in the science curriculum: 1) the attitude and background of students undertaking science courses, 2) the constraints of the various science degree program structures.

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FACILITATING TIMELY FEEDBACK IN THE BIOMEDICAL SCIENCES

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KEYWORDS: feedback, biomedical science, learning gains

ABSTRACT

It is clear that feedback is one of the most influential factors on student learning gains (Hattie & Timperley 2007). However, student course and subject evaluations reveal that the provision feedback is rated poorly, and students often fail to engage with the feedback that is provided (Price, O'Donovan, & Rust, 2007). Students regularly seek more feedback, but as class sizes increase, the ability of academic staff to provide timely and detailed feedback to individuals decreases.

This project developed a method of providing detailed, specific and timely feedback to students of the biomedical sciences in large class settings at institutions in Australia and the UK. We investigated the extent and quality of feedback provided through analysis of annotated scripts, and examined how students interpreted and used the feedback received, by identifying how student work was modified in response to feedback. Further, we examined the effectiveness of feedback in enhancing student learning through improvements in student learning gains.

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BUILDING A SUPPORTIVE LEARNING AND TEACHING CULTURE FOR SCIENCE ACADEMICS

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KEYWORDS: community of practice, science academics, teaching staff engagement, student experience

ABSTRACT

The introduction of the Bradley voucher system has resulted in many universities focussing on specific strategies to enhance student engagement and retention. This is particularly the case with undergraduate science programs where interest is already lower than other disciplines (Norton, 2012). In one strategy, our SaMnet team has been working to facilitate an active culture with all teaching staff (both continuing and sessional) involved in the learning journey of second year science students. In the hard, pure world of science academia (Becher & Trowler, 2001) the pressures to produce high levels of quality scientific research actively compete with academic priorities towards issues around teaching and learning and student experience. Identifying and overcoming potential barriers to success (Buckley & Du Toit, 2010) and ensuring key elements of community of practice (CoP) development are addressed (Kimble, Hildreth, & Bourdon, 2008), are critical to the success of this strategy.

Our SaMnet team has been guided by the knowledge and resources of both the SaMnet team leaders and our own dynamic group capabilities. We have been strategically identifying and developing information to support the implementation of a Second Year Student Experience CoP within a research-focussed science school. These include the "What's In It For Me?" matrix to help facilitate this process.

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THE IMPACT OF SYSTEMATIC REFLECTION AND STUDENT LEARNING OUTCOMES IN A FIRST-YEAR NUMERACY SKILLS SUBJECT AT A REGIONAL AUSTRALIAN UNIVERSITY

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KEYWORDS: quantitative skills, maths anxiety, maths confidence, computing, teaching methods

ABSTRACT

The need to equip university graduates with skills and understandings to develop solutions to the multi-faceted problems faced by 21st century society has never been greater. Solutions require creative and sophisticated approaches that rely on manipulating quantitative information collected by multiple methods and drawn from diverse disciplines. Hence, science educators are urged to place considerable effort to enhance the quantitative problem solving skills of science graduates. However, the integrated teaching of mathematics and other disciplines poses major challenges including physical and emotional disengagement when students are presented with mathematical stimuli. This can result in diminished performance with detrimental effects on mathematical confidence. Compounding the problem is the need for computing technologies to facilitate numerical calculations and graphical representations of mathematical solutions to real world problems. This poses enormous challenges for science educators, most of whom have undertaken their scientific educational training in discrete disciplinary environments. It is of vital importance that educators reflect on the impact of different methods and approaches of teaching and assessment and share experiences while learning to navigate through an evolving maize of interdisciplinary science education. This paper will report on the improved outcomes of teaching interventions that were put in place as a result of systematic reflective process by the teaching team to address issues surrounding levels of maths anxiety, computing and maths confidence, and overall student satisfaction.

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WHICH REPRESENTATION IS BEST? HOW STUDENTS USE REPRESENTATIONAL INFORMATION IN PROBLEM SOLVING

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KEYWORDS: multiple representations, optics, Snell's law, graphs, equations, ray diagrams, university physics

ABSTRACT

We can present information to students, but the representation we use may change the way it is understood. Both diagrams and equations are seen as abstract physics representations, part of the physics disciplinary discourse (Airey & Linder, 2009), and can be notoriously difficult for students to understand (Woolnough, 2000). In this respect, Fredlund, Airey, and Linder (2012) have suggested that different physics representations have different disciplinary affordances, that is, they perform different disciplinary work. In the area of refraction, Snell's Law is often regarded as the essential form of information, but can Snell's Law distract students from understanding simple questions? In this study, a survey with either a ray diagram or Snell's Law as an equation was administered to over 300 first year university physics students. It was found that a ray diagram drawn as an example instead of Snell's Law allows for a better reasoning tool to understand refraction of light for students both novice (219 students who had not studied physics previously) and experienced (98 students who had studied physics at high school). This finding has an impact on the way that optics is taught and understood at a high school and university level. The work suggests that the choice of representation may also be educationally critical in other areas of physics and science where a variety of representations including equations and diagrams are commonly used to share knowledge.

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RESULTS OF REDESIGNED ORAL PRESENTATIONS AND ASSESSMENT

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KEYWORDS: oral presentations, formative assessment, summative assessment

ABSTRACT:

One of the most important aims of tertiary education is to teach students how to communicate effectively, with good oral skills being of utmost vocational importance (Hay 1994). Thus, students are required to give a 15 minute oral presentation to their peers in a 2nd year genetics subject. In the past, students were only summatively assessed by their demonstrators. This year, they were given the opportunity to prepare a practice presentation for which they would receive formative feedback from their demonstrators prior to their assessed presentation. The students also received formative feedback from their peers.

Most of the students in our course took this exercise seriously, both in their capacity as presenters and as participants. Only 10 students out of a class of 177 chose not to prepare a practice presentation. Overall, 60% of students showed improvement on their assessed presentations compared to their practice ones, indicating that the redesign of this component was successful.

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BIOSCIENCE ASSESSMENTS: MAKING CONNECTIONS TO CLINICAL PRACTICE

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KEYWORDS: bioscience literacy, nursing students, clinical practice, assessment, IT literacy

ABSTRACT

Evidence suggests that undergraduate nursing students feel a disconnect between bioscience theory and clinical practice. Students tend to utilise rote learning as their primary means of learning, as bioscience is often heavily content driven. In addition, many assessments promote surface learning which appears to impact on students understanding of bioscience integration with clinical practice and therefore, does not align with curriculum strategies.

We report on the infusion of novel assessment items to promote and contextualise bioscience knowledge within clinical application. Students will be required to produce evidence-based patient and clinician-focussed *support materials* to reinforce linkage of disease understanding with clinical best practice guidelines. In this way, bioscience knowledge translation occurs in a pragmatic and realistic mode with direct application to student clinicians within acute care health settings. This pedagogical approach is underpinned using concept maps, which have been shown to improve understanding of complex physiological interrelationships.

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CHANGE PROCESS FOR A LABORATORY PROGRAM

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KEYWORDS: laboratory teaching, chemistry, change management, skills focus, action-learning project

ABSTRACT

An approach to develop a skills-oriented laboratory program for 2nd- and 3rd-year chemistry at La Trobe University is presented. In addition to the educational principles underlying this approach, practical aspects of its implementation and preliminary data from student surveys will be discussed.

The redeveloped laboratory program aims to systematically build students' laboratory skills, ranging from basic manipulation and safety skills to more complex inquiry and problem solving capabilities, over the course of years 2 and 3. This project is embedded in an ongoing university-wide curriculum restructure (*Design for Learning)*, which aims to align the curriculum with the University's graduate capabilities. It has also been accepted as a SaMnet action-learning project.

The changes will be implemented in three stages (reorganisation; development of new activities; consolidation and evaluation) over a three-year period, starting in 2012 for 2nd year and 2013 for 3rd year. Key challenges of this process including strategy development, obtaining support from stakeholders, efficient use of limited resources and evaluation will be discussed.

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MATHS SKILLS PROGRAMS FOR FIRST YEAR SCIENCE AND STATISTICS

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KEYWORDS: mathematical skills, mathematical support, science

ABSTRACT

Mathematical skills are important for students studying science and statistics. The Faculty of Science, Technology and Engineering at La Trobe University is attempting to design and construct academic support for quantitative literacy for students in first year of their undergraduate science degrees through its Maths Skills Programs. These are integrated programs of support for students who need to improve their mathematical skills with a multi-faceted approach, including face-to-face help sessions, worksheets, and 24/7 online activities. The programs are linked to first year subjects and have been constructed collaboratively with discipline academics. The programs cater for large cohorts in Chemistry, Biology, Physics and Statistics at the Bundoora, Albury-Wodonga and Bendigo campuses.

The program is initiated with a selection phase to ensure appropriate students participate. All students in each first year subject are invited to complete a screening test to help them, and staff, identify their need for improvement. Students are also able to join the program directly by self-nomination. Screening tests include common mathematics questions and some discipline-related maths problems to emphasise the connection with the subject. Topics for inclusion in the Maths Skills Program are chosen in consultation with discipline academics reflecting essential knowledge and troublesome concepts for students.

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USING RASCH MODEL TO ASSESS LEARNING OF MATHEMATICS AND ENGLISH AT A PUBLIC UNIVERSITY IN MALAYSIA

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KEYWORDS: Rasch Model, outcome based education, student centered learning, Bloom Taxonomy

ABSTRACT

The aim of teaching Mathematics and English to engineering students is to achieve the right balance between the practical application of mathematical understanding and the correct verbal and written skills for their careers. Education experts have presented methods to develop teaching and learning Mathematics and English such as Outcome Based Education (OBE) and Student Centered Learning (SCL). One public university in Malaysia have taken such pedagogical approaches. However, little is known about whether the marks attained by students have actually demonstrated the students' ability in completing the task. As such, this study employs the Rasch Measurement Model (1980) in assessing students' attitudes, belief and ability in learning Mathematics and English. Data in this study was taken from approximately fifty undergraduate engineering students who learn Mathematics and English courses in the public university that has employed the new pedagogical approaches of OBE and SCL. The assessment considers different levels of Bloom's (1956) Taxonomy, namely, psychological, cognitive, psychomotor and affective, based on the current observations and interview. The course learning outcomes are measured by the marks attained by students in tests.

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VIDEO BLOGS TO ENHANCE STUDENT EXPLANATIONS OF STRUCTURE/PROPERTY RELATIONSHIPS IN CHEMISTRY

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KEYWORDS: Student-generated explanations, video assessment, chemical literacy, conceptions

ABSTRACT

Student generated explanations provide insight into their mental models and their understanding of chemical concepts. Novice chemistry learners often develop poorly structured mental models because they have little time to construct their understanding either within class or in a self-regulated way. In 2011, a new assessment task was introduced into a one semester introductory chemistry course with the aim of both enhancing engagement through a personal connection to chemistry and to strengthen their understanding of chemical structures and representations. In 2012, over 350 enrolled students created a 2-3 minute video where they explained the structure and properties of a molecule/substance that was personally relevant to them. Students were required to create a visual aid of a structural model to support their explanation and also appear in the video at least once to establish their personal connection. The videos were uploaded to Youtube or Vimeo and the link shared with the instructor for assessment.

Evaluation of the student videos revealed significant insight into the role of the visual aid in supporting their explanations[1]. The range of chemical vocabulary was related to students' conceptions. Students had an opportunity to be creative with some outstanding visual presentations – reflecting the diversity of the students enrolled in the course.

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Proceedings of the Australian Conference on Science and Mathematics Education, University of Sydney, Sept 26th to Sept 28th, 2012, page 51, ISBN Number 978-0-9871834-1-5.

GAMES FOR PHYSICS

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KEYWORDS: games, physics education, electromagnetism, Lorentz force, game design

ABSTRACT

Games can and have been used to educate and train in many diverse areas. Most educational games are directed at primary and high school students. Yet the average age of a 'gamer' is around 30! In this paper we present our case for why games provide another tool in the repertoire for education. We state the WUPI Principle: Teaching, Learning, Assessment and Fun 'While yoU Play It'.

We describe our process for creating games to educate students at the university level. We develop our process largely independent of any particular subject so as to be of use to a wide variety of educators in many different subjects.

We focus on games for physics students and demonstrate our efforts with a game prototype.

We compare and contrast our prototype with existing educational software.

Finally we discuss our study design to examine the efficacy of using games in first year physics.

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‘JUST IN TIME’ FOR THE LECTURE

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KEYWORDS: active learning, just in time teaching, misconceptions

ABSTRACT
In ‘traditional’ science lecture-based courses we don’t demand that students come to lectures prepared, having read the textbook for example. This would not be acceptable in many other disciplines such as English or History. In addition, in the lecture environment we are often unaware of student problems and misconceptions and miss the opportunity to enhance their understanding by adjusting our presentation to their needs. It is only via assessment (possibly too late), or perhaps anecdotally in other learning situations such as tutorials, that we judge the match between our standards and student understanding and ability. We need better engagement between the students and the staff!

‘Just in Time’ teaching (e.g. http://jittdl.physics.iupui.edu/jitt/what.html) is an active learning technique in which students do brief, web-based pre-work before a lecture and the lecturer adjusts and organizes material based on the student responses – just in time for the lecture. It helps bridge the disconnect between staff and student standards at a time when it can make a difference. We have recently trialled a ‘just in time’ approach in several different classes teaching first and second year physics and report on the practical realities of this attempt to bring the staff and student standards closer together.

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INQUIRY BASED APPROACH TO LABORATORY EXPERIENCES: INVESTIGATING STUDENTS' WAYS OF ACTIVE LEARNING

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KEYWORDS: traditional laboratory, design activities, inquiry, students' engagement

ABSTRACT

It is a common perception that traditional recipe based laboratory experiences are generally boring, non-interacting and non-engaging. As a result, it is unlikely to promote higher order thinking and learning. As a part of the SaMnet project, we are investigating a systematic approach to introduce lab experiences which are likely to equip first year physics students with concepts and skills required in designing an experiment. Our aim is to motivate and arouse students' interest, where they explore experimental activities and design their own experiments. Etkina, Karelina, Ruibal-Villasenor, Rosengrant, Jordan, and Hmelo-Silver (2010) emphasises that when students engaged in the design of experiments, they not only developed scientific abilities but use them without prompts and scaffolding on transfer tasks. We are implementing an inquiry based lab activities for non-physics majors in semester 2, 2012 at both universities. To gauge students' prior knowledge of radiation and radioactivity, we distribute a pre-lab survey questionnaire prior to the commencement of experiments. Based on survey results, a list of laboratory activities will be posted online for students to choose from. Students are expected to acquire knowledge from textbooks, synthesis information and design experiment incorporating innovation and techniques. At the end of semester 2, we are planning to collect students' feedback to check the effectiveness of design experiments over recipe based experiments. This presentation will describe the progress of this project.

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SOPHISTICATION SNAPSHOT: ANALYTICAL TOOL FOR MEASURING LECTURERS' ONLINE TECHNOLOGY USE IN SCIENCE EDUCATION

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KEYWORDS: Learning analytics, blended learning, technology-enhanced learning, academic development

ABSTRACT

Learning analytics methods used to collect and investigate data pertaining to educational endeavours is of increasing interest for researchers. With respect to technology-enhanced learning, the need for evidence to support and inform provision and management of support strategies is integral, but still developing. This paper describes the sophistication snapshot tool, a resource developed for monitoring standards in blended and online teaching in the Sciences at the Australian National University. This five-level rubric measures individual subject performance against a series of standards descriptors of increasing sophistication, generating comparative scores that can be used to track changes over time, and between the various science disciplines.

Each "snapshot" identifies weaknesses and failures to meet stipulated minimum standards in blended and online learning environments, such as the need to include subject contacts, or a subject outline, and can be used to track trends in technology use between subjects and disciplines over time. Finally, the value of such data in the evaluation of trends, improvements in blended and online teaching, and professional development initiatives is discussed.

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USING LABORATORY EXPERIENCES TO INVESTIGATE STUDENT LEARNING TRENDS IN CHEMISTRY

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KEYWORDS: ASELL, learning experience, multiple representations, practicals

ABSTRACT

Surveys commonly utilised as part of the Advancing Science by Enhancing Learning in the Laboratory (ASELL) project have been used to investigate the perceptions of first year undergraduate chemistry students during their laboratory sessions at the University of Adelaide. From 2011, data from these surveys has provided insights into many facets of the learning experience. Quality of experiments and laboratory courses in first year undergraduate chemistry has been evaluated from the student perspective, and the effects of any revisions to past experiments and the overall laboratory course structure have been identified. Trends have been observed in the overall perception of experiments, with relation to macro, sub-micro and symbolic representations of concepts. Prominent factors contributing to the overall learning experience have been investigated, and cases in which these factors contribute most and least prominently have been observed. Reasons for relatively poor perception of experiments often appear related to effects generated by difficulty thinking beyond the macro domain of representation. Additionally, visual appeal has been seen to be a strong source of interest in experiments. The degree to which particular facets of the laboratory experience contribute to the perceived overall learning experience appears to be variable.

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ENABLING CHEMICAL CONVERSATIONS: INVESTING FIVE MINUTES IN FIRST YEAR STUDENTS

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KEYWORDS: first year, engagement, chemical conversations.

ABSTRACT

Have you ever considered the benefits of being able to orchestrate a five minute one-on-one chemical conversation with every member of a large first year class? Even better where each student presents you with a piece of work which clearly shows whether they have understood and can apply key concepts of the topic, and your conversation is then directed productively. Students receive immediate, personal feedback and benefit from direct interaction with staff around an area of personal difficulty, staff benefit from the direct insight into the students' level of engagement and understanding and can direct students to a support network where any issues or gaps in background knowledge or application beyond the scope of the conversation can be dealt with in a supportive friendly environment. Easy identification of "students at risk" is also a benefit. This has been successfully done in all first year chemistry topics at Flinders University since 2008 with large cohorts (up to 421). While we don't deny it has taken a great deal of hard work the benefits are enormous.

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VISION AND INNOVATION IN BIOLOGY EDUCATION (VIBEnet)

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KEYWORDS: biology education, biology learning outcomes, core concepts and competencies

ABSTRACT

We hear repeated calls for future graduates to develop inter and multidisciplinary approaches as well as flexible and rigorous mathematical and computational modelling skills to deal with a complex world. What, then, are the current priorities for biology education in Australia? Unlike physics and chemistry, there is no single biological professional association to provide a forum for the discussion of undergraduate tertiary biology. The Vision and Innovation in Biology Education discipline network (VIBEnet) was formed to address this need within the tertiary biology community and to discuss:

- key concepts and competencies that graduate biology students should understand and be able to demonstrate;
- innovative curriculum and appropriate teaching strategies to help graduates achieve these outcomes,
- appropriate assessment strategies to measure this achievement; and
- sharing effective learning and teaching practices for undergraduate biology and mentoring the next generation of biology educators.

Our Vision and Innovation Statement will articulate a collective understanding of tertiary biology education including the Biology Threshold Learning Outcomes for biology graduates. Common concepts which are emerging as the result of workshops and surveys attended by >60 academics include; characteristics of life, information flow, evolution and structure and function while competencies include inquiry, communication, critical thinking and quantitative skills.

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THE PERSPECTIVES OF SCIENTISTS AND MATHEMATICIANS ON QUANTITATIVE SKILLS

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KEYWORDS: quantitative, interdisciplinary, curriculum

ABSTRACT

Mathematics is important in science, and becoming increasingly so. Not surprisingly, the scientific community is calling for graduates with higher standards of quantitative skills (QS), that is, the ability to apply mathematical and statistical thinking and reasoning in the context of science.

How are academics addressing this QS challenge? Some see this as an interdisciplinary endeavour, with science and mathematics academics working together to develop the QS of students in undergraduate science programs. We present evidence which suggests that scientists and mathematicians have different attitudes to what is happening in universities currently.

This work is a part of the ALTC funded *QS in Science* project in which 48 interviews were conducted with academics in both teaching and leadership roles from 11 universities in Australia and two in the USA.

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USE OF AN ONLINE SYSTEM FOR STUDENT RESPONSES IN FIRST YEAR CHEMISTRY

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KEYWORDS: student response systems, large classes, peer instruction, technology adoption, technology continuance model

ABSTRACT

Although the benefits of clickers for monitoring student understanding during lectures are well-established (Gebru, Phelps, & Wulfsberg, 2012; Lin, Liu, & Chu, 2011; MacArthur & Jones, 2008; Patry, 2009; Smith, Wood, Krauter, & Knight, 2011), their cost makes them inaccessible in many Faculties. Recently, several websites have been launched that offer academics the ability to monitor student understanding in a similar way, using any mobile internet enabled device (phone, tablet, laptop computer). We have trialed the use of one such system with first semester chemistry students and the results are reported here. There were some technical difficulties to be overcome and the importance of these should not be understated; in a time-limited setting with a very large class, a system needs to run flawlessly in every session. Student feedback was largely positive in other respects, but a significant drop in use was observed over the course of the trial and also during each lecture.

The trial was undertaken as an action learning project within the SaMnet framework (http://www.samnet.edu.au) and aimed to promote the use of student response systems among other academic staff. To this end, staff were invited to attend lectures, participate in the student response questions and provide feedback on the system. This feedback also indicated that technical ease of use and stability are critical factors to encourage uptake of the system. This and other aspects of adoption have been investigated in the United States (Emenike & Holme, 2012). In this poster, we discuss adoption and factors leading to continuance with new technology using an established model, and propose mechanisms to improve uptake.

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TARGETING KEY STUDENT ATTRIBUTES: USING POGIL IN A SENIOR UNDERGRADUATE CLASS TO DEVELOP SPATIAL REASONING

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KEYWORDS: group theory, spatial reasoning, Process Oriented Guided Inquiry Learning, senior undergraduate chemistry

ABSTRACT

Group theory, as a branch of mathematics, can systematically describe molecular properties that are influenced by their three-dimensional symmetry. This topic often forms part of a senior undergraduate chemistry curriculum, where it is used to explore chemical bonding and vibrational spectra. This approach requires rapid manipulation of representations of molecular-scale three-dimensional phenomena to apply the principles of group theory and interpret the outcomes. Students utilise spatial reasoning to achieve this manipulation, which is often conceptually challenging. The literature suggests this challenge may confound learning and lead to student disengagement.

Spatial reasoning was identified as a desirable attribute of our Chemistry graduates, and integrated into our curriculum. To overcome student disengagement, Process Oriented Guided Inquiry Learning (POGIL) was used as a model pedagogy, where students work through a carefully structured activity in small groups. The paucity of existing materials required development of new POGIL resources, which will be illustrated. An existing instrument, the Purdue test of visualisation of rotations, was used to measure one aspect of spatial reasoning. Using the results of this test, observations from the class and results from student assessment, we can begin to demonstrate how students attain this key attribute.

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USING ASELL AS A FRAMEWORK FOR DRIVING CHANGE

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KEYWORDS: laboratory teaching, evaluation, ASELL

ABSTRACT

A 2009 Australian Council of Deans of Science report (Rice, Thomas and O'Toole, 2009) identified the quality of undergraduate laboratory curricula as an important issue in tertiary science education. Evaluation of undergraduate labs traditionally relies on anecdotal evidence about what works and why; changes are often ad-hoc. We need an appropriate evidence-based methodology to clearly articulate the goals and aims of the teaching labs, and evaluate the curricula against these.

Fortunately, such a methodology exists: the ASELL framework (ASELL, 2012) employs research-led surveys and workshops to identify pedagogical and logistical issues with science laboratory experiments, and an iterative process for improvement. Building on past experience with this framework, we are using the ASELL tools to examine laboratory experiments in the Schools of Physics and Molecular Bioscience at the University of Sydney to gain feedback about the level, relevance, degree of challenge, experimental techniques and class logistics. We will identify several experiments at the first year (physics) and second year (biochemistry) level to focus on, and implement changes based on the ASELL analysis — and so armed, to influence colleagues to spread the framework across the Faculty.

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DEVELOPING DISTANCE LEARNING CURRICULUM FOR OUTCOME ACHIEVEMENT

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KEYWORDS: distance learning, blended learning, curriculum planning, standards

ABSTRACT

Prospective mature aged students who seek career change are often restricted through mobility and financial constraints. Alternatives to traditional classroom based teaching are their only option. With traditional distance education modalities, supported through online learning managements systems, content is relatively easily presented to students in a number of ways such as PowerPoint with recorded audio, access to library readings or notes. Outcomes are more than "just content"; student' development of outcomes such as teamwork relies on collaboration and interaction. Traditional, on-campus students have multiple opportunities to informally meet and interact both socially and professionally. They also have opportunities for small group face to face discussions. In distance education connection with fellow students and teaching staff and consequently discussions can be facilitated through approaches such as asynchronous discussion forums, video conferencing and more recently synchronous technology in the form of web conferencing.

A critical question addressed in this presentation is — how do we use technology to connect and engage students studying in a distance mode with learning opportunities efficiently and effectively in addition to the face to face opportunities afforded by mandated intensive schools? How do we ensure that all our students can achieve the threshold standards across all outcomes set for our students, irrespective of discipline and learning mode?

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REFURBISHING AND ASSESSING THE CONCEPT OF 'PRE-READING': MULTIMEDIA SNAPSHOTS AND WEB-BASED ASSIGNMENTS

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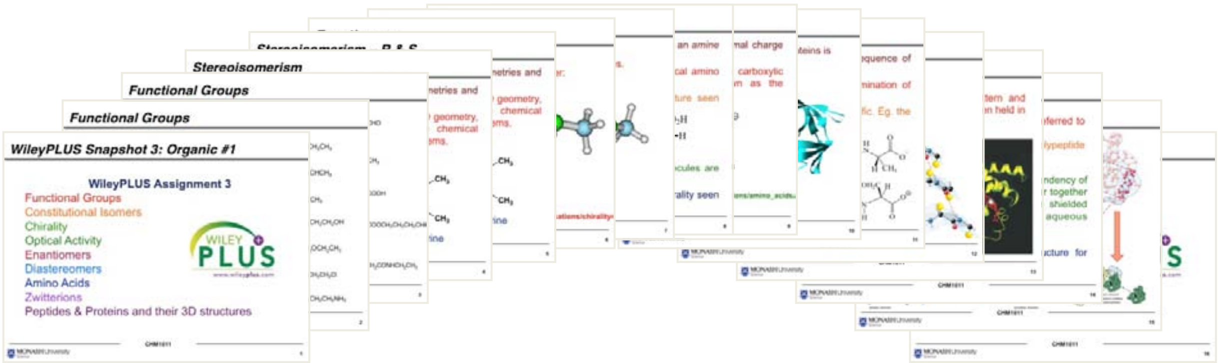
KEYWORDS: pre-reading, online assessment, retention

ABSTRACT

Tertiary students have been traditionally instructed to prepare for lectures by completing a 'pre-reading' task. This may be a book chapter or a section from the lecturer's notes, covering material which is to be discussed imminently in class. However student participation in this non-compulsory task is often poor, with many students either under significant time pressure, finding the task intimidating or lacking appropriate access to the resources.

In first-year chemistry we have adopted a new approach to this concept by developing short videos – *'snapshots'* – which are ultimately tethered to a short web-based assignment. The closing date for the assignment falls *before* the material is covered in lectures, and each one is worth a small component of the overall assessment. The videos are generated using a tablet PC, via screen capture of a PowerPoint presentation. Invariably these presentations have also been annotated using 'digital ink'. A number of flash animations developed between this author and the textbook publisher have also been incorporated.

Project aims include delivering a compact overview of upcoming lecture topics, a glossary for introducing new terminology, and conveying three-dimensional perspectives of complex molecular structures and dynamic chemical systems. We discuss some of the early and very encouraging retention and outcomes statistics.



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USE OF ONLINE VIDEO IN THE TEACHING OF EXPONENTIAL FUNCTIONS

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KEYWORDS: mathematics education, online video, visualisation

ABSTRACT

Graduates with high level mathematical skills are a commodity that Australia needs more of. However the number of high school students taking a level of mathematics sufficient for their university studies is on the decline. This lack of relevant mathematical preparation makes the teaching of these students in their first year mathematics units challenging. Visualisation is an important tool in mathematical problem solving. The use of online videos (eg, YouTube) to illustrate applications of mathematical concepts can help to enhance a student's engagement and ultimately their conceptual understanding. Conducted at a large Australian university with students enrolled in a first year service teaching mathematics unit taught in a traditional lecture and tutorial format, online videos were introduced to enhance students' understanding of the exponential function. The videos present the concepts in real world contexts in a visual way that is relevant and thus provides a starting point for engaging students in mathematical thinking. Online video was augmented with specific exercises in the same context as the videos. The outcomes of this intervention will be discussed.

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PERSONAL STANDARDS: MEASURING THE IMPACT OF VALUES AND IDENTITY ON FIRST-YEAR PHYSICS LEARNING

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KEYWORDS: equity, engagement, diagnostic test

ABSTRACT

This paper explores how beliefs about self affect learning in students at risk of performance anxiety. We examine the generalisability of recent work on value-affirmation from the USA to Australian science students. The frequently reported gender gap in physics performance (–with females lagging behind males) was eliminated via a value-affirmation intervention [Miyake et al, 2010]. In theory, those who identify with a group “known” not to perform well, experience “identity threat” but if they think about values important to them personally, they perform better because of a bolstered sense of self. This study raises the following questions:

- Are Australian students susceptible to stereotype threat relating to gender?
- Is the value-affirmation exercise proven in one context transferable to ours?
- Can it improve learning performance of those who are fearful of physics, perhaps because of previous education?

We measure how strongly and how commonly students endorse a negative belief that “other” people succeed in core physics and service teaching courses. We surveyed confidence and attitudes. We will present statistical analysis of pre- and post-instruction results on a well-established physics diagnostic test, showing the distribution of assessment performance for randomly-assigned control vs intervention groups, and with respect to the strength of endorsement of negative beliefs.

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EMPLOYING AN ONLINE MICROSCOPY TUTORIAL IN THE COLLABORATIVE CLASSROOM TO REINFORCE LABORATORY-BASED PRACTICAL SKILLS

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KEYWORDS: laboratory skills, biomedical science, virtual microscopy, collaborative classroom

ABSTRACT

Biomedical Skills 1 is a new first semester unit that was introduced in 2012 into QUT's Bachelor of Biomedical Science. One of the main aims of the unit is to facilitate the competent learning of laboratory skills for the study and practice of biomedical science. Microscopy is one such laboratory skill that can prove challenging for some students and which has largely been taught in the wet laboratory. Time in the wet laboratory is often limited so learning needs to be maximized. By using a collaborative classroom with students working in groups of five with access to a networked PC, we employed an online virtual microscopy tutorial (courtesy of the University of Delaware) to reinforce the use of the compound microscope. The virtual microscope was able to be manipulated in the same ways as a real microscope. Students were given a group worksheet to complete which encouraged them to engage with each other as they progressed through the tutorial as well as conferring with each other as they answered the questions. Feedback from the students was overwhelmingly positive, with students commenting that they felt much more confident in using the microscope in the laboratory sessions following the virtual microscopy tutorial.

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DESIGNING A CONCEPT INVENTORY TEST FOR STUDENTS IN FIRST YEAR GENETICS

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KEYWORDS: concept inventory, conceptual understandings, testing

ABSTRACT

The 1st year genetics subject at La Trobe University has a large cohort (~ 700 students), who come to us with a wide range of backgrounds in knowledge of genetics. The academics teaching into the subject have some expectations of a basic knowledge of biology and the use of a pre-knowledge test or concept inventory would be helpful in determining the range of abilities within the cohort.

Concept inventories have been in use in many disciplines, in particular physics has been using a force concept inventory since the early 1990's (Hestenes, Wells, & Swackhamer, 1992). The design of our test will utilise studies already in progress around the world, for example the Genetics Concept Assessment Test at the University of Colorado (Smith, Wood, & Knight, 2008) and the Genetics Literacy Assessment Instrument (GLAI) at the University of Cincinnati (Bowling, Acra, Wang, Myers, Dean, Markle, Moskalik, & Huether, 2008).

The opportunities to use this test as both a pre- and post-test will also allow us to measure not only the intended learning outcomes for the subject but also the students conceptual understanding of the subject matter (Bowling et al., 2008).

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HOW CAN WE DESIGN ROBUST MCQ (MULTIPLE CHOISE QUESTION) TESTS, AND IS IT POSSIBLE TO ASSESS HIGHER-ORDER SKILLS USING MCQS?

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KEYWORDS: assessment, higher-order thinking, multiple choice

ABSTRACT

In an era of widening participation, and limited resources, how can we effectively assess students in a timely way? The use of automatically-marked MCQs is quite common, so how can we do it "better", and ensure our assessment instruments are fair and effective (as well as efficient, in terms of time taken for academic staff to create the questions/problems)? The conference theme is around "measuring and benchmarking our teaching practice to provide evidence that our students are learning and achieving the standards" we expect of our graduates, and assessment forms a key component in achieving the quality outcomes we are required to demonstrate. Given the work pressures academic staff face in the sector, and which will likely increase post-Bradley Review*, with larger first-year cohorts from a variety of academic and socio-economic backgrounds, this session is intended to be practical and interactive.

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ONLINE DONE RIGHT – LEARNING BY DOING IN AN ONLINE WORLD

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KEYWORDS: online learning, virtual labs, smart courses

ABSTRACT

In a world is in the midst of an online education revolution, Science educators face a tough reality - teaching science online simple does not cut it. PDFs, PowerPoints and multiple choice quizzes are not enough for a discipline that is based on experimentation, hypothesis testing and “learning by doing”.

Smart Sparrow is the young start-up behind the “adaptive eLearning platform” – a technology that now underpins several large national multi-million science education projects. In this presentation, Dr Dror Ben-Naim, Smart Sparrow CEO will showcase Virtual Labs and Smart Courses as exemplars of next-generation intelligent educational content.

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REVITALISING THE TRADITIONAL LECTURE

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KEYWORDS: engagement, clickers, feedback

ABSTRACT

Learn how clickers can improve conceptual understanding and engagement through:

- **Better feedback**– response data, on student understanding and satisfaction, encourages focus on ways to improve teaching
- **Enhanced effectiveness** – clickers enable teaching methods such as Peer Instruction, Assessment for Learning, Agile Learning, Retrieval Practice
- **Greater preparation** – students are rewarded for their preparation and involvement in class

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STANDARDS AND LEARNING OUTCOMES FOR UNDERGRADUATE RESEARCH PROJECTS

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KEYWORDS: undergraduate research experience, learning outcomes, critical thinking

ABSTRACT

Undergraduate research projects are increasingly being incorporated as assessed components, into a range of degrees, both those aimed at elite students and in standard BSc degrees. While students and staff are generally positive about such experiences, the literature shows that students report a wide range of learning outcomes and that the student experience is very dependent on the supervisor. This immediately raises issues of equity and standards; each research project is unique and how each one compares to other research projects or normal courses can be problematic. In principle, clearly articulated learning outcomes can help implement benchmarking or moderation processes; however if these learning outcomes focus on advances in disciplinary knowledge, methods and skills, comparison across sub-disciplines (let alone disciplines) remains hard. We propose an alternative, complementary focus for assessing learning: the development of students' understanding of the processes and practice of science, together with generic skills such as critical thinking, elements which should be developed in all projects.

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DEVELOPING HIGHER ORDER THINKING SKILLS

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KEYWORDS: higher order thinking, graduate outcomes, learning outcomes

ABSTRACT

University education is based on a set of graduate outcomes or educational principles of the university. The essence of a university education is higher order thinking. Learning outcomes are developed for each unit and the overall course to guide students in their learning. Assessment tasks are designed to enable students to demonstrate that they have achieved the learning outcomes to a certain level or standard.

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THE ADELAIDE EXPERIMENT – WOULD YOU LIKE AN IPAD WITH THAT?

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KEYWORDS: iPad, engagement, re-imagining of curriculum

ABSTRACT

In September 2010 the Faculty of Sciences at The University of Adelaide commenced preparation for the largest deployment of Apple iPads in an educational context in the world. At the beginning of 2011 850 iPads were given to commencing Sciences students and teaching staff. This was followed up by with a further 800 iPads for the commencing cohort in 2012. However, this initiative is much more than just a story about a technology platform – it's also firmly grounded in a re-imagining of our curriculum that is deeply connected to the Faculty's strengths.

In this presentation the framework for the re-imagining of our curriculum will be introduced, then outcomes from the mass deployment of the iPad will be discussed.

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LEADING CHANGE BEYOND YOUR CLASSROOM – CAPACITY BUILDING IN SOTL AND LEADERSHIP BY SAMNET

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KEYWORDS: leadership, change, national, capacity building

ABSTRACT

The introduction of quality standards can place delegates to the ACSME conference in the forefront of reflection on, and changes to, teaching in their school, faculty, and university. How do you make the transition from being someone who experiments and implements strategies to teach more effectively into someone who leads colleagues in doing so? Furthermore, what support can you gain in that process, both support from within your institution, as you work to help others to satisfy externally imposed standards, as well as support from outside your university?

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ASSESSING STANDARDS IN SCIENCE

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KEYWORDS: science, standards, assessment

ABSTRACT

Internationally there is recognition that critical thinking, analytical reasoning, problem solving and communication are critical for citizenry of the 21st century. At the same time assessment of “quality” and “standards” is on the agenda (e.g. AHELO, QAA, Tuning project). In 2011, the Australian government legislated for a Quality and Standards framework (by formation of TEQSA – the Tertiary Education Quality & Standards Agency) which will regulate tertiary education against an agreed set of standards developed by the Higher Education Standards panel. Prior to this, the Australian Government through the Australian Learning and Teaching Council funded the Learning and Teaching Academic Standards project. The tertiary sector in Australia is yet to initiate and agree on the assessment of these standards (the ‘Threshold Learning Outcomes) for Science (Jones & Yates, 2011) to determine whether these standards have been reached. Our current assessment practices, are mostly not 'fit for purpose' in a standards based paradigm where the accretion of 50 marks across a number (sometimes a LARGE number) of assessment tasks does not necessarily mean that a student has met the requirements of the course (even though they have arithmetically 'passed'). In the “standards” era, students will need to be able to demonstrate a greater range of problem solving and communication skills and an understanding of how scientific knowledge is both contested and testable. Our assessment practices in science will need to be more holistic covering a greater range of skills that students will require “beyond the course” if we are to certify graduates for a 21st century unpredictable future.

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SCIENCE TEACHING AND LEARNING – GET IT RIGHT BEFORE WRITING STANDARDS

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KEYWORDS: ethics, community service, citizenship

ABSTRACT
Before designing a framework or benchmarks for standards, the nature of an objective or activity must have characteristics which are identifiable, durable, and, hopefully, recognized by others, in similar ways. Also, hopefully, there will be a rich inventory which vividly and comprehensively reflects the experiences where these objects or activities are present. I suspect 'science' do have many identifiable characteristics well recognized in similar ways by many people. I also am confident that the inventory of how science is present in our world is also a rich inventory. I seriously doubt, however, that the attempt to distil or discern standards which can adequately reflect and respect the privileged place of science in our society will amount to much of merit. The culture of modern science, especially of competitively convened research and its expert leaders does little to foster reflective and capacious, balanced, tolerant, enduring, holistic visions of the strengths of scientific endeavour. An important caveat overriding this doubt, is the possibility that IF the raising of standards reflects on the moral foundations and practices of science, its philosophy as well as the particular way knowledge is translated via intentioned, engaged and interrelated service which addresses the needs of our world, then the exercise of standards may just well be one of the best things ever to happen! Such standards would ensure our graduates will serve our future communities as agents of mutually beneficial stewardship, caring for each other. This service would be empowered by the authority of the education they have received. Such philosophical and moral insight, if we invoke its full presence in our deliberations, has ripples which can course through domains of teaching and learning, research and community service. We should be encouraged to re-vision our teaching and learning, and raise up standards which are worthy of the confidence our society has in its scientists to do good.

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ACHIEVING GENUINE CRITICAL ENGAGEMENT OF THIRD YEAR STUDENTS WITH THE SCIENTIFIC LITERATURE

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KEYWORDS: critical thinking, practical class, critique

ABSTRACT

Most universities include a statement in their graduate attributes that their University prepares its graduates to be something like ‘critical and creative scholars’.

As part of a Bachelor of Science, students learn to read and analyse the scientific literature by completing assessment tasks such as literature reviews, essays and practical reports. However, throughout their degree, students need to make a transition from a surface, non-critical, view of the literature in which they rely on the author’s conclusions towards a deeper approach in which they interpret and critique the results.
I aim to develop a teaching framework in which third year students are specifically trained in two key skills:

1) critical reading of the scientific literature
2) genuine interpretation of practical class results.

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CODE FOR SUCCESS: A ROADMAP AS AN ORGANISING DEVICE FOR THE TRANSITION OF FIRST YEAR SCIENCE STUDENTS AND THE DEVELOPMENT OF ACADEMIC SKILLS

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KEYWORDS: transition to higher education, eCommunity, academic skills

ABSTRACT
An online roadmap has been introduced to improve the standard of academic skills by embedding a semester long sequence of stimuli and resources for new students within our large, general science degrees. This device is faculty managed and links administration, curricular and support services to the just-in-time needs of the students. This institution-wide curricular and co-curricular approach extends and supports our existing workshop and mentoring activities. It answers and prompts frequently asked questions, inducts students into the broader culture of the faculty and integrates information literacy and other academic skills which will be taught, practised and assessed during their first semester at university.

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INTRODUCTION
Students start university from a wide variety of backgrounds and with a large variation in their preparedness for study. The Australian university campus can be an arena in which the ability for self-directed and independent study is often a synonym for being able to survive in large classes (Kift *et al.*, 2006). These problems may be exacerbated in big, research-intensive universities and in programs of study that require students to move conceptually and physically between multiple disciplines from the day they arrive on campus.

Kift (2004, 2008 and 2009) and Kift, Nelson, and Clarke (2010) have outlined and demonstrated the efficacy of a "transition pedagogy" for cross-institutional integration, coordination and coherence of first year experience policy and practice. One approach to achieving a successful transition employs a "just-in-time" method involving a faculty-managed but student-centred timeline. Such a process (Macken, 2009) develops the important elements of the student's transition when it is needed: namely, just before and at each key milestone in the semester.

STATE OF PLAY FOR INCOMING FIRST YEAR SCIENCE STUDENTS
The Faculty of Science at the University of Sydney enrols a large number of students into its 5 degrees. The Faculty is made up of 8 Schools and a number of research institutions. These are themselves large institutions and are effectively semi-independent with their own approaches to teaching and learning. In addition, students in a wide range of professional and generalist degree programs from other faculties enrol in its science units, either because these degrees require core scientific knowledge or because of intrinsic interest. All of these students have a wide range of abilities and family/personal experience of higher education. This arrangement is quite typical of research-intensive universities.

The transition process is thus divided between, at least, 3 organisational units: the whole university, the faculty and the disciplines. This presents a particular challenge for developing an institutional approach to transition (Kift *et al.*, 2010) and for avoiding "piecemeal" approaches (Krause, Hartley, James, & McInnis, 2005). As noted by Kift *et al.* (2010), successful transition is strongly influenced by activities that relate both to the curriculum and to co-curricular support. Our experience at Sydney is that many students do not take advantage of the academic support available in orientation week and in the first part of semester. Interaction between this support and the formal academic program and a realisation of their relationship are the keys for success. There is a clear necessity for an “organising device” to “bring the two together for program coherence” (Kift *et al.*, 2010).

To be useful and hence successful, such a device needs to present logically and help to manage curricular and co-curricular activities for students. It needs to minimise overlap and workload for the different cogs in the institution and to recognise that orientation is “a process, not an event” (Kift *et al.*, 2010) which occurs across the “whole of first semester” (Kift, 2004).

In recent years, the number and diversity of students entering the university mid-year (i.e. at the start of semester 2) has increased. Alongside international students enrolling following a northern hemisphere summer, this cohort typically contains mature and transferring students. The orientation of these students is problematic: institution-wide activities are more subdued and tend to be targeted at the international students whilst teaching staff need to balance the needs of the new students with those already familiar with the institution. The organising device thus needs to be flexible enough to be useful to both cohorts in semester 2.

Many students commute to the campus, sometimes over large distances, and a majority of the cohort continues to rely on their existing social circles for, at least, the first part of the higher degree. Whether these students are transitioning from state or private schools, or from the workplace, the size of the campus and of the classes can be a real shock. Alongside the more independent style of learning that is expected, students can choose to, or may drift into becoming disconnected from the whole experience. Having a formal transition process in place can help avoid this disconnection and enhance the experience.

Students have a variety of academic skills and proficiencies when they begin university. For students in our main science degrees, there are no core units and there is no introductory unit or time within the first part of semester to try to ensure adequate preparation for study at the higher education level. Depending on their strengths, preferred major or interests, students have the choice to study from a range of fundamental sciences and mathematical topics and electives. Most of these subjects offer multiple streams as well as variations for students with no, or advanced, high school knowledge.

The positive side of this is, of course, that students have a wide range of choices while the downside is that students’ timetables are complex. Friends starting their degree together may well end up in different classes even with the same combination of choices. Whilst this may be seen as a positive in the long term, this separation can cause angst at the start of the year. Individuals may only get the opportunity to meet up with new people once or twice a week unless they proactively chose to do so by seeking people out in the large lecture theatres and laboratories. Forming social and study networks beyond their existing circles can be difficult.

At Sydney, there is presently a reluctance to introduce a separate ‘study skills’ unit into the already crowded first year of the BSc degree, despite a growing appreciation of the variability of the standard of skills amongst incoming students (Pyke, 2011). At worst, information skills are seen as “someone else’s business” (Arndell, 2012). At best, a number of discipline-based initiatives have been introduced to patch up these deficiencies. These include some interesting and effective interventions – see, for example, Lilje, Breen, Lewis, Yalcin (2008) and Bridgeman and Schmid (2010). When individually effective but isolated, discipline-based interventions are introduced, however, the improvements are similarly isolated. Moreover, duplication naturally results, leading to increased workload and frustration for students.

The range of disciplines that are offered and the lack of a core or introductory unit also mean that it can be difficult to integrate any faculty-managed response to these issues. Each discipline’s approach for introducing the student to higher education is likely to be different and to reflect perceived discipline-specific requirements. Coordinating a transition process with limited funding and a diverse set of procedures is daunting.

To reflect these challenges, the Faculty of Science at Sydney introduced an annual one-day ‘transition workshop’ (Peat, Dalziel, & Grant, 2000). This event occurs before the formal and informal orientation week events and covers both social and academic orientation with a parallel session for parents. All students enrolled in the Faculty of Science are invited and 40 – 50% attend the workshop, even though the event is not mandatory. A strong correlation between attendance at the workshop and academic success has been demonstrated (Dalziel & Peat, 1998).

Attendees are given the opportunity to meet and talk to current students and academic staff in a relaxed setting, as well as to each other. For part of the day, the students are grouped by planned major so that they are in relatively small groups and can meet educators and students with direct experience of “the route to success” in that subject area. The students are encouraged to form social networks, and even study groups, and have a point of contact in a particular discipline. After this workshop, a mentoring program is used and a number of follow up meetings are instigated to further facilitate contact between the students and ensure the success of the networks (Donohoe & Taylor, 2010).

Although the main benefits from the workshop are probably social, a large amount of valuable information and advice is presented at such an event. Attendees leave with a “showbag” containing valuable tips and details of services (Peat, Dalziel and Grant, 2001). Such resources are expensive to produce and it is an interesting question as to how much they are used, given the volume of information being presented and the other distractions at this point in a student’s life.

The workshop is rapidly followed by the social whirl of orientation week (“O-week”). The main academic input from the Faculty of Science to this is the “Welcome” event in which the Dean introduces the First Year Directors from each discipline as well as representatives from the faculty and student services. As with the transition workshop, the amount of information presented is considerable. Whilst highly valuable, the information in the workshop “showbag” and in the “Welcome” event is, of course, often lost in the flurry of events at this time of the year. Moreover, although the workshop and “Welcome” event are well attended, it is probable that the students in most need of assistance do not attend.

The initiative described in this paper aims to build on the success of our transition workshop and mentoring program, within the framework of the transition pedagogy. A “roadmap” for students is introduced as the faculty-managed, organising device for students to keep to during their first semester. The roadmap purposefully links academic support with the formal curriculum through direct links between students, teachers and the University Library. This provides a way for students to follow the advice already available from our existing events but in a managed and simplified timeline.

eCOMMUNITY

Every student enrolled in a unit of study taught by the Faculty of Science is also enrolled in a website on the University’s learning management system (LMS) called the ‘First Year Science eCommunity’. This site contains program-level information such as resources for developing graduate attributes and answers to frequently asked questions. Its purpose is to impart a sense of “being a scientist in a community of scientists” to students just beginning higher education.

As noted above, beginning students have a breadth of academic skills. As participation at university widens, this range is likely to increase. It is likely that many more students will not have some of the fundamental skills which those teaching them assume they have. The resources on the eCommunity site provide opportunities for students to develop or sharpen these skills in a set of scaffolded and modularised tasks (Knecht & Reid, 2009). The University Library offers a range of online modules in key research and information skills, and these mini-tutorials are short and accessible to new students (Arndell, 2012).

Having a single site containing these resources and having it housed within the LMS is extremely useful. The LMS is an online venue for coursework resources and is therefore heavily used by students. Most students naturally look to it for academic information rather than to the main university or faculty websites. Such a site is obviously only useful if students (a) discover it and (b) use it.

TRANSITION ROADMAP

Figure 1 shows a screen shot of the front page of the community site that students see when they visit it during orientation week or during the first two weeks of semester. It was designed using feedback from the Learning Centre, Library, eLearning Helpdesk and Faculty on transition issues, from a student-focus group and in collaboration with the faculty marketing team to provide a simple, organising device for first semester. The image on the left shows a sequence of steps up a stylised

DNA "ladder" with tasks, questions or information coded by week in which they are most relevant. For O-week, the steps are:

- What is eLearning?
- How do I access my timetable?
- How do I access and redirect my email?
- What is a unit outline?

Figure 1: Front page for First Year Science eCommunity site showing roadmap for orientation week and weeks 1 and 2.

Some of these are frequently asked questions but others are questions that *we* want or need students to ask. For example, the necessity to use eLearning for providing access to tutorial worksheets and lecture slides begins in Week 1 yet many students will not be aware of its key role in content delivery at university. Others will discover software and hardware issues when they attempt to use the more complicated tools of the LMS. It is clearly better to have this awareness and to solve these problems before classes and assessments begin in earnest.

Hovering over these generates a small pop up window, as illustrated in Figure 2, with more detailed information. For the eLearning question, for example, this provides links to deal with common issues reported by faculty, the eLearning helpdesk and the student focus group such as browser compatibility and plugin requirements. Such issues are often easily solved once help is sought. Many students, however, assume the problem lies elsewhere, or may simply move on, leading to a delay in accessing online resources. The roadmap aims to prompt the student to seek assistance and to link them with it.

These questions and steps are presented in 3-week blocks so that students can plan ahead and see upcoming barrier points. Thus, the last date to change enrolment and, of course, the census date do not rely on just-in-time communication. Students can also backtrack for events and transition steps that they may have missed or overlooked.

If a student is seeking answers to these questions then administration time and queuing for information is reduced. If a student is not asking these questions then hopefully they are prompted to consider that these are the types of questions that they *should* be asking and addressing.

Whilst the O-week steps are directed to encouraging organisation and readiness to study, Weeks 1 and 2 mix such issues with questions aimed at triggering academic skill development. In Week 1 students may ask:

- Where are my classes?
- Where can I get my lecture notes?
- How do I find books and articles?

- When are my assessments?

The electronic nature of the roadmap means that, for example, the answers to the first two of these questions link directly to the campus maps and the appropriate website respectively. The last question encourages students to investigate and plan their assessments for each subject/course. The eCommunity site also allows them to download a calendar of their assessments to their preferred app on their mobile phone. Such an approach actively encourages student responsibility in delivering on the assessment deadlines whilst recognising their lack of experience by scaffolding and supporting this process.

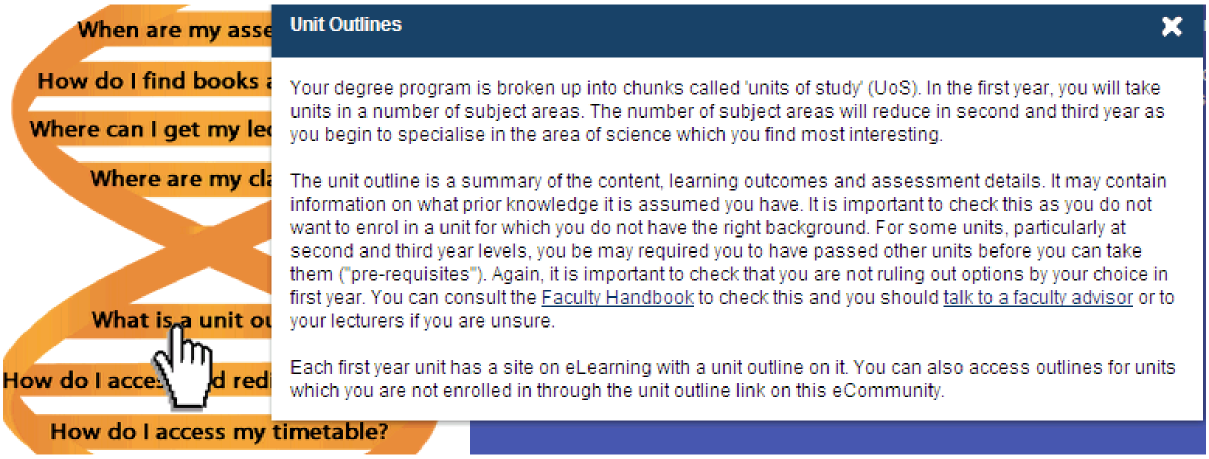

Figure 2: Example of an information pop up for a week 1 task on the roadmap.

The third question, “How do I find books and articles?”, is the first rung on the ladder which seeks to join co-curricular support with the science curriculum (Arndell, 2012). It sends the students to one of the Library’s Research and Information Skills modules. This question and the associated module attempts to steer them to consider the type of resources that are available and most useful in higher education. It is introduced at this stage of the roadmap to coincide with tasks being set in the formal program. If a student missed a formal tour of the Library’s facilities in O-week, this link with the module is invaluable. For all students, it is important to embed the “missing link” between the formal curriculum and support services

In Week 2, only two tasks are suggested and both of them encourage students to proactively build academic skills:

- What is plagiarism?
- What is a ‘scholarly resource’?

These questions actually directly relate to the tasks set in the units taken by the students at this point. They probably also reflect two of the most important differences in the learning skills expected in higher education compared to high school. The answers to both of these questions direct students to complete matching modules on the Library website.

Written assessments are beginning to be set at this point of the semester. An appreciation of what constitutes plagiarism becomes important for these assessments and for the laboratory courses that are also just beginning. Similarly, the question of what is or is not a reliable source of information should be considered *before* they begin assessed work. Developing these academic skills and informing students of their responsibilities on these issues also satisfies policy requirements in a logical and progressive manner.

After finishing these modules, students can download a “certificate of completion”, which may be required across multiple units of study. All students taking a unit of study with a laboratory component, for example, are required to complete the plagiarism module. Rather than having separate, overlapping and possibly conflicting requirements for dealing with this topic, the student is presented with a consistent and short task which they need only complete once, for all first year assessments.

To aid this skill development and the student's individual responsibility for their own learning, the students are also presented with the opportunity and instructions on how to use these certificates in an ePortfolio. At this stage of their first semester, the ePortfolio may well be no more than a convenient place to store these certificates. However, this forms the basis for developing its wider potential at a later stage in the year. The roadmap is updated every 3 weeks, grouping together key dates, such as enrolment variation deadlines and the release of the examination timetable, with links and prompts for information skill resources. Figure 3 shows the complete Roadmap for semester 1 of 2012. Following Johannessen (2004), the information literacy requirements are deliberately scaffolded and organised to provide a pathway from basic library skills, such as finding books, to more challenging academic concepts, such as referencing.

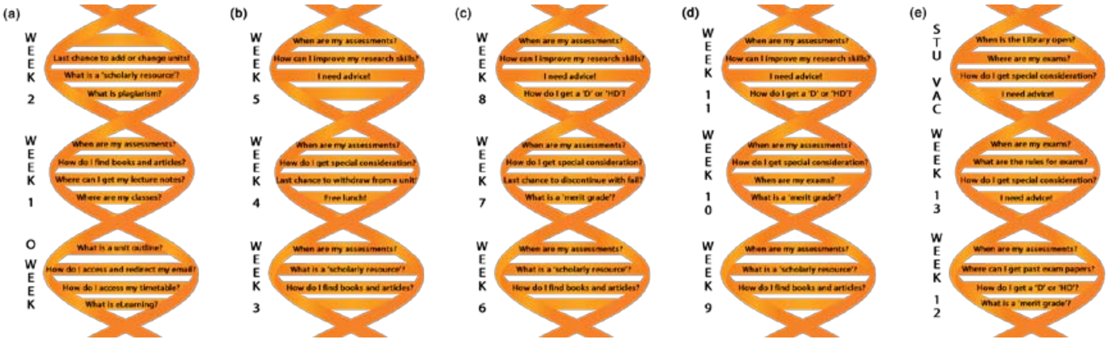

Figure 3: Roadmap for (a) orientation week and weeks 1-2, (b) weeks 3,4 and 5, (c) weeks 6, 7 and 8, (d), weeks 9, 10 and 11 and (e) weeks 12 and 13 and the study vacation.

ENGAGING STUDENTS WITH THE ROADMAP

As outlined above, the transition workshop represents our key interaction with many new students and the roadmap and the eCommunity now form a key part and background resource for this event. In the part of the day in which the current students and academic staff are facilitating a discussion of the steps for success, the process for logging on to the eCommunity site is introduced and the front page, shown in Figure 1, is then displayed for the remainder of the session. A slightly modified version of this page, shown in Figure 4(a), is then included as a leaflet in the "showbag". This version of the page contains step-by-step information on how to log on. The reverse of this leaflet, shown in Figure 4(b), lists the key aspects of a successful first semester.

The front of the leaflet is also printed out as an A0 poster for displaying in the First Year Laboratories, Enquiry Offices etc so that students who miss the transition workshop can also access the site. Finally, the lecturers in the Week 1 classes are all encouraged to show and talk through the roadmap as part of their course induction activities.

SUMMARY

The roadmap is an organising device to aid a smooth transition for new first year students. It uses the transition pedagogy (Kift *et al.*, 2010) to build on and extend our successful transition workshop into a semester long sequence of prompts and resources, which are presented in parallel and in support of mentoring program events. It is a practical and efficient means of providing an ongoing as well as a just-in-time approach for a large and diverse cohort of new students. By linking administration, curricular and support services, it answers and prompts frequently asked questions, inducts students into the broader culture of the faculty and integrates information and activities about a range of skills which will be taught, practised and assessed during their first semester at university.

(a)

(b)

Figure 4: Flyer for transition workshop showing (a) instructions for locating eCommunity site and (b) tips for a successful semester. Side (a) is also used as an A0 poster for the enquiry offices and laboratories of each discipline in the Faculty of Science.

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A CONSIDERATION OF QUALITY, STANDARDS AND COMPLIANCE

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KEYWORDS: quality, standards, compliance, TEQSA

ABSTRACT
With the advent of the Tertiary Education Quality and Standards Agency (TEQSA) there is an increased focus, at all levels in the university community, on the quality of teaching, learning and research. Quality itself is not well defined within the framework of TEQSA, the definition is however approximated by a set of minimum standards. This is problematic as there is scant evidence that threshold standards produce a high quality education. Often the good quality, and high standards, that are achieved within the university are due to the good quality, and high personal standards, of the staff. The appraisal of quality is therefore left to a number of stakeholders, within the university community, and with external course accreditation bodies. This means that individual unit coordinators, and members of the university community, have to amass a large collection of disparate material to create the body of evidence for compliance with standards, and to act as quality indicators. Managing this information can be very time consuming at the individual level. It is therefore essential that there be streamlined methods for enabling compliance and capturing and storing the evidence.

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INTRODUCTION AND BACKGROUND

As a unit co-ordinator it feels that we are surrounded by checks and balances on our work which itself is under continuous scrutiny from within and without the university. With the advent of the Tertiary Education Quality and Standards Agency (TEQSA) everybody at every level in the university will be accountable for the quality of the teaching and research within a university. It is therefore timely to investigate the effect this intense interest has on the day-to-day workload of a unit co-ordinator. Firstly though it is important to define quality and discuss the relationship between quality and standards.

Quality appears to be one of those difficult to pin-down concepts. The Collins Australian Pocket Dictionary (1992) defines quality as a "degree or standard of excellence" but unlike temperature, in Kelvin, or pressure, in Pascals, there is no absolute scale to measure it by. We all make judgements about the quality of something, usually relative to something else, and "we all know good quality when we see it", but when asked to define what quality is, people start to define by analogy. For example we might tell a student that a good quality piece of writing is like a fine red wine, it is a pleasure to read and leaves you feeling content and satisfied at the end. How would one explain how to achieve that to a student who is asking what they need to do to get a good grade?

This was the very problem that lecturer Phaedrus wrestled with in Robert M Pirsig's *Zen and the Art of Motorcycle Maintenance*

> if you can't say what Quality is, how do you know what it is, or how do you know that it even exists? If no one knows what it is, then for all practical purposes it doesn't exist at all. But for all practical purposes it really does exist. What else are the grades based on? Why else would people pay fortunes for some things and throw others in the trash pile? Obviously some things are better than others -- but what's the "betterness"? (Pirsig, 1974).

Also the definition of quality is a very contextual thing which depends on personal values and experience. If I had never been exposed to beautiful writing, logical argument and clear thinking then what I deem to be a high quality piece of work may not rank as high, on the quality scale, as a person who has had such an experience. Quality is also level dependant: what is good quality writing at a first year undergraduate level might be a very low quality piece of writing at a PhD level. By getting his students to judge one piece of writing against another Phaedrus was able to convince them that even though they could not define quality they knew what it was, and he was able to show them how to improve the quality of their own work

> He singled out aspects of Quality such as unity, vividness, authority, economy, sensitivity, clarity, emphasis, flow, suspense, brilliance, precision, proportion, depth and so on; kept each of these as

> poorly defined as Quality itself, but demonstrated them by the same class reading techniques (Pirsig, 1974).

This is the path that Phaedrus took to raise the quality of his students work. This was what we would now consider an example of "best practice" in teaching and learning and as far as he was concerned, "The whole Quality concept was beautiful. It worked. It was that mysterious, individual, internal goal of each creative person" (Pirsig, 1974).

As the Tertiary Education Quality and Standards Agency will be directing our quest to provide students with a quality education we thought we would find out what they have to say about quality. If you go to their website and type in "quality" you find **no** results reported (accessed 20/06/2012). If you type in "standards" you get 8 results, links to further information

1. Higher Education Standards Panel
2. Information Standards
3. Research Standards
4. Provider Standards
5. Teaching and Learning Standards
6. Qualification Standards
7. Higher Education Threshold Standards
8. Higher Education Standards Framework (TEQSA, 2012)

How does the setting of standards translate to judging the quality of a university, course, unit offering, graduating student or the work of you and me? It appears that because of the difficulty of defining good quality we have moved to setting standards, in the hope that if enough of the basic standards are met, the whole will be greater than the sum of the parts, and out of meeting the basic standards will come good quality. We leave this as a statement of what we are doing, and the correctness or not of the underlying assumption as a discussion for the philosophers among you.

Another point of caution is that TEQSA specifies "Higher Education Threshold Standards" i.e. the *minimum standards*. This is then not a quest for high quality, it is in-effect, a risk management, minimum standards, quality assurance process. The following quotes come from *TEQSA's DEVELOPING A FRAMEWORK FOR TEACHING AND LEARNING STANDARDS IN AUSTRALIAN HIGHER EDUCATION AND THE ROLE OF TEQSA, MARCH 2011*, discussion paper

> TEQSA's regulatory role is concerned with agreed minimum levels within the standards framework...
> The emerging focus upon standards as central to quality assurance signals a shift in emphasis for Australian higher education. Previously, approaches to quality have principally been conceived as 'fitness for purpose', and quality assurance has involved investigating the alignment between the established goals of an institution and the policies and processes in place for achieving these goals. Quality assurance, when framed in these terms, operates largely around internal reference points. In contrast, the concept of standards implies a greater emphasis on agreed, external points of reference in measuring and improving quality...
> TEQSA is developing learning standards because there is consensus that Australia must be confident that all graduates meet national minimum levels of attainment appropriate for the field or discipline in which they have studied, and appropriate for the level of the award they are granted (DEEWA, 2011).

As the governing body, TEQSA is required to evaluate the quality of our institutions, but the method it chooses to do this is to require compliance with national teaching and learning standards.

> TEQSA will be required to undertake evaluations of the quality of providers, provide information about the quality of higher education and provide independent advice on standards, quality and regulation. Developing an agreed approach to national teaching and learning standards is an essential step in achieving these functions (DEEWA, 2011).

It appears that without a direct chain of reason between quality and standards it will be necessary for TEQSA to lean heavily on the ability of other professional accrediting bodies to determine if a degree has good quality, while all of us, at all levels within the university, will need to collect a large body of evidence of compliance with the standards and benchmarking with other institutions.

What then constitutes evidence of compliance with standards? Back to the Collins Australian Pocket Dictionary (1992), a standard is “an accepted example of something against which others are judged or measured”. So firstly, as a body, we have to find good examples and then we have to judge what we are assessing, against those examples. This leads us to more questions. Who are these good-example-finding bodies of people? How do they go about finding the good examples that can be used as standards? What aspects of university life and work are being measuring against these standards?

The last question is perhaps the easiest to answer. To a humble unit co-ordinator, who has spent time on several university committees, and has undertaken service as an Academic Chair it feels like everything is under continual assessment against one standard or another. Let us begin then with your own personal standards which come from experience, professional development, personal investment in the units that you teach, personal integrity and professionalism. How do others, who do not know you, check that your standards are good standards? What are your observables and what are they measured against? Such metrics as publications, grants, teaching awards, student surveys about your teaching and unit organisation, ad hoc student feedback, unit materials, your educational qualifications within your discipline, within education and within other areas, peer reviews and referee reports are all part of the “body of evidence” and they are measured against similar material obtained about your peers. It is therefore worthwhile keeping track of all this material for external quality assessment processes and particularly for promotional reasons.

Other things we measure against standards within a university fall into the following broad categories, physical facilities, administrative support facilities, teaching support facilities, educational process, ethics and safety. In many of these areas standards are maintained by university policies and there is much talk in university committees of compliance or non-compliance with one policy or another. These policies and procedures are formed and polished in university committees i.e. “the example finding bodies of people”, previously mentioned. The committees at Murdoch University that report to Academic Council include the: Academic Quality Audit Committee; Committee of University Entrance; Learning and Teaching Committee; Research Degree and Scholarship Committee and the Student Equity and Social Justice Committee (Murdoch University, 2012). This means that edicts from these committees, including anything they think is relevant from TEQSA, will percolate down through faculty and school based committees, and administrative systems that are trying to ensure compliance in everything from Graduate Attribute mapping of units and courses, to inclusion of information about plagiarism and collusion in unit guides.

Going in the other direction from schools and academics through various committees to Academic Council is information from: School Senior Management Boards; Board of Examiners; Plagiarism Investigators and Arbitrators and Ethics Committees. We find it truly amazing the amount of work done to ensure high quality and good standards within a university. All of this information flow can be considered as part of the “body of evidence” for compliance with the standards and perhaps even the quality of the university.

There are also external accrediting bodies that attempt to assess the quality of a degree. One such accrediting body is the Australian Institute of Physics. The following is taken from the AIP accreditation report for Murdoch University Physics October 2008

> In examining the above courses for accreditation purposes, the accreditation panel considered the following factors:
>
> - The general academic practices and standards of education at the institution.
> - The objectives of the course and the methods adopted to achieve these objectives.
> - The standards of admission to the course.
> - The duration of the course.
> - The breadth, depth and balance in the subjects involved and the intellectual effort and demands of the course.
> - The extent and range of methods of assessment of student progress.
> - The arrangements for practical training and experience as part of the course.
> - The teaching staff conducting the course, their numbers, professional qualifications, experience and educational expertise.
> - The accommodation and facilities available including equipment, libraries, laboratories, workshops etc.
> - Previous examination papers and student responses.
> - Examples of student laboratory notebooks.

- Examples of other written work submitted for appraisal by students.
- Evidence of a review and quality improvement process (AIP, 2008).

In all of this we find very little evidence of any of these bodies providing good examples that can be used as standards. It appears to me, that in many situations, it is left to the academics to provide the evidence of good quality within the university. While all this activity may highlight the value of good quality, it feels that much of the evidence for the good quality, and high standards, that are achieved within the university are because of the good quality, and high personal standards, of the staff. In other words most of them would have done it anyway.

A good example of standards having little effect on quality comes from a paper on "ISO 9000 registration's impact on sales and profitability: A longitudinal analysis of performance before and after accreditation" by Heras, Dick and Casadesus (2002). They tell of a study in which they compared the business performance of companies that were not ISO (International Standards Organisation) compliant to those that became compliant. They also compared the business performance of the compliant companies before and after certification. What they found was that "superior performance of certified firms is due to firms with superior performance having a greater propensity to pursue ISO 9000 registration" (Heras, Dick, & Cassadesus, 2002). This "Illustrates the potential dangers in inferring that ISO 9000 certification leads to superior business performance... Certification is a major investment yet the findings show that inflated expectations of performance improvement after ISO 9000 accreditation may be unfounded." (Heras, Dick, & Casadesús, 2002).

Supplying evidence for accreditation and standards setting bodies and ensuring compliance with policy, while following correct procedure, takes time. If these things are done inefficiently that time detracts from teaching and research. Forewarned is forearmed and if you know what evidence different bodies are likely to ask for, then, as that evidence becomes apparent, it can be filed appropriately to be produced at the required time. It would ease the load on individual academics if the bulk of the evidence could be collected and stored centrally in the university. Research information is already being collected in such archives as IRMA. For teaching, a streamlined content management system could blend learning management and course content management by holding not only unit materials, but also, databases of student surveys, ASELL benchmarking, and evidence of educational development. This would leave individual academics only their personal information to keep track of and they might choose to use Wikis or electronic portfolios to do this.

In a time poor environment judging the value of evidential information is important when prioritising what to collect and how much time to spend collecting it. One way of doing this would be to use something similar to Table 1 below, which indicates the type of evidence that could be collected in the left hand column, against the interested parties and shows directly, by the number and placement of ticks, the usefulness of each piece of evidence.

In conclusion, because of the difficulty in defining and systematising metrics for quality, the governing bodies have plumbed for compliance with minimum standards. This is a risk management approach to quality assurance and does not necessarily promote aspirations of high quality work from either staff or students. This does not mean that compliance with standards will reduce the quality of an institution or its students, because good quality staff will still do good quality work, and produce good quality students. The only problem with the new system is that there could be less time for teaching and research, because more time is being spent on compliance with standards, and sourcing evidence to demonstrate this compliance. It is therefore essential that there be streamlined methods for enabling compliance and for capturing and storing the evidence.

Table 1: Evidence vs. Stakeholders who might be interested for compliance or accreditation purposes.

	Students	Academics for teaching	Academics for research	Staff reviews	School reviews	University reviews	Employers	AIP	ALTC & similar bodies	TEQSA
Graduate attributes	y	y			y			y		
Staff professional development		y	y	y	y			y		
Teaching surveys		y	y	y						y
Unit surveys (MOSS)		y	y	y				y		y
Alignment and matching of units		y			y			y		y
Consistent on-line format / interface	y	y			y			y		
Education research and reflection	y	y	y	y	y			y	y	
Benchmarking against other universities for educational and research purposes		y	y	y	y	y			y	y
ASELL (benchmarking)	y	y	y		y	y		y	y	y
Course aims and objectives	y	y						y		
Course structure integration	y	y			y			y		
Assessment aims and criteria	y	y						y		y
Evidence of review and quality improvement process	y	y			y			y		
Examples of a range of student work	y	y			y			y		
Unit materials and examination papers	y	y						y		
Information about facilities		y						y		
Up –to-date CV				y	y			y		
Historic database of grades		y			y			y		
Grades analysis		y			y			y		
AIP accreditation	y				y	y	y	y		

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[1] This is the report that the AIP gave to Murdoch University at the end of the accreditation process for the Physics degree. A similar criteria list was given to the school in a generic letter before the accreditation process took place and then it was modified by the accreditation panel to best reflect their activity during the accreditation process

PROGOSS: MASTERING THE CURRICULUM

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KEYWORDS: curriculum design, curriculum mapping, learning standards, mastery, assessment

ABSTRACT

In education, we need to design effective degree programs of study that meet authoritative curricula guidelines. This is challenging because of the size of the curriculum and complexity of degree program structures. When dealing with data of this size and complexity, traditional spreadsheets are a clumsy way of storing the data. A database is a better option, especially when the database is accessible over the web. We created ProGoSs to effectively tackle this complexity. ProGoSs is a web-based system that maps curricula learning goals and mastery levels to individual assessment tasks across entire degree programs. ProGoSs enables academics to answer important questions such as: Does our degree teach the essential core defined in a recommended curriculum? Where in our degree are particular parts of the recommended curriculum taught? Does our degree ensure a solid progression in building skills? Where and how do we assess the learning achieved by bare-pass students on particular parts of the recommended curriculum? We present the design and implementation of ProGoSs and report on its evaluation by mapping multiple programming subjects from multiple universities to the ACM/IEEE Computer Science 2013 topics and learning objectives. This includes a mapping to various levels of Bloom's Taxonomy to capture mastery.

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INTRODUCTION

Hausman (1974) proposed that by 'mapping' out all the elements of the curriculum and their relationships to learning activities, 'it should be possible to analyse and compare the structural qualities of a continuing series of lessons' and to better plan more effective programs of study. Eisenberg (1984) noted that 'those interested in curriculum need accurate assessments of the current state of affairs in an educational institution ... mapping is intended to reveal the bottom line, the actual curriculum being taught to students'. However, Eisenberg also acknowledged that doing so is 'cumbersome and rarely undertaken'.

Until recently, most published degree-level curriculum mappings were in the medical domain. Britton et al. (2008) described a system developed at the University of Oklahoma that was designed to 'make the implicit curriculum explicit and transparent to ... identify gaps or unnecessary redundancies in course content [and to] link elements of the curriculum together within a course, a semester, a professional year, and the entire program'. Faculty members were required to define specific learning objectives for their subjects, map these to relevant professional accreditation syllabus documents and program outcomes, and specify how they were taught and assessed in each subject. This data was then used to generate semester-level and program-level reports outlining 'course integration in the curriculum, sequencing of courses, adequacy of prerequisite coursework, course effectiveness in holding students accountable for prior knowledge and skills, assessment methods'. The system helped the faculty identify subjects that needed 'revision and renewed alignment with program outcomes', and also subjects that 'required re-sequencing in the curriculum in order to build students knowledge and skills more intentionally and effectively'. Willett (2008) provided a review of similar systems also in the medical educational domain.

Within Australia, the academic attitude toward defining curricula and learning standards has recently taken on a greater sense of increased importance due to the creation of the Australian government's Tertiary Education Quality and Standards Agency (TEQSA, 2011). This agency will register and accredit all higher education providers. As part of its role, the TEQSA standards framework will assess graduate outcomes against agreed academic disciplinary standards. As a consequence of the creation of TEQSA, a number of projects have been started in Australia, to devise learning standards in various disciplines (Krause, Barrie, & Scott, 2012). The Australian Learning and Teaching Council (ALTC) conducted the Learning and Teaching Academic Standards Project. The project defined threshold learning outcomes in eight discipline groups. For example, the discipline group for Engineering and ICT (ALTC, 2010) devised a broad set of five outcome areas: (1) Needs, context and systems, (2) Problem solving and design, (3) Abstraction and modelling, (4) Coordination and communication, and (5) Self management. While providing a useful, high level categorization of learning outcomes, those five broad outcomes leave implicit much of the detail of recognized Engineering and ICT curricula. We illustrate that complexity in the next section, for the computer science curriculum.

CURRICULA COMPLEXITY: COMPUTER SCIENCE AS A CASE STUDY

Approximately every 10 years, the Association for Computing Machinery and IEEE Computer Society (ACM/IEEE) release curricula recommendations that specify a list of topics and learning outcomes for Computer Science. The first draft ('Strawman') of the Computer Science Curricula 2013 (CS2013) is now available (Computer Science Curricula 2013: Strawman Draft). This 172 page document lists 1366 topics and 1041 learning outcomes. These are categorised into 18 top-level Knowledge Areas (KAs) and 155 sub-level Knowledge Units (KUs). The 1366 topics are further categorised into Tier-1 Core (257), Tier-2 Core (328) and Electives (781). Tier-1 Core topics are considered essential for all Computer Science programs in every institution. That is, 'a curriculum should include all topics in the tier-1 core and ensure that all students cover this material'. Tier-2 topics are also regarded as highly important, and institutions are required 'to include at least 80%' of these in their Computer Science programs. Institutions are free to select whichever Elective topics are most relevant for their individual programs. The learning outcomes defined in each KU relate to the topics in that KU, but also contain a 'level of mastery' component. The CS2013 Strawman draft proposes a three level mastery scale that appears to be loosely based on Bloom's Taxonomy (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956). The aim of these objectives is to capture the maturity and proficiency of students as they progress through the subjects of a Computer Science program.

The Knowledge Areas and Knowledge Units of the CS2013 are not designed to, or expected to, have a one-to-one mapping to actual program subjects. That is, subjects may teach and assess topics from multiple KUs, and even multiple KAs. It is thus up to the program designers and individual subject lecturers at each institution to coordinate which of the 585 core topics and 781 elective ones are taught and for those that are to be included, where this will happen. This includes coordinating the order and the level of mastery that topics are taught and assessed in. The program design process is critically important. An ineffective design may result in serious flaws in the curriculum. For example, it may unintentionally omit even core topics, or it may fail to ensure that students reach the necessary level of mastery, or it may lack continuity in a student's study path (that is, insufficient pre-requisite knowledge in going from one subject to the next).

Program design is further complicated by the need to differentiate between the aspirational outcomes that are typically only achievable by the top-performing students vs the minimal outcomes that are to be achieved by all passing students. That is, while the subjects of a program may cover all core topics at an appropriate level of mastery, how many of these topics and at what level do bare-passing students graduate with?

PREVIOUS WORK ON COMPUTER SCIENCE CURRICULUM MAPPING

CITIDEL (Knox, 2002) is a Digital Library repository. It includes a Syllabus section that has a collection of resources that are mapped against the Computer Science Curriculum 2008 (CS2008) Knowledge Areas and Knowledge Units. These resources however are mostly subject outline documents or lecture schedules from different institutions. The granularity of mappings is very coarse, and there is no notion of a full program or a higher-level structure above a subject. CITIDEL in itself does not help visualise and design actual Computer Science degree programs.

COMPASS (Abunawass et al. 2004) is a Moodle plugin that allows mapping of Computing Curricula 2001 outcomes to subject assessments, using Bloom's Taxonomy to classify the level of mastery. The system was developed to support review and accreditation of the Computer Science curriculum at the University of West Georgia. This system has several limitations. Subject lecturers were directed to external websites and Word documents to pick relevant outcomes and fill in the COMPASS web-forms. Also, all reporting was done manually via running custom SQL queries against the system database.

THE DATABASE APPROACH: *ProGoSs*

Many of the learning standards projects currently under way in Australia are using spreadsheets to record curriculum mapping data. However, spreadsheets are a clumsy solution when dealing with data of this nature, size and complexity. Introductory textbooks on databases often describe the advantages of databases over spreadsheets, so in this paper we shall only briefly describe those advantages. Databases separate how the data is stored inside the computer and how it is presented to the user. Furthermore, this separation allows many different views for the same data, so that data is presented in the most appropriate way for different types of users, or even for the same user when that user requires the data for different purposes. The methods of presentation need not be anticipated in advance, as new ways of presenting data can be added without altering existing presentations, provided the underlying way of storing the data in the computer was well designed in the first place (i.e. the database is 'normalized', to use computer science terminology). In contrast, many creators of large spreadsheets will have found themselves having to laboriously reorganize a spreadsheet, as their project progresses, in response to needs that were not initially anticipated. (Or, alternately, they find themselves using clumsy quick fixes to adapt a spreadsheet to an unanticipated need.) Database systems are also designed to handle efficiently very large quantities of data; unlike spreadsheets which can slow dramatically as the quantity of data increases. Another advantage of databases is the ability of perform sophisticated checks on the validity of new data when it is entered.

Three broad types of checks can be done: (1) domain integrity (i.e. the datum entered has a legal value or form), (2) entity integrity (i.e. a value intended to uniquely identify something has not already been used to identify something else) and (3) referential integrity (e.g. a subject number entered corresponds to a real subject). Finally, a web enabled database delivers instantly the most recent data to a large number of users, in contrast to the clumsiness of distributing new versions of a spreadsheet via email – not to mention the problems that can arise when people are accessing different versions of the spreadsheet, or even worse, entering data into incompatible versions of the spreadsheet.

ProGoSs (Program Goal Progression) is the web enabled database driven system we created to support systematic modelling of degree programs. It provides effective interfaces for users to model their programs, and generates big-picture visualizations that enable users to answer key questions about a curriculum. Figure 1 shows the *ProGoSs* system architecture, which is comprised of three main components: program, goals and progression. The top-half of the figure represents degree programs within institutions. As shown, *ProGoSs* supports multiple institutions; each with multiple degree programs. Each degree program is in turn modelled as a collection of subjects (called units or courses at some universities). For each subject, it is possible to define the pre-requisite knowledge, the intended topics and outcomes, and a collection of assessed activities (e.g. exams, in-class quizzes, take-home projects). Other activities such as lectures or labs could also be modelled in the system; although these were not included as part of this study as we chose to focus on assessed activities only. The bottom-left part of Figure 1 deals with the representation of curriculum guidelines or goals, such as the CS2013.

The bottom-right of Figure 1 shows the use of mastery scales, such as Bloom's Taxonomy, as a way of representing progression. In this study, we chose to use Bloom's Taxonomy, as it has been used widely in computer science education, such as the Australian Computer Society (ACS) Body of Knowledge (Gregor, Konsky, & Wilson 2008). Note, however, that *ProGoSs* is not limited to a specific curriculum definition or a specific mastery scale. We use Bloom's Taxonomy and CS2013 in this study as a validation of *ProGoSs*. Other discipline curricula, or any other list of topics/outcomes/competencies/goals, can be loaded into ProGoSs. Likewise other mastery scale frameworks, such as the SOLO taxonomy (Biggs & Collis, 1982), or an institution's own internally defined scale, could be used instead of Bloom's Taxonomy.

When a subject pre-requisite (or outcome or assessed-activity) is mapped against a curriculum topic, the user also selects a relevant mastery level for that specification. For example, a lecturer may specify that the CS2013 curriculum topic 'Conditional and iterative control structures' Tier-1 Core topic is a pre-requisite for a particular subject, and that students are expected to have a minimum Bloom mastery level of 'Comprehension' for that topic.

Figure 2 shows one part of the data-entry interface. Here a lecturer has defined Question 1.a) of a Final Exam in a Data Structures subject, and has mapped one Key Assessed Topic and two Key Assessed Learning Objectives from the ACM/IEEE CS2013 curriculum guidelines. The sliders on the right are used to set the mastery level for each topic and objective (in this case, Bloom's Taxonomy). The interface is optimised for rapid data entry. A user may simply type a keyword to search through an entire curriculum, and then selecting from among the matches found. Additionally, for each assessment question, the subject lecturer specifies: (1) if the student is familiar with the task (i.e. has practiced similar examples in lectures/labs); (2) if bare-passing students are expected to be able to answer correctly; and (3) the estimated expected time required to answer the question by bare-passing students vs. top-performing students. This additional metadata is used to distinguish between the aspirational curriculum (i.e. what top-performing students achieve) and the threshold curriculum (i.e. what bare-passing students achieve).

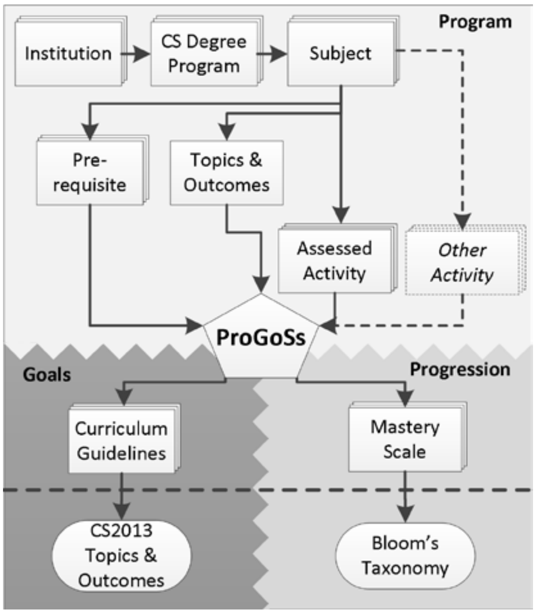

Figure 1: ProGoSs system architecture.

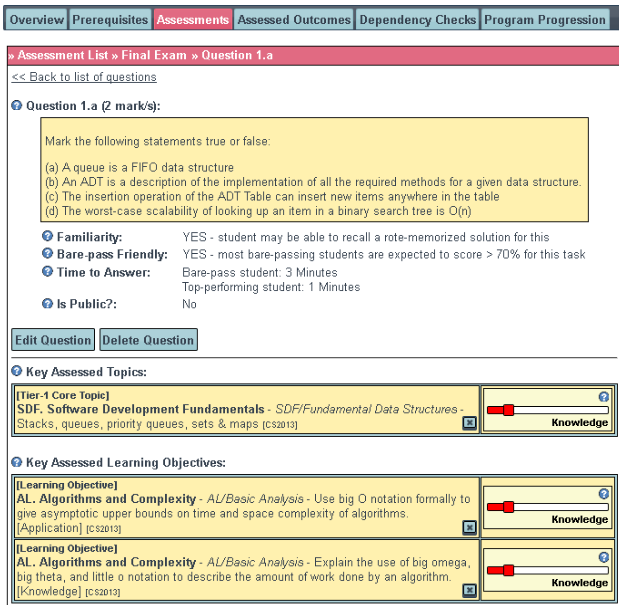

Figure 2: Interface for mapping assessed outcomes

Figure 3 contains a subject-level report that shows the different levels of mastery between bare-passing students (top-left chart) and top-performing students (top-right chart) based on (in this case) Bloom's taxonomy (y-axis). The x-axis represents the percentage-weight of overall subject assessment targeting each mastery level. Figure 3 also shows the bare-pass vs. top-performing Bloom assessment for (in this case) each ACM/IEEE CS2013 topic and objective that is assessed in the subject.

Additional interface screens not shown here allow a user to inspect the dependencies between subjects in terms of the mapped topics and objectives. That is, a subject lecturer is able to immediately identify where each pre-requisite topic or objective is taught and assessed in the degree program. Additionally a subject lecturer is shown which successive subjects rely on the topics and objectives assessed in his or her own course. This provides lecturers with a clear picture of the abilities of students as they progress through the semesters of a degree program.

EVALUATION

We began our evaluation of the *ProGoSs* architecture by translating the Body of Knowledge from the ACM/IEEE CS2013 Strawman curriculum guidelines into our system database. The next step was to define a mastery scale, and so we loaded the six levels of Bloom's Taxonomy into our database. We then used *ProGoSs* to model the core sequence of programming subjects from a computer science degree from one institution. Finally, exam papers from seven computer science subjects were entered into *ProGoSs*. Each exam question was mapped to relevant CS2013 topics and outcomes, at appropriate Bloom's Taxonomy mastery levels. The time taken to model a full exam paper from each subject was between one hour and two hours, with minor additional iterative refinement as required. An exam with 26 plus multiple-choice questions, for example, took longer than an exam with 10 extended questions. The overall time required to map an entire exam paper is not overly demanding, and can be done in a single sitting by a subject lecturer.

EFFECTIVENESS OF CURRICULUM REPORTING INTERFACES

The goal of *ProGoSs* is to facilitate the program design and curriculum review process and to enable stakeholders to easily do the following:

1. Determine overall coverage of core/elective topics and outcomes.

2. Identify where in a program a specific topic/outcome is covered.
3. Identify topics/outcomes that are not covered anywhere in a program.
4. Identify the mastery level at which a topic/outcome is covered in a subject.
5. Differentiate between bare-passing students vs. top-performing students.
6. Inspect program sequence in terms of prerequisite dependencies.

To evaluate the effectiveness of the system for allowing users to answer these questions we invited nine computer science educators to complete a printed questionnaire about *ProGoSs*. The questionnaire guided users through logging into the system and then asked them to answer a series of eleven specific questions by interrogating the *ProGoSs* database. Some of the questions were 'What total percentage of Tier-1 Core topics does our program cover in the top-level Software Development Fundamentals knowledge area', and 'Which subject teaches/assesses the prerequisite topic SDF. Software Development Fundamentals - SDF / Fundamental Programming Concepts / Simple I/O, and at what level of mastery?' Each of the eleven questions mapped to one or more of the six goals above.

The participants comprised of three tutors and six lecturer/professors. Two of the tutors were from the same institution as the subjects modelled in the system. The remaining seven participants were from various other institutions and had limited to no knowledge of the content of the modelled subjects. Some of the nine participants had some previous exposure to *ProGoSs*, but none had used the reporting screens before. All nine participants answered all eleven questions, except for one slip, where the participant's answer revealed that s/he was looking at a neighbouring bar-chart category and hence wrote down an incorrect response.

Participants were not working under any time restriction, nor were they instructed to complete the exercise quickly. Participants took between 15 and 30 minutes (avg. 24 minutes) to learn to use the *ProGoSs* interfaces for the first time and to answer the eleven questions about the modelled curriculum. Thus, the evaluation demonstrated that *ProGoSs* enables users to answer complex questions about the curriculum of a degree program with limited to no prior knowledge of the program content or of the *ProGoSs* interface. It also shows that the *ProGoSs* architecture is an effective approach to fine-grained systematic curriculum design.

Participants were also asked if they knew of any other system or method that would allow them to answer similar questions about their own degree programs. All answered "no". Participants were asked if they would use *ProGoSs* in their own institutions. Eight out of nine said "yes".

CROSS-INSTITUTIONAL PROGRAM COMPARISON

After the above evaluation, three participating computer science educators from institutions other than our own accepted our invitation to enter into *ProGoSs* a zero-prerequisite computer programming subject from their own university. *ProGoSs* was then able to generate comparison reports showing differences in coverage of CS2013 topics/outcomes between any two of those subjects. This is presented as two charts, shown side-by-side, where each chart is like the single chart shown in Figure 4. These charts show the percentage of topics or objectives covered in each Knowledge Area. A user is also able to drill-down for more details, by clicking on appropriate parts of the chart, revealing percentage weights associated with each topic, mastery levels and bare-pass vs. top-performing student expectations.

FACILITATING SYSTEMATIC COMMENTING ON DRAFT CURRICULUM GUIDELINES

While mapping exam questions to topics and outcomes from the CS2013, we encountered a number of cases in which we could not find appropriate matches. For example, an introductory programming subject had a question relating to the 'scope' of a variable. The scope of a variable is a well known concept that is often taught in an introductory programming course. However, the *ProGoSs* interface enables exhaustive keyword searching through a curriculum, and we found that the scope of a variable did not contain that topic. (We also tried commonly used variations on this term, such as 'visibility', without success.)

To capture feedback on the CS2013 proposal itself, such as missing topics, *ProGoSs* includes an integrated form that allows the user to leave comments in each screen that involves mapping topics/outcomes to subject assessment or pre-requisites. Thirteen such comments were captured in the mapping of questions from one Introductory Programming Final Exam alone. These issues are exportable into a single file. We sent such a file to the CS2013 review committee through appropriate channels. Thus *ProGoSs* is also a useful tool for assessing the relevance and completeness of a draft curriculum specification.

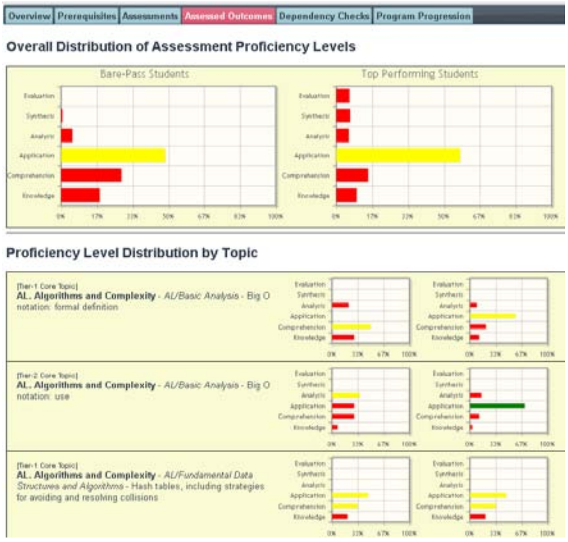

Figure 3: Bare-pass vs. top-performing students

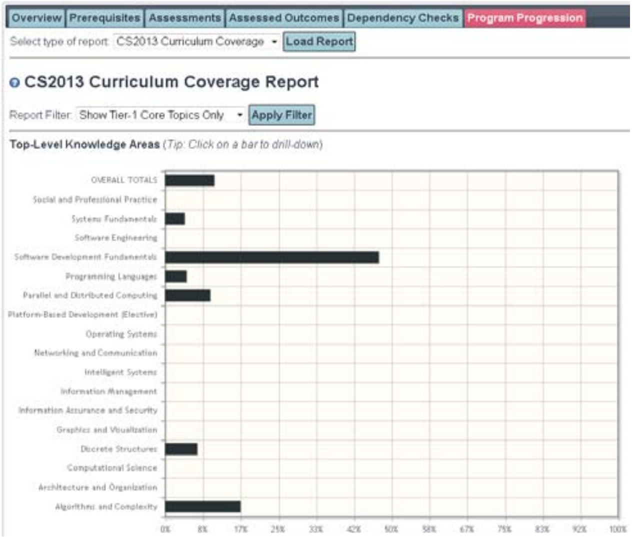

Figure 4: Whole-program curriculum coverage

CONCLUSIONS

In this paper, we have presented the architecture and implementation of our *ProGoSs* system, along with an evaluation demonstrating its effectiveness. *ProGoSs* enables educators to represent a degree program in terms of a given curriculum specification. It enables educators to answer key questions about the mapping between a degree program and a curriculum specification. *ProGoSs* also allows educators from different institutions to systematically compare the teaching and assessment in related subjects. And finally, *ProGoSs* allows a community to systematically provide feedback on a draft curriculum specification. While we evaluated *ProGoSs* in a computer science context, it is easily adaptable to other disciplines.

The tradition of university departments largely setting their own curricula and standards appears to be giving way to an environment of accountability to externally mandated curricula and standards. Many of the difficulties in making this transition have been identified, not least of which is changing the academic culture. However, one difficulty that has not yet received sufficient attention is the difficulty of managing the large amounts of information generating when degree programs are mapped to externally mandated curricula and learning standards. It is not enough to document curricula and document learning standards. In conjunction with those activities, suitable web-enabled database systems will need to be developed to support the mapping between curricula and learning standards. Current projects relying on spreadsheets are already struggling to manage the data generated and we have only just begun the process of generating and handling all this data. Systems like *ProGoSs* are essential for mapping curricula against TEQSA and other learning standards.

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MEASURING THE IMPACT OF EARLY MATHEMATICS SUPPORT FOR STUDENTS ENROLLED IN AN INTRODUCTORY CALCULUS UNIT OF STUDY

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KEYWORDS: mathematics support, bridging courses, evaluation

ABSTRACT

In this study we report data relating to a cohort of students who participated in support programs at our Mathematics Learning Centre or took part in mathematics bridging courses. The students were enrolled in an introductory calculus unit of study at our university, most of them starting Science degrees. Demographic data, performance data and attendance figures are presented with the aim of gauging the effect of the support. While the study is observational and so conclusions are tentative, the results are encouraging and support the efficacy of the assistance received with over three quarters of the Centre's attendees completing and passing the unit.

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INTRODUCTION

The need for mathematical support at university is now greater than ever as student cohorts become increasingly diverse, university entry requirements become more flexible and students' mathematical preparation and skills are seen to be significant factors in the retention and success for students in science and engineering, as well as in many other disciplines (Varsavsky, 2010). Support centres and facilities for assisting students in mathematical topics have been established in many universities in Australia, the United Kingdom and Ireland, amongst other countries. At our university, the Mathematics Learning Centre aims to assist eligible students to develop confidence and skills in mathematics and/or statistics, where eligibility means that students are undergraduate, enrolled in a first level mathematics or statistics unit and are demonstrably less well prepared for that unit than desirable. The Centre operates during the academic year, while students are studying, and is a free service provided to these students. Students can 'drop in' or attend small group tutorials and workshops. The University also offers bridging courses in mathematics, which are short intensive courses held in February, prior to the first semester. These bridging courses are open to all and are fee paying. They constitute 24 hours of class time held over 12 days.

Measuring and benchmarking the effectiveness of our practice for those of us who work in mathematics support is and always has been problematic. One challenge to evaluating such support is that there is no assessment for degree credit associated with support programs. As MacGillivray and Croft (2011, p.196) propose: 'the essence of learning support is that it is not formal'. Indeed, Godden and Pegg (1993) suggest that evaluation, in the traditional sense, may be incompatible with the successful conduct of tertiary mathematics support programs. Further, (eligible) students are educationally diverse and self-select whether to utilise a support centre. The questions: 'What constitutes success for bridging course students (Taylor & Galligan, 2006) and students using mathematics support centres?' and 'What is the role of that support in students' success?' are complex.

Some frameworks for evaluating mathematics support at various institutions include attendance data in programs and support facilities, performance of students in their mathematics units and qualitative data recording students' perceptions about the help they receive and its effect on their learning and confidence (Dowling & Nolan, 2007; Pell & Croft, 2008). Attendance data are a measure of demand and, since mathematics support programs are usually 'optional extras' for students, a measure of how well students' needs are being met (MacGillivray & Croft, 2011). Lawson, Halpin, and Croft (2001) suggest that counting return visits is a more sophisticated measure of the effectiveness of the mathematics support than simply attendance figures. Qualitative data from internal student feedback surveys provide insights into how the mathematics support is perceived by students themselves. This feedback is therefore an important indicator of effectiveness but has some limitations. As MacGillivray and Croft (2011) point out, it is rare to find negative feedback about mathematics support from the students who use it. Measures of effectiveness based on attendance or student feedback data have been characterised by Croft (2008) as ‘soft measures’. Measures characterised as ‘hard measures’ (Croft, 2008), are attempts to quantitatively measure the effect of mathematics support on student performance. Dowling and Nolan (2007) compared the examination success of ‘at risk’ students who attended their Mathematics Learning Centre (MLC) with those who did not. They claim that the MLC contributed directly to the retention of a significant number of ‘at risk’ students. Similarly, in a study of engineering students, Patel and Little (2006) showed that mean module scores for Mathematics Study Support (MSS) students were significantly greater than those for non-MSS students; an estimated difference of about 4%.

While we have used attendance and student feedback data for many years to inform our practice, in this paper we will examine student performance in an introductory calculus unit of study in an attempt to provide a ‘hard measure’ of its effectiveness. We do not claim direct causal links from the findings – our students are self-selecting and many variables that affect students’ performance, such as motivation levels, are unknown and cannot be controlled. Rather, as suggested by MacGillivray and Croft (2011), we present our findings as quantitative evidence of the value of mathematics support.

METHODOLOGY

The cohort we selected for this study were students enrolled in an introductory calculus unit of study as enrolment in this unit of study is restricted. It is not open to students who have previously completed either intermediate mathematics or advanced mathematics. That is, a student who has previously completed a course containing substantial calculus content may not enrol in this unit. Hence, while the mathematical preparation of this cohort includes students who may have completed studies in elementary mathematics in years 11 and 12 (General Mathematics for the HSC, that is Higher School Certificate in New South Wales), their mathematical backgrounds are not as diverse as in other mathematics units of study. All students enrolled in this unit are eligible to use the Mathematics Learning Centre.

Data were obtained for 176 students from the student database including demographic information, their degree program, whether they had studied General Mathematics for the HSC and their final mark in the introductory calculus unit of study. Information on student enrolment in the mathematics bridging course and total attendance in Mathematics Learning Centre programs was obtained from local databases. For some variables of interest information was available for only a subset of these students.

The data were analysed using *SPSS* (statistical software package) to gauge the effectiveness of the Centre’s support on students’ performance in their calculus unit. We reiterate that we do not claim causality.

RESULTS

DEMOGRAPHIC INFORMATION

Data were obtained for 176 students, 106 female (60%) and 70 male (40%). Most of these students (130, 74%) were between 18 and 21 inclusive, while 12 students (7%) were 30 or older. Ninety four percent of the students (166) were Australian domestic students.

Sixty nine percent of the students were enrolled in a variety of Science degrees. Students enrolled in Science programs are required to take 12 credit points of junior (1st year) mathematics or statistics, so enrolment in the introductory calculus unit of study constituted 50% of this requirement. Importantly, Science students who do not pass this unit cannot fulfil their mathematics requirements in that (standard academic) year. Seventy three students (41%) were known to have studied General Mathematics for their HSC, but no other information on prior mathematics was available for the remaining students.

Table 1 shows the final grades of students in 2010 in the introductory calculus unit of study.

Table 1: Unit of study grade (n=176)

Grade	Number	Percentage
Withdrawn	24	14
Discontinued, Fail	1	<1
Discontinued, Not Fail	3	2
Absent Fail	3	2
Fail	39	22
Pass	73	41
Credit	23	13
Distinction	10	6

MATHEMATICS BRIDGING COURSE ATTENDANCE

Mathematics bridging courses are preparatory courses that enable a prospective student to obtain prerequisite or assumed knowledge before commencing their degree program (MacGillivray, 2009). Accordingly, these courses represent the first opportunity for students to learn some of the mathematics assumed for their degree programs at our university. Further, our recent research (Gordon & Nicholas, 2012, in press) shows that students perceive these bridging courses not only as a resource to ameliorate previous difficulties with mathematics and learn new topics but also as an important part of their transition from school to university – 'a taste of the big time' – as one student put it.

The 2 unit mathematics bridging course introduces students to the concepts of differential calculus. Although the assumed knowledge for the introductory calculus unit of study was 'at least year 10 mathematics' and the unit is described as an 'introduction to differential and integral calculus[2], 26 students, about 15% of the cohort, attended the 2 unit mathematics bridging course.

There is evidence suggesting that attending a mathematics bridging course has a positive impact on retention in the unit of study. Table 2 shows that no mathematics bridging course attendee withdrew from their unit of study compared with 27 of the non-attendees, indicating that 18% fewer bridging course students withdrew from their unit of study compared to non-bridging course students. This difference is statistically significant (Fisher's exact test; $p = 0.016$).

Table 2: Student withdrawals from the unit of study for Mathematics Bridging Course students and other students

	Withdraw *	Completed	Total
Non-bridging course	27	123	150
Bridging course	0	26	26
Total	27	149	176

* includes students who discontinued, not 'fail'

For the 149 students who either completed the unit of study with a grade or were classified as absent fail or discontinued fail, the unit of study mark was, on average, 3.9 marks higher for the 26 bridging course attendees compared to those of the 123 non-attendees. However, this difference was not statistically significant ($t_{147} = 1.00$; $p = 0.32$).

ATTENDANCE AT MATHEMATICS LEARNING CENTRE SEMESTER PROGRAMS

The students in the introductory calculus unit of study were advised during their second lecture (and with a follow up email in Week 3) that there was a weekly support tutorial held at 8am on Thursdays at the Centre. Students were also informed that they were eligible to come to the 'Drop-in' Centre for assistance.

There were 56 students who attended the Mathematics Learning Centre (MLC) for more than 1 hour during the semester. In accord with Lawson, Halpin and Croft (2001) we will classify these students

[2] School of Mathematics and Statistics, Junior Mathematics and Statistics 2010 Handbook

as MLC attendees, as these students represent those who used MLC programs on more than one occasion. Males were under-represented with 32% (18) of the attendees being male.

Table 3 shows the final grades of the MLC attendees in the introductory calculus unit of study compared to students who did not attend the Centre.

Table 3: Unit of study grade for MLC attendees (>1 hour) and non-MLC students

Grade	MLC Attendees n = 56 Number (%)	Non-MLC students n = 120 Number (%)
Withdrawn	2 (4)	22 (19)
Discontinued, Fail	0 (0)	1 (1)
Discontinued, Not Fail	2 (4)	1 (1)
Absent Fail	0 (0)	3 (2)
Fail	7 (13)	32 (26)
Pass	36 (64)	37 (31)
Credit	7 (13)	16 (13)
Distinction	2 (4)	8 (7)

Table 3 indicates that only 4 MLC attendees (about 7%) did not complete the unit compared to 27 (about 23%) of non-MLC students (statistically significant: $\chi^2 = 6.21$, df=1, p=0.01). Moreover, about 80% (45) of the MLC attendees achieved a Pass grade or better, compared to approximately 51% (61) of the students who did not attend the MLC. This result is statistically significant ($\chi^2 = 13.89$ df=1, p<0.001).

One hundred and forty nine students either completed the unit of study with a grade or were classified as absent fail or discontinued, fail. There was evidence that the 52 MLC attendees achieved, on average, 5.8 marks more in their unit of study compared to the 97 students who did not attend the MLC (t = 2.17, df=145, p=0.03). Figure 1 shows the 95% confidence intervals for the mean marks of each group. Note that the width of each confidence interval depends on the number in each group and the variation within the group.

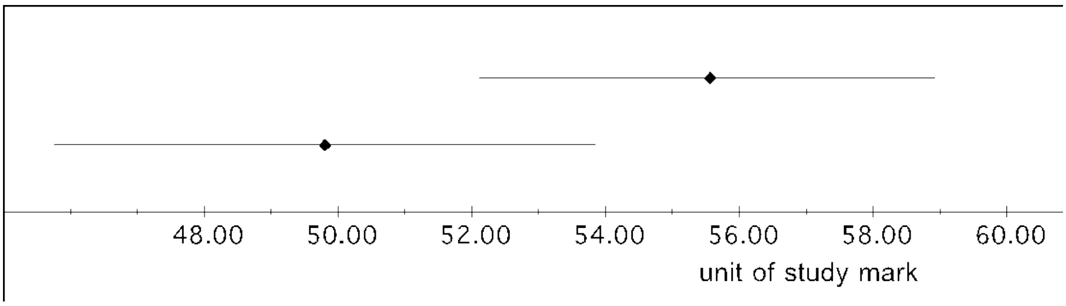

Figure 1: Confidence intervals for mean marks in the unit of study (upper interval: MLC attendees, lower interval: non-MLC attendees).

The fifty-two students who made up the MLC attendees were divided into two groups, depending on whether or not they attended for ten or more hours during semester. Students who attended MLC programs for ten or more hours are referred to as MLC frequent attendees. Table 4 breaks down the grades for these students according to the frequency of their attendance at the MLC.

There is strong evidence (from Table 4) that number of hours of MLC attendance was not independent of the grade achieved ($\chi^2_4 = 14.76$, p = 0.005). Further, about 92% of students who attended the MLC for 10 hours or more passed the unit of study compared to 82% of MLC attendees who did not attend as frequently and 63% of non-MLC students.

Table 4: Unit of study grade according to MLC attendance group

Unit of study grade	Number of hours (t) of attendance at the MLC			
	$t \leq 1$ hour	$1 < t < 10$	$t \geq 10$	Total (%)
Fail	36 (24)	5 (3)	2 (1)	43 (29)
Pass	37 (25)	19 (13)	17 (11)	73 (49)
Credit or higher	24 (16)	4 (3)	5 (3)	33 (22)
Total (%)	97 (65)	28 (19)	24 (16)	149 (100)

Interestingly, 25% of the non-MLC students achieved a grade of credit or better, compared to about 21% of MLC frequent attendees and 14% of MLC attendees who did not attend as frequently. This, together with data from Table 2, suggests that there is a small group of high achieving (distinction) students enrolled in this unit of study for whom MLC assistance may not be necessary to pass the unit but who used the resource to improve their mathematics skills.

Figure 2 shows the 95% confidence intervals for the mean marks of each group. Note that the width of each confidence interval depends on the number in each group and the variation within the group.

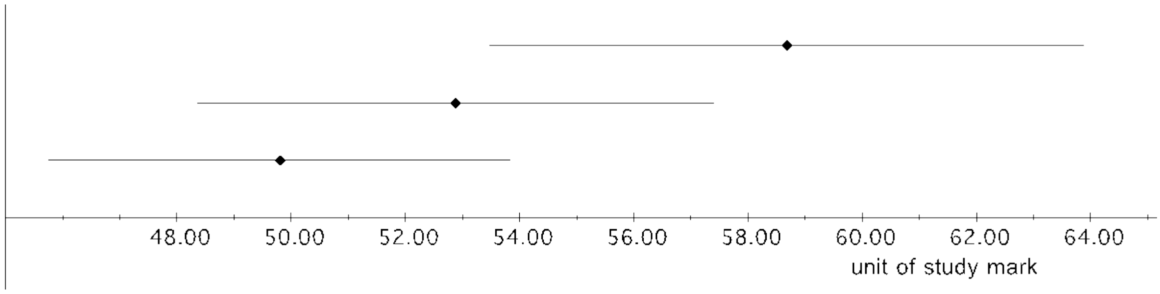

Figure 2: Confidence intervals for the mean marks: MLC frequent attendees (top), MLC less frequent attendees (middle) and non-MLC attendees (bottom)

Further, our analysis indicates a statistically significant linear relationship between total hours attended at MLC (if greater than 1 hour) and Unit of Study mark for the 52 students for whom these data were available ($t_{50} = 2.735$, $p = 0.009$). The equation suggests that about 13% of the variation in Unit of Study marks for MLC students is explained by the total hours students attended the Centre ($r = 0.36$). Hence the students who devoted more time to studying in the MLC benefitted from this accordingly.

DISCUSSION

The introductory calculus unit provided a useful context for evaluating the impact of mathematics support. The results suggest a relationship between students' usage of the MLC and their achievements in the introductory calculus unit. Further, higher hours of attendance at the Centre's programs are linked to better results. These findings indicate that a combination of student engagement with mathematics and appropriate support is favourable for success. There are also indications that retention is increased for mathematics bridging courses students; further research is needed to explore the impact of bridging courses and ongoing support on students' perseverance and retention in first level mathematics units.

One implication of our findings concerns the lack of participation by students who are 'at risk', yet fail to utilise the resources to help them, sometimes with unfortunate outcomes. In particular the disproportionally lower numbers of males attending the Centre's programs is a concern and requires further investigation.

Despite the challenges of evaluating mathematics support, the collection and analysis of a range of data – both soft and hard measures (Croft, 2008) – is important to mathematics support centres for a number of reasons. Firstly, for funding to such centres to continue, it is essential that evidence is presented on usage and other aspects (MacGillivray & Croft, 2011). Secondly, publications that disseminate the experiences and outcomes in one support centre can be useful to the many similar facilities in Australia and overseas. Our research and scholarship contributes to a community of practice in support centres.

CONCLUSION

As universities in Australia pursue policies of widening participation, the responsibility of providing effective support in mathematics is clearly part of an institutional ‘duty of care’ enabling students, whose previous opportunities to learn appropriate levels of mathematics were less than optimal, to succeed in their entry level degree units. The results presented here are encouraging and provide quantitative evidence of the value of mathematics support. Finally, as qualitative feedback reveals what is important to students participating in the support programs and why these aspects are important, we leave the last word with a student (in a written MLC survey):

It has increased my confidence in so many ways. Going over the fundamentals has filled so many huge gaps in my knowledge and allowed me to understand how things fit together in mathematics. I have always approached anything mathematical with fear and frustration and avoided these things wherever possible. … I now enjoy mathematics and the challenge of using the other side of my brain.

ACKNOWLEDGEMENTS

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LEARNING AND TEACHING ACADEMIC STANDARDS FOR SCIENCE: WHERE ARE WE NOW?

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KEYWORDS: academic standards, curriculum, learning outcomes, science discipline, TEQSA

ABSTRACT
One year on from the ALTC Learning and Teaching Academic Standards (LTAS) Project for Science, it is time to take stock of how the outcomes of that project are being implemented. In this paper, we shall discuss the current national regulatory environment, and what it might mean for us as practitioners in science education. We present examples of how the Science Threshold Learning Outcomes (TLOs) are being used in curriculum review and renewal and how they are being adapted to different disciplinary contexts.

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INTRODUCTION AND BACKGROUND
This paper reports and reflects on the Science Learning and Teaching Academic Standards (LTAS) Project that was funded by the Australian Learning and Teaching Council (ALTC). We discuss the tangible and non-tangible outcomes of the funded project, and report on how these are being implemented at the national level. We contend that the Science LTAS Project has catalysed the review, refinement and reinvigoration of science curricula at Australian universities, and is thus contributing to current debate on the challenges in adapting science education to meet the needs of society in the twenty-first century.

The LTAS Project was commissioned by the ALTC in response to the Australian Federal Government's announcement that it intended to establish the Tertiary Education Quality Standards Authority (TEQSA) that would audit Australian tertiary institutions against five sets of academic standards, including learning and teaching standards. As a proactive strategic initiative, the ALTC funded this major project to demonstrate that disciplinary communities could work together to develop learning and teaching standards (defined as learning outcomes) and achieve endorsement and commitment to integrate those standards into educational practice. The underlying assumption was that a discipline-led, collegial approach would more likely produce an outcome that would be acceptable and usable by educators and aligned to employer and student needs (Ewan 2010). For each participating discipline in the LTAS Project, threshold learning outcomes (TLOs) would be defined in terms of the discipline-specific knowledge, skills and professional capabilities to be achieved by pass-level graduates.

THE LTAS PROJECT FOR SCIENCE
PROCESS
A key driver for the Science LTAS Project was its championing by the Australian Council of Deans of Science (ACDS). Indeed, Science was not in the group of disciplines originally selected to take part in LTAS Project. However lobbying of the ALTC by the ACDS ensured that Science was included. We (Yates & Jones) were appointed as co-Discipline Scholars for Science, and Jo-Anne Kelder was selected as the Project Officer. Our project was funded for one year, from July 1st 2010 to June 30th 2011. Our inaugural workshop was presented by the LTAS Project Director Prof. Christine Ewan and the Discipline Scholars at the ACDS Teaching and Learning Forum (Sydney, July 15th, 2010). The audience for this initial presentation was the Associate Deans (Teaching and Learning) for Science, which ensured that this important group of 'gatekeepers' (Holmes & Freeman, 2012) were engaged and involved right from the start of the project. At the conclusion of that workshop, the overall approach for the Project was articulated and endorsed by the Executive of the ACDS.

The core project aim was to define Threshold Learning Outcomes (TLOs) for Australian graduates of bachelor level degrees in science (not necessarily a Bachelor of Science): that is, a set of TLOs that are applicable to all sub-disciplines encompassed within the Science cluster. Additionally, *Chemistry* and *Mathematics* were selected as appropriate groups to test the adaptability and applicability of the Science TLOs to their particular sub-disciplinary context. Chemistry and Mathematics represent, respectively, an experimental and a non-experimental discipline. In addition, there is substantial international documentation on standards (i.e. learning outcomes) for Chemistry and Mathematics graduates in, for example, the Tuning Europe Project (http://www.unideusto.org/tuningeu/) and the UK Quality Assurance Agency (QAA) (http://www.qaa.ac.uk/Pages/default.aspx).

The project was designed around three cycles of engagement focused on developing the discipline-specific content of the *Science Standards Statement*, in particular, the threshold learning outcomes (TLOs). We employed three mechanisms for inviting stakeholder commentary: consultation workshops, an online survey and written submissions. This approach ensured that a broad range of peer review and commentary was gathered. In addition, five formal groups were established very early to directly support the work of the Discipline Scholars.

1. The *Science Discipline Reference Group* (RG) was established vey early in the project. Its role was to support the Discipline Scholars in the development of TLOs for Science graduates at Bachelor degree level. Membership of the RG was carefully designed to be broadly representative of the Science sub-disciplines and include representatives from professional bodies and representatives of other stakeholders including employers of Science graduates and students. The terms of reference included the provision of advice to the Discipline Scholars on the direction and implementation of the Science LTAS project. They were also required to approve the Science TLOs prior to their dissemination to the broader discipline communities, and to facilitate such dissemination through their professional networks.

2. A *Science Discipline Advisory Group* (AG) was a small group of expert colleagues recruited to act as a high level working party of 'critical friends'. Their responsibilities were to provide the Discipline Scholars with timely, high level feedback on drafts of TLOs and associated documents, and to provide expert advice throughout the project. In particular, the AG worked with the Discipline Scholars to develop a draft set of TLOs for Honours degrees in Science that are included as an Appendix to the *Science Standards Statement*.

3. The *Local Reference Group*, consisting of representatives of the science-based disciplines in the University of Tasmania's Faculty of Science, Engineering and Technology were recruited to act as a readily available sounding board of peers. As well as commenting on drafts of the *Science Standards Statement*, members were pilot participants for the consultation workshops and the online survey, providing feedback that informed revision of the final designs.

4 & 5. Selected disciplinary experts with educational expertise were invited to form the *Chemistry and Mathematics Working Parties* associated with the Science LTAS Project. They were commissioned to adapt the (then draft) Science TLOs to develop parallel TLO statements for their own disciplines and to report and reflect on any difficulties or challenges with that task. They served as models for other disciplinary groups that might take on such a task.

Engaging stakeholders in consultation
The communication and consultation strategy included several strands of activities designed to: 1) identify relevant individuals and organisations (particularly 'gate keepers' who could connect us to wider groups); 2) design and implement communication mechanisms to contact stakeholders (contributing to the national project newsletter and website, writing our own newsletters, conference presentations and workshops); 3) consultation workshops offered to every Australian university delivering a science degree program; 4) survey to elicit anonymous and detailed commentary on the draft *Science Standards Statement* (SSS); 5) growing a database of contacts to disseminate information about the project to those interested, especially how to engage.

In all, the project team arranged over fifty meetings with groups of stakeholders (Table 1). In particular, eighteen meetings were held with the Reference Group or Advisory Group to develop the draft *SSS.* Once the draft *SSS* was formally endorsed by the Reference Group, the project moved into actively soliciting feedback and commentary from the wider Science Discipline community. The draft

SSS was published on the ALTC's website for the LTAS project with the invitation to engage in its development via formal email submissions, the survey and consultation workshops.

Table 1: Consultation activities undertaken during the Science Learning and Teaching Academic Standards (LTAS) project (July 2010 – June 2011) (adapted from Jones, Yates, & Kelder, 2011).

Consultation activities	Number	Explanatory comments
Total number of meetings held:	50 meetings	18 meetings to develop draft TLOs; 32 consultation workshops
Total number of attendees at meetings (estimate):	750	350 to develop draft TLOs; 400 consultation workshops
Number of visits (consultation workshops) to each state/territory:	NSW: 7 QLD: 3 SA: 2 WA: 4 TAS: 1 VIC: 8 ACT: 2 NT: 1	All but two of the Australian Universities delivering a science program hosted or co-hosted a workshop, or their staff attended workshop at other institutions. We also had separate meetings with Science students at Charles Darwin University, La Trobe University, University of Sydney and University of New England.
Number of persons on the project's email contact list:	412	39 on email database; additional 373 via consultation workshop attendance.
Survey participants:	122	Online survey on the draft TLOs
Written Submissions:	6 formal responses 3 informal email comments	• Association of Mining and Exploration Companies • Australian Institute of Geoscientists • Geological Society of Australia • Chemskill • Peter Meier; UTS response • Peter Adams, Chair Mathematics Working Party

OUTCOMES

The tangible product of the Science LTAS Project was the *Science Standards Statement* (Jones, Yates, & Kelder, 2011), which is now available as a downloadable pdf booklet from http://disciplinestandards.pbworks.com/w/page/52767997/Science, as well as from the Australian Government's Office for Learning and Teaching (OLT) website (Resources section). The core of the booklet contains the statement on the Nature of Science, the Science Threshold Learning Outcomes (p.23) and explanatory notes upon them. The contents of the booklet represent the consensus views of the Science discipline community. The *Science Standards Statement* is endorsed by the ACDS as "a generic high-level statement of Bachelor of Science threshold learning outcomes", and the ACDS also commended the consultative process and its outcomes.

The less tangible outcomes of the project include an enhanced focus on learning outcomes as a major tool for curriculum review and design across the national disciplinary sector, and the establishment of sub-disciplinary groups (i.e. representing disciplines under the Science umbrella) whose aims include the adaptation of the Science TLOS to achieve TLOs specific to their discipline.

During the life of the Science LTAS Project, it became clear that the Science TLOS could form an effective framework for curriculum review or revision. Indeed, the use of learning outcomes emphasises that curriculum planning should begin with the student, and what is learned, rather than with what is taught (Allan, 2006). For example, we (Jones & Yates, as Discipline Scholars for Science) were invited to contribute as external experts to formal curriculum planning workshops at the University of Western Sydney and at La Trobe University, and we currently lead a project at our own University that is mapping the current BSc curriculum against the Science TLOs as a prelude to a major curriculum review.

ADAPTING THE SCIENCE TLOS FOR SPECIFIC DISCIPLINES
The Chemistry Standards Statement included as an appendix to the *Science Standards Statement* (Jones et al., 2011) was an overt demonstration that the Science TLOs can be adapted to a specific disciplinary context. This process was led by the Chemistry Working Party, with considerable input from the relevant peak professional bodies. The Chemistry TLOS overtly reference the Science TLOS but also reflect the 'nature of Chemistry' and the 'ways of working' in that discipline.

The challenge of defining TLOS for particular disciplines has, to date, been taken up by a range of disciplines, including, for example, Biology, Physics, Mathematics and Agricultural Science. These groups either represent ALTC/OLT-funded Discipline networks (VIBE.net for Biology; Mathematics), or networks supported by deans' councils, professional societies, or, in the case of Agricultural Science for example, an initiative by one School at one institution (University of Tasmania). For example, VIBE.net recently held a national workshop at which draft Biology TLOs were peer-reviewed, while Chemistry is contemplating how the Chemistry TLOs will articulate with accreditation requirements.

The next step is development of exemplars of learning activities that will support students to achieve these TLOS, and assessment tasks that will allow educators to demonstrate that their students have met the TLOS. Such work should draw from the work of previous ALTC-funded projects, for example: *Enhancing the assessment of learning in Australian Higher Education: Biological Sciences; Forging new directions in physics education in Australian Universities; Tertiary science education in the 21st century;* or *Advancing science by enhancing learning in the laboratory (ASELL)(*details of these and other relevant projects are available on the OLT website: http://www.olt.gov.au/resources?page=1&text=science

FUTURE STEPS

There is a great deal of creative work to be done if the impetus of the Science LTAS project is to continue, and if this work is to realize its potential for improving tertiary science education in Australia. To this end, we (Yates & Jones) were successful in gaining ALTC funding for one year to continue our own leadership and advocacy through an Implementation project. The specific aims of that project were:

- To continue to act as advocates and role models for an approach to curriculum design that is firmly focused on student learning outcomes;
- To personally lead two core implementation projects;
- To champion and advise on a range of implementation projects by other colleagues.

We are currently engaged in two specific implementation projects:

1. Develop examples of teaching activities and assessment that demonstrate student achievement of Science TLO 1.1.
The need for exemplars of teaching and assessment strategies that are clearly linked to specific Science TLOs has been frequently raised as a key issue in discussions of how we, as a community of science educators, may be able to overtly demonstrate that our students do meet the Science TLOs.

In particular, colleagues frequently commented that, while we as a community strongly agree that we want our science graduates to understand and appreciate the methods and philosophy of science (expressed as TLO 1.1: Understanding Science: see Jones et al., 2011, p.23), this is usually not taught explicitly, and is rarely assessed. Indeed, many science academics we talked to during the LTAS project for Science admitted that they expect their students to absorb such ideas "by osmosis". Some courses do include a capstone research unit and/or a first year level unit on science as a broad discipline, but there appear to be few examples of a structured scaffolded approach to developing students' appreciation of science across the degree programme. There is therefore a clear need for a project that will identify and critique learning activities that specifically address Science TLO 1.1, as a basis for developing a teaching resource for other academics. Following the example of Sally Kift (Discipline Scholar for Law), we have therefore embarked on the production of a series of Good Practice Guides (Kift, 2012). In the first instance, we have commissioned Robyn Yucel (La Trobe University) to produce a Good Practice Guide for TLO 1.1.

In addition, we convened a workshop for Associate Deans (Teaching and Learning) for Science in February 2012 at which we considered strategies for implementing TLO 3: Inquiry and problem –

solving. This workshop drew on the expertise of Les Kirkup (ALTC National Teaching Fellow), whose Fellowship topic is *Inquiry-Orientated Learning in Science*. The outcomes of this workshop are available at: http://www.iolinscience.com.au/2012/03/science-tlos/. The production of a full set of Good Practice Guides addressing each Science TLO is a priority for the next implementation phase.

2. Production of a "student friendly" version of the Science Standards Statement.
Essentially the Science TLOS describe a graduate of an Australian science degree, and therefore should form good grounds for discussing with students the benefits of a science degree – which may not necessarily lead to working as a professional scientist. The recent Report from the Office of the Chief Scientist (2012: p.10) commented that: "Science-related study prepares a student for a lifetime of critical thinking and promotes a drive to find evidence and develop an understanding of how our society fits into the broader picture of the world." However, talking with students during our project, it was clear that they do not and will not relate to the formal expression of the Science TLOs as expressed in the Science Standards Statement. A simplified version, in the form of a coloured brochure, will provide useful, succinct and accessible information for both potential and current students, their parents or employers, school teachers and career advisors. Such a publication is under development with the input and feedback of potential and current undergraduate students of science.

In conclusion, the Science LTAs project has laid the groundwork for educational change by catalyzing a national discussion of learning outcomes for Australian science graduates. What are needed now are practical examples of the way the TLOs can be used by Associate Deans and degree coordinators to facilitate curriculum renewal in their degree programs and across Faculties, practical exemplars for lecturers and teaching staff of the way the TLOs can be addressed through teaching activities and assessment tasks, and practical examples of student work that can help Deans of Science develop an understanding of the learning and teaching academic standards that are expected if a student is to meet these TLOs. Much activity in each of these areas is currently occurring in science faculties across the country, and we will continue to provide examples to help stimulate the discussion of ideas with other teaching and learning champions. This collective and work will position the sector to meet the new quality agenda represented by TEQSA's Teaching and Learning Standards Framework. However for many academics the primary driver will be the motivation to enhance their teaching programs and their students' learning outcomes.

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USING VERY SHORT WRITING TASKS TO PROMOTE UNDERSTANDING IN CHEMISTRY

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KEYWORDS: active learning, writing across the curriculum, POGIL, writing

ABSTRACT
Writing promotes deeper learning and critical thinking and can assist in knowledge retention, yet students write very little in lectures and tutorials. Very short and informal writing tasks requiring students to explain, describe and summarise their understanding in 1 or 2 sentences have been introduced into chemistry lectures and tutorials as part of our active learning activity toolkit. Development of writing skills is the responsibility of each discipline and every level of a degree and these tasks are used regularly throughout the semester to encourage students to use writing as a way of clarifying ideas and learning new concepts.

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INTRODUCTION
Writing assignments can help students improve their conceptual understanding, clarify their ideas and develop their critical thinking skills. Regular writing tasks promote deep learning and active engagement in their studies. They also provide students with the opportunity to build their own arguments in their own words and to learn from their peers. Science has its own language and reading and presenting are not enough for students to develop fluency in its use.

The ability to write well is, of course, an extremely important graduate attribute. The graduate attributes at most universities refer to communication skills. Graduates of The University of Sydney, for example, “value communication as a tool for negotiating and creating new understanding, interacting with others, and furthering their own learning” (The University of Sydney, 2004). The Faculty of Science graduate attributes specifically mention writing skills: its graduates “write and speak effectively in a range of contexts and for a variety of different audiences and purposes” (The University of Sydney, 2004). As probably *all* graduates will need to write in their working lives, it is imperative that students practice and improve their writing continually during their undergraduate studies.

Despite the recognised importance of writing, many students do no or very little writing at all during a semester. It is not uncommon for students in our classes to take no notes at all during lectures. Indeed, some students do not come equipped with a pen or an electronic device capable of recording their own notes. Although some lecturers lament this change, some lecturing styles promote it. In many classes, the lecture centres around the pre-written words and images projected onto the screen, either live or as a recording.

Before the widespread incorporation of electronic presentations, lecturers would cover blackboards with notes that students would dutifully copy. Although this physical act of copying might promote a somewhat more active engagement than watching a screen, it still relies on the passive transmission of knowledge rather than construction of understanding. As a half way house, some lecturers deliberately leave gaps in their handouts for students to complete during class. Indeed, this tactic is often recommended in teaching seminars as an easy way of promoting attendance and engaging students in class. The gaps sometimes cover a key definition, a derivation or a model answer to a problem. These gaps, however, are almost always filled in by students copying what the lecturer presents. It is, perhaps, not surprising that the use of gaps is commonly seen as a purely artificial device by students, particularly by those who are not confident or quick enough to copy the words and symbols on the screen.

In many large first year subjects, examinations are dominated by or completely constructed from multiple choice questions. Where some short answer questions are included, these are often problem-based requiring equations and numerical responses. As assessment drives learning for many students, this may further convey the message that writing is not valued or valuable. Thus, some students may completely avoid serious writing for the whole semester.

In many science and in most chemistry courses, writing assignments are reserved for laboratory reports. Much effort is used to develop students' ability to write in the formal style expected in the discipline and to convey results and conclusions in a scientific way (see, for example, Drury and Jones, 2007). Writing laboratory reports are important as a stepping stone to writing academic papers and for formally reporting scientific results according to the rules of science and of the discipline. They are designed to communicate results and conclusions to a specific audience. They can also be used to develop skills in scientific inquiry through an understanding of the scientific method and the need to form arguments around evidence (Keys, Hand, Prain, & Collins, 1999; Burke, Greenbowe, & Hand, 2006). Whilst the laboratory report may shift to an online or collaborative task (Taylor, 2006), it should continue to have a central role in our courses. Unfortunately, time and financial pressures often mean that the number of reports that many students complete may be lower than is optimal, particularly in first year courses.

'Writing Across the Curriculum' (WAC) programs were developed in North America during the 1980s as a response to the perception that students were not regularly writing and that the writing ability of graduates was deteriorating. The central philosophy of these programs is that "writing is the responsibility of the entire academic community" and that "writing must be integrated across department boundaries" (The WAC Clearinghouse). Courses that integrate WAC seek to use formal and informal writing tasks continually, at all stages of a degree. By doing this, students become used to writing as a integral part of their studies and use it to learn material, improve critical thinking and understanding and to develop as independent learners (Anson, 2002). In the WAC system, writing laboratory reports is an example of a 'Writing in the Disciplines' (WID) task, as it involves the development of discipline specific conventions, whereas short and informal writing activities designed to promote thinking are termed 'Writing to Learn' (WTL) tasks.

Over recent years, chemistry educators in Australia have been involved through the 'Active Learning in University Science' (ALIUS) group in a sustained effort to establish a new direction in learning and teaching (Bedgood, Yates, Buntine, Pyke, Lim, Mocerino, 2008; Bedgood, Yates, Buntine, Pyke, Lim, Mocerino, Zadnik, Southam, Bridgeman, Gardiner, & Morris, 2010a, 2010b; Bedgood, Mocerino, Buntine, Southam, Zadnik, Pyke, Lim, Morris, Yates, Gardiner, & Bridgeman, 2010). As part of this, active learning techniques for large classes have now become fully integrated into lectures and tutorials in first and some second year chemistry at the University of Sydney. In particular, we have adapted the 'Process Orientated Guided Inquiry Learning' (POGIL) approach widely used in North America (Moog & Spencer, 2008) to our context. Our version of this approach involves the use of worksheets that seek to guide students towards building their own understanding of concepts and ideas.

In place of our traditional didactic lectures, these are now broken up into parts. These typically include an instructor led review of the previous class with some review questions for students followed by interspersing of segments involving 10-12 minute mini-lectures, chemical demonstrations and 4-5 minute worksheet-based group tasks and feedback. Such variation and pacing seems to be optimal for keeping students engaged in class (Bunce, Flens, & Neiles, 2010). In place of tutor-led problem solving, tutorials now are completely student-centred with all of the time given over to POGIL-style worksheets that are completed and reported in groups.

Our implementation of a POGIL-like approach has also been strongly influenced by a realisation of the responsibility of all first year units in developing academic skills (Arndell, Bridgeman, Goldsworthy, Taylor, Tzioumis, 2012; Kift, Nelson, & Clark, 2010) and the WAC philosophy discussed above. It has also been informed through our engagement with an expert in language learning and teaching (Zhang, Lidbury, Richardson, Yates, Gardiner, Bridgeman, Schulte, Rodger, & Mate, 2012). The latter work identified the significant role that difficulties with scientific language, nomenclature and symbolism play in preventing success across both home and international students. This paper discusses the use of 'Writing To Learn' activities as part of POGIL style classes in first and second year chemistry which seek to embed regular, informal writing tasks throughout the semester as a normal part of the students' learning.

Around 2000 students in semester 1 and around 1800 students in semester 2 take first year Chemistry units at The University of Sydney. These students come from every faculty in the university and a large number of degree programs. A significant number of these are international students or have English as their second language.

VERY SHORT WRITING TASKS IN THE LECTURE

In a chemistry lecture, there is often very little time for writing more than 2 – 3 sentences. In large classes, this may be exasperated by the need to keep the class on task and the very wide range of times it may take different students to write anything substantial. Many students have a tendency to use inflated or over-complicated language, perhaps in an attempt to write academically, whereas scientists usually value simple explanations and summaries.

Forcing students to commit their ideas to paper and to condense their thoughts in just 1 – 2 sentences can be hugely beneficial. Indeed, in some activities, students are limited to 140 characters (the limit commonly used by microblogging sites, such as Twitter). As described below, short writing tasks can be incorporated as stand-alone activities, as part of POGIL-style worksheets or included as part of the lecture notes. However implemented, they can be a valuable tool for engaging students, for helping them learn subject material and concepts, and for developing the habit and the skill of note taking.

(i) Writing to learn using worksheets in lectures

The worksheets used in the author's lectures are provided in hard copy to each student who attends. Based on the POGIL model (Moog et al., 2008), they follow a learning cycle (Abraham, 2005) to guide students through:

- an exploration phase in which students are given information or data and develop a hypothesis
- a concept invention phase in which new concepts are introduced based on this understanding, and
- an application phase in which these concepts are applied to new situations.

The students work on these tasks in groups. In our implementation, the exploration phase is often developed in a mini-lecture and in the lecture notes, to save time and to reduce photocopying costs. Both the concept invention and application phases may suit short writing tasks.

Each worksheet contains at least one very short writing task. Students are given a minute or so to write 1 or 2 sentences. These tasks are not assessed and are not marked by the instructor. As the motivation of the intervention is to improve students ability and willingness to use writing as a way of clarifying their own understand, peer and class sharing and feedback are used to keep students on task. After trials in individual lectures, in-class writing assignments have been used in each lecture for 3 years in a second semester, first year general chemistry unit aimed at students without high-school chemistry and for 2 years in a first semester, second year quantum chemistry and spectroscopy unit. In each case, some students are initially reluctant to engage with writing but participation grows steadily when the tasks are used regularly.

Such very short writing tasks can be used for situations where a short description or explanation in words would clarify or simplify the concept or would assist in knowledge retention. Examples include writing short summaries of concepts, descriptions of mathematical or graphical relationships, development of analogies from every-day life and prediction of behaviour. A few examples are briefly outlined below.

In a class on the concept of conjugate acids and bases, the mini-lecture segment consists of the standard Brønsted-Lowry definitions of an acid and base. On the worksheet, the students are given a couple of acid-base equilibria, such as those below, and are asked in their groups to identify the acid and base for the forward and reverse reactions.

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$
$$HCN(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CN^-(aq)$$

Having done this, the students are asked to spot and discuss the relationship between the role of a species in the forward and the backward reaction: they discover the concept of conjugate acid-base pairs. To embed this newly invented concept, the students are asked to describe the general relationship they have deduced to each other. When they agree, each member of the group writes down the relationship in words – without chemical symbols or equations – in 1 or 2 sentences. A couple of these are then chosen randomly and shared and reviewed by the whole class.

This activity typically takes 4 – 5 minutes and involves argumentation verbal articulation and use of writing to force students to organise and express their understanding. Although less precise and technical than those in the lecture notes or in the textbook, the words used by students often contain contemporary jargon that may help other students understand. Definitions in lecture notes tend to invite being memorised rather than understood. Of course, the review session may also reveal misconceptions, which can then be tackled straight away.

Having discovered that water can act as both an acid and a base, the students are then asked on the worksheet to consider and predict what happens in a glass of water and a glass of ammonia. Alongside writing the relevant chemical equations, they are again set a short writing task of describing the chemical nature of water and ammonia.

The following classes build on these conceptual ideas using a more quantitative approach. Students calculated the pH of strong and weak acids with the aim of developing an understanding of the relationship between pH and the concentration and strength of the acid. There a number of language issues associated with this topic that lead to misconceptions: 'strong' and 'weak' are used to describe the extent of dissociation of the acid in solution and 'concentrated' and 'dilute' are used to describe how much acid is present. Thus, a beaker might contain a concentrated solution of a strong acid, a concentrated solution of a weak acid, a dilute solution of a strong acid or a dilute solution of a weak acid. The precise, technical definition of strong vs concentrated and weak vs dilute are clear to the expert but can be difficult to explain. At the end of the section, the students are thus asked to describe in one sentence what is present in each of these 4 solutions.

Perhaps surprisingly, writing tasks seem ideally suited to helping students develop their understanding and appreciation of quantum chemistry. Before their introduction, most lectures were very mathematical and abstract. In a couple of worksheets, students work out the energy levels of a particle in a box and on a ring. They are then asked to predict and then describe in words what happens to properties such as energy and position probability when the mass is large. In a following class, the students are asked to apply the particle in a box model to themselves trapped in the lecture theatre, and then commit to paper a couple of sentences describing their behaviour.

In a subsequent lecture on electronic spectroscopy, students are presented with the different ways in which energy can be lost from an electronically excited molecule. After labelling the different routes (such as fluorescence, phosphorescence and non-radiative decay) on a diagram, each group is asked to describe these in words. In small groups, they then produce a mini-story detailing the sequence and nature of the events.

(ii) Writing to learn by summarising topics

At the end of each section of a lecture or at the end, students are requested to briefly discuss the topics covered with their neighbours and to write a very brief summary of the general principals covered. In first year classes, students are asked to answer the question:

- What were the most important points made in today's class?
- Such 'one minute papers' have been shown to enhance students' marks and recall of material (Davis & Hult, 1997). Again, the activity is entirely informal and is not marked. Student participation is often enhanced, however, by asking a random group to report their response to the class. Every fortnight, or at the end of a part of the course, students are asked to agree an answer to a second question:
- What idea in this part of the course are you still unclear on?
- Responses to this question provide material on which to base revision or remedial material in future classes. A refinement of this activity is to ask students to write their own learning outcomes and then compare them to the 'official' one. This activity can encourage greater engagement with learning outcomes and help students organise their notes and revision.

(iii) Writing to learn using gapped lecture notes

Many of the activities discussed above are firmly embedded in the author's own lectures and are beginning to be adopted by others in the School. However, in attempting to promote change, a more gentle break from fully teacher-centred lecturing is sometimes more effective. As noted in the Introduction, many lecturers use the tactic of leaving gaps in their handouts in an attempt to promote note taking and engagement. These gaps are often filled by the class copying from the lecturer's presentation with subsequent requests by students for the "full notes" to be posted online. Instead of simply providing the missing text for the class to copy, students can be asked to fill the gap in their *own* words by asking for a summary, a description of a mathematical relationship or their own example. Responsibility for provision of the "full notes" is passed to the students, whether they are present in the class or are studying at home.

VERY SHORT WRITING TASKS IN TUTORIALS

All tutorials in first year chemistry now use POGIL-style worksheets. The tutors, who consist of the relevant lecturers as well as postgraduate teaching fellows, act as facilitators and the vast majority of each tutorial class is given over to group work. Although writing assignments are not suited to every topic, the majority of the worksheets do include at least one very short writing task. Every first year chemistry student is thus writing regularly throughout each semester.

An early topic in most of our first semester units is the quantum mechanical description of the atom. Many students find this topic extremely abstract and unconvincing, when compared to the Bohr model of the atom they met at high school. The first task on the first worksheet of the semester therefore is for students to write down a summary of their understanding of this model. The worksheet then guides them through the structure of the Periodic Table, some of which match the Bohr model and some of which do not. Finally, the students are asked to discuss these features and to write down a critique of the evidence for the Bohr model being right or wrong according to the evidence in the Periodic Table. This worksheet is included as Appendix 1 to this paper.

Organic chemistry is highly symbolic, with the course of reactions shown using curly arrows to represent the flow of electrons. This device is extremely powerful in the hands of an expert, allowing for the prediction of reactions and the design of synthetic routes. Students introduced to curly arrows, however, often find it extremely difficult. In a couple of worksheets, the desired learning outcome is for students to be able to reproduce and understand the mechanism of the reaction of interest. In the first of these, students are now presented with the mechanism for nucleophilic substitution and are asked to describe the sequence of events implicit in this representation in 2 sentences. In the next tutorial, they first describe the reaction events in words and then transfer this to the curly arrow representation.

A couple of short writing tasks for lectures on acid-base chemistry were described above. These are built on in the tutorials through a more detailed set of guided calculations. These include students working through the calculation of the extent of dissociation of weak acids as a function of concentration. The groups then share their results to draw a graph showing the relationship that the calculations reveal. After having done this, the students discuss the relationship and describe it in 1 sentence. This part of the writing task thus requires them to be able to describe a mathematical relationship in words – something which many students are very poor at doing. These descriptions are shared and reviewed by the class.

The second and final part of the writing task asks them to describe in 1 sentence what happens to the *number* of ions that are present during the dilution. This is actually quite tricky, as students need to join together all of the information present: although the extent of dissociation increases, the dilution reduces the overall number of ions present. Having to write a description using words and no mathematical symbols forces the students to process the information at a much deeper level.

Getting students to commit their ideas through writing is a good way to identify and address misconceptions. One misconception that is particularly hard to shift is the relative strength of intermolecular forces. Many students arrive at university with a set idea that dispersion forces are very weak. In a worksheet devoted to developing understanding of the importance of hydrogen bonding, dipole-dipole and dispersion forces in the main group hydrides, students are given a number of pieces of evidence through graphs showing the variation in melting and boiling points down groups and across periods. For each piece of evidence, they are asked to interpret the data in terms of these forces and to write down their conclusions. Finally, they are asked to summarise the arguments and then argue which force is the strongest.

Valuing Writing

As noted several times above, expecting students to write regularly is key. It is vital to explain to students in the first few classes why writing tasks are being given and that writing clearly and concisely is a valuable generic attribute. As the types of assessments we use undoubtedly signal our values to students, it is important to include examination questions that draw on the writing tasks from classes. Thus, alongside conceptual multiple choice questions and problems to solve, our examinations include questions which require short written descriptions of concepts and explanations of phenomena.

CONCLUSIONS

Writing tasks are a valuable tool for active learning in lectures and tutorials. Writing promotes deeper learning and can develop critical thinking. Writing tasks help support the development of desirable graduate attributes, especially communication skills. Such development is the responsibility of each discipline and every level of a degree. Informal, very short writing tasks when integrated and given regularly promote engagement and understanding.

Some students are reluctant to write and it is important to incorporate such tasks consistently and in places where they genuinely assist learning. In unit of study surveys, students commented very favourably on the use and design of worksheets incorporating writing tasks. Examples of open response comments include:

- "The worksheets are a good approach to learning in lectures. Writing down my ideas really helped when I came to revise."
- "We were encouraged to work together in each lecture with the worksheets. It is actually helpful to discuss and then write things down."
- "Writing really helped cement ideas."

The introduction of writing tasks in tutorials across all units has been accompanied by an increase in the student evaluation of graduate attribute development, from an average of 3.2 / 5 to an average of 3.6 / 5 across all units. However, other interventions have undoubtedly influenced this more, especially as the writing intervention has been deliberately presented to students as a device to improve learning rather than preparation for the workplace.

The underlying idea behind the use of writing is the belief that students learn chemical concepts most effectively when they are actively engaged in doing and communicating about them rather than passively rote-learning, listening and watching. Very short writing tasks are scalable to large and small classes, and are fully adaptable to other topics beyond introductory chemistry. They connect with a desire amongst students to be social and to learn from peers and help to ensure that classes are vibrant and engaging.

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APPENDIX 1

CHEM1405 Worksheet 1: Does Bohr's Model Explain the Periodic Table?

Model 1: Bohr's Atomic Model

Bohr's model is sometimes called a "planetary" model; protons and neutrons are found in a central nucleus and electrons are placed in orbits that circle around the nucleus at a specific distance.

Critical thinking questions

1. Discuss your understanding of Bohr's atomic model within your group. Summarise your discussion below in 2-3 grammatically correct sentences. (*Hint*: what are shells and how many electrons are allowed in each shell?)

2. Draw a diagram showing Bohr's model of the atoms below, showing as many relevant features as you can think of.

   (a) He (b) Li (c) Ne

   (d) *Ask your tutor for another example for you to work on and share with the class.*

3. What is the relationship between the number of electrons in a shell and the number of the shell? Write down this relationship in 1 sentence and read it out to your neighbour.

4. Share your ideas of Bohr's atomic model with the whole class.

Model 2: The Periodic Table

The figure below shows part of the Periodic Table in which the elements are placed together in *groups* (the columns) and *periods* (the rows).

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe

Critical thinking questions

1. Discuss any features and patterns you can see in the Periodic Table within your group. Summarise your discussion below in 2-3 grammatically correct sentences. (*Hint*: look for blocks of elements in each row).

2. What filling patterns can you identify in the Periodic Table? (Your tutor will have a copy of the whole Table if you want to extend your work.).

3. Can you relate these features and patterns to Bohr's atomic model? Summarise your discussion below in 2-3 grammatically correct sentences.

4. Are there any discrepancies between Bohr's model and the Periodic Table? Summarise your discussion below in 2-3 grammatically correct sentences. Read your sentence out to the rest of your table and ask them to comment on your arguments.