# A cross-disciplinary approach to language support for first year students in the science disciplines

## Final Report 2011


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The University of Canberra (lead institution)
The University of Sydney
The University of Technology Sydney
The University of Tasmania
The University of Newcastle

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Resources produced by the project are in the Resources book, available from www.olt.gov.au

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# List of abbreviations and acronyms

| | |
|---|---|
| ALTC | Australian Learning and Teaching Council |
| BCI | Biology concept inventory |
| BEMA | Brief electricity magnetism assessment |
| CCI | Chemistry concept inventory |
| CSEM | Conceptual survey of electricity and magnetism |
| FCI | Force concept inventory |
| GCI | Genetics concept inventory |
| GPA | Grade point average |
| HSC | High School Certificate |
| IE | Interactive engagement |
| LMS | Learning management system |
| MCQ | Multiple-choice questions |
| PI | Peer instruction |
| RACI | Royal Australian Chemical Institute |
| SERG | Science Education Research Group |
| SETL | Student evaluation of teaching and learning |
| SFR | Student feedback results |
| USE | Unit of study evaluation |
| USS | Unit satisfaction scale |

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# Executive summary

The project, ‘A cross-disciplinary approach to language support for first year students in the physical sciences’, commenced in October 2007. It was funded by the Australian Learning and Teaching Council to address the language needs of a diverse student body by investigating and testing strategic approaches to learning and teaching in First Year sciences. This project was concerned with the acquisition of language specific to science in addition to the implicit teaching of meta-cognitive skills required in doing science. The disciplines covered by the project were biology, chemistry and physics. Around 3400 students were involved in the project from the University of Canberra, the University of Technology, Sydney, The University of Sydney, the University of Tasmania and The University of Newcastle.

One of the key achievements of this project is that it succeeded in changing the teaching practices of science lecturers, not by imposing a set of ‘best practices’ onto them, but by directly involving them in designing, testing and implementing practices that they would use in their own teaching. With the idea of disseminating sustainable strategies in mind, the guiding principle of selecting suitable strategies is that the strategy must be easy to use and flexible enough to be modified to suit different institutional contexts. As a result of the cross-disciplinary collaboration between the science lecturers and the educationalist (the project leader), some twenty five hot potato exercises, over forty critical thinking activities, and over forty five multiple choice questions and a large number of Votapedia questions in the disciplines of Chemistry, Biology and Physics have been created. These teaching materials can be used either online or in face-to-face contexts, in lectures or tutorials and are not constrained by institutional computer infrastructure such as the Learning Management System (LMS). These materials have been made accessible on OLT website www.olt.gov.au to the general public who might be interested in science education.

Documented evidence in this report also attests to the effectiveness of the strategies developed in this project. The ease of implementation of the strategies developed in the project has resulted in the adoption of the learning strategies into entire first year program within some institutions and a wider uptake of project strategies to subjects not involved in the project. The project provides a sustainable model for professional development for academic staff.

In conclusion, a number of positive outcomes were obtained; these are:

- Students demonstrated better achievement scores at every university and in almost all disciplines;
- The failure rates for almost all subjects in the disciplines decreased;
- Passing, credit, distinction and high distinction rates in each discipline increased dramatically;
- Students’ perceptions of lecturers’ abilities to teach were dramatically improved;
- student awareness of the characteristic language used in each discipline was enhanced;
- staff competencies, knowledge and skills were enhanced in the development of language oriented activities for online learning and face to face lecturing environments using tools such as audience response devices to promote student engagement;
- staff competencies in evaluation practices with a language focus were also developed.

# 1 Overview of the project

## 1.1 Background

Student retention and progression rates are a matter of concern for most institutions in the higher education sector (Burton & Dowling, 2005; Simpson, 2006; Tinto & Pusser, 2006) There is also substantial literature concentrating on the first year experience at university (Krause, Hartley, James, McInnis, & Centre for the Study of Higher Education. University of Melbourne, 2005).

Currently, there are two broad approaches to providing extra academic (rather than language) support to help students succeed during their first semester at university: targeting all students who wish to participate in extra learning opportunities; or targeting only those students deemed to be at risk.

For example, the peer assisted study support schemes at the University of Wollongong, University of Queensland (Miller, Gregg, & Kelly, 2000) and now at the University of Technology, Sydney and a number of other universities, offered academic support to all interested students. Students usually self-select to participate in these schemes. While there are considerable resource implications associated with such broad-based schemes, they are widely reported to be effective (O'Byrne, Britton, George, Franklin, & Frey, 2009). However, the problem with both of the approaches above is that students either have to self-select or be selected for such extra academic support. This works on the assumption that students who are not selected are all coping with their first year science study. This project questions this assumption and offers proof that as far as language in science is concerned, all students need support. Thus, we aimed to offer language support to all students who attended lectures and tutorials thereby developing an approach of academic support that supports all students.

In developing teaching and learning strategies to cope with the increasing diversity of students in the physical sciences, this project responds to ALTC's Competitive Grants Program, priority 2: "Strategic approaches to learning and teaching that address the increasing diversity of the student body". It also seeks to fulfill objective (f) which is to "identify learning and teaching issues that impact on the Australian higher education system to address these" (Competitive Grants Program Guidelines and Supporting Information, 2007, p. 5).

## 1.2 Project aims

Specifically this project aimed to:

- target the issue of language in science and suggest ways of solving some of the language issues by importing techniques and strategies frequently used in the teaching of foreign languages;
- create innovative online teaching modules which directly address the language difficulties in the targeted disciplines in science
- expand and reshape the current teaching approach to include a language focus in the teaching of science in the face to face mode;
- increase student awareness of the language used in the targeted disciplines by presenting student and staff insights of the particular types of language used in that context;
- rigorously evaluate the implementation of these learning strategies on student learning to enable their transportability to other teaching contexts in higher education in Australia.

## 1.3 The project team

Dr Felicia Zhang (University of Canberra), project leader, responsible for overseeing and coordinating the project and liaising with the reference group.

Dr Brett Lidbury (University of Canberra) responsible for conducting research in Genetics.

Dr Jurgen Schulte (University of Technology, Sydney), responsible for conducting research.

Dr Adam Bridgeman (University of Sydney), Associate Professor, responsible for conducting research.

Professor John Rodger, Director of the Tom Farrell Institute for the Environment, University of Newcastle (University of Newcastle), responsible for conducting research in the project;

Professor Brian Yates (University of Tasmania), School of Chemistry, University of Tasmania, responsible for overseeing and conducting research including the supervision of a research assistant.

Dr Michael Gardiner (The University of Tasmania), School of Chemistry, University of Tasmania, responsible for conducting research under the direction of Professor Yates.

Research assistants:

Mr Bryce Lockhart-Gillett (University of Tasmania)

Mr Dennis Bryant (University of Canberra).

# 2 The project context and rationale

## 2.1 Science background of students

Students undertaking tertiary studies in the physical and biological sciences are a highly diverse group and that diversity is increasing (Harris et al., 2007). For instance, at The University of Sydney there are usually around 2000 students from various faculties in the first year chemistry cohort. Some of these students had little or no Higher School Certificate studies in chemistry (especially students in Sports Sciences). However, others have very high Universities Admissions Index chemistry scores (>98 for Veterinary Science students). With such a diverse group there is also, naturally, a wide range of interest in and aptitude for the subject. Such diversity is typical for classes in biology, chemistry and physics at a number of Australian universities (see Table 1).

Table 1: Summary of discipline areas studied through a language focus, host universities for each discipline and features of large student cohorts and learning environments.

| Name of University | Discipline | Average UAI | No. of students in subject/ unit | Web supp-ort | Prerequisites |
|---|---|---|---|---|---|
| University of Technology, Sydney | Physics (1st year) | 77 | 410 | Yes | None |
| University of Sydney | Chemistry (1st year) | 83 | 2000; 200 per class | Yes | High School Certificate (HSC) in Chemistry OR no HSC Chemistry. |
| University of Newcastle | Biology (1st year) | N/A | 450 | Yes | None |
| University of Tasmania | Chemistry (1st year) | 82.5 | 250 | Yes | Year 12 Chemistry |
| University of Canberra | Genetics (2nd year)* | 82.9 | 85 - 90 | Yes | 1st year Biology or Chemistry |

*Second year Genetics at the University of Canberra was the target unit for the first language-based study in university science education performed by Drs. Zhang and Lidbury in 2006.

## 2.2 The role of language in science

Specialist terminology in biology, chemistry and physics has proved difficult for most students (Wellington & Osborne, 2001). Previous research in the language of science (Gardner, 1977; Gardner & Australian Science Education Project, 1972; Pickersgill & Lock, 1991; Wandersee, 1988) further suggests that students have problems with both technical and non-technical vocabulary. This applies especially with logical connectives such as ‘and’, ‘or’, ‘but’, and ‘although’. In other words, students have difficulty recognising where a concept begins and ends and therefore cannot put different concepts into relation. This is despite the often obvious meaning of ordinary conjunctions such as those listed.

Research into the problem of enabling students to better acquire scientific vocabulary suggests that 'technical' words make up only a small percentage of vocabulary in scientific texts. They therefore pose fewer difficulties than vocabulary which is used in everyday English as well as in a science context. Wellington (cited in Marais & Jordaan, 2000) suggested that scientific words can be classified according to their level of abstraction. The higher this level, the more difficult they are to understand. In the opinion of Wellington, mathematical words (known as symbolic language) represent the highest level of abstraction. The next level of abstraction includes concept words which can be theoretical constructs such as 'energy' and other sensory concepts which might be in common everyday use. A lower level of abstraction includes process words and less difficult naming words.

With words that are peculiar to science, certain concepts seem to be easily derived from everyday experience. Other words that have both a scientific and everyday meaning such as 'work', 'energy' or 'power' can cause confusion for learners. As students bring the everyday association of the words with them, these same words, when introduced in a physics class, can cause confusion. Itz-Ortiz, Rebello and Zollman (2003) suggested that a weak version of the Sapir and Whorf hypothesis might be dictated by the language habits of our community predisposing certain choices of interpretation of words. This would cause confusion in students with scientific terms. Researchers have studied semantics in physics (Touger, 1991; Williams, 1999).

## 2.3 Language and science education

Scientists became interested in how to teach science as far back as the 1980s. Initial attempts had been made to describe and understand what it is that we would like students to learn. This is evident from titles such as 'Scientific approaches to science education' or 'Learning to think like a physicist: A review of research-based instructional strategies' (Yore, Florence, Pearson, & Weaver, 2006). However, as Jay L Lemke pointed out (1998) such research constitutes a cognitive model of science education which cannot tell us enough to become better teachers of science as 'it lacks the necessary vocabulary to tell us just what we must lead students to do in order to learn to reason and act scientifically' (p. 1).

In order to transfer to students what they must do in learning to reason and act scientifically, the teacher is the role model 'who can model for students how scientists talk and write and diagram and calculate, how scientists plan and observe and record, how we represent and analyse data, how we formulate hypotheses and conclusions, how we connect theories, models, and data, how we relate our work and results to those of other researchers.' (Lemke, 1998, p. 1). In addition, teachers do not model these abilities by simply telling students a list of concepts they need to 'understand'. They participate in social semiotic dialogues (Lemke, 1998) in which teachers and students become engaged together in scientific sense-making, and scientific doing. These dialogues are carried out in languages of science which integrate multiple languages of representation such as visual representation, mathematical symbolism and languages of experimental operations. We would argue that these should be seen to include the meta-language of learning such as checking, problem solving, reflecting and so on, to learn how to synthesise, monitor, critique and reflect on the information gathered in the process of learning. Furthermore, acquiring scientific terms is, of course, a basic part of scientific literacy education which would include the ability to read and write a science text which is, in turn, a dominant genre used by practicing scientists (Yore, Hand, & Prain, 2002).

In order not to fall into the trap of 'activitymania' (Yore & Treagust, 2006), we place teachers in the centre of learning by asking them to model explicitly (a verb) how to test reality 'by checking, monitoring, coordinating, and controlling deliberate attempts to execute learning activity (Koch, 2001). This is why, in the lectures and tutorials involved in this project, interventions were designed to increase student to student and student to staff discussions in activities which promote sense-making rather than just completing calculations.

From a foreign language teacher's point of view (this is the project leader's area of expertise), it is heartening to see that the three-language problem (home language, instructional language, science language) that exists for most science language learners is acknowledged as parallel to that of English language learning. In her opinion, this also applies to foreign language learning, in which learners need to move across many discourse communities of their family, school, science and foreign language cultures. However, as pointed out by Yore & Treagust (2006, p. 297): 'There has been little consideration between science education and language arts reforms…because it is difficult to convince science majors in teacher education programs that language is an essential part of doing science.' This project thus represents one of the first attempts to link practices frequently used in language teaching to the teaching of science by providing examples of how and what to include in science curricula. These examples have been chosen for their simplicity and for the fact that they can be easily constructed with or without the help of technology. In other words, this project is an exemplification that even if one is not a linguist, one can still incorporate language-focused practices in one's teaching.

## 2.4 Changed teaching practices regarding the use of language

This project also documents the change process the lecturers went through in order to build language-focused and inquiry-based practices into their day to day teaching.

Gunstone (1994) argued that metacognition is central to constructivist perspectives of learning. This idea is reaffirmed and embraced by Yore & Treagust (2006). Metacognition was first used by Flavell in 1976 (Flavell, 1976). He describes it in these words:

> Metacognition refers to one's knowledge concerning one's own cognitive processes or anything related to them, e.g., the learning-relevant properties of information or data. For example, I am engaging in metacognition if I notice that I am having more trouble learning A than B; if it strikes me that I should double check C before accepting it as fact.
> J. H. Flavell (1976, p. 232*)*.

*A number of strategies were deployed. These are outlined in the following table* which includes *the research that supported the use of these strategies.*

Table 2: Strategies implemented in the project and the research that supported them

| **Strategies** | **Experimental sites** | **Meta-cognitive skills practiced** | **Research supporting use.** |
|---|---|---|---|
| 1. Small group work in tutorials using guided questions | All institutions | Learning to use oral language to express and explain scientific ideas | (Kempa & Ayob, 1995; Ritchie, 2001) |
| 2. Students are provided with a list of terms and, through the process of group work, place these terms in relation | The University of Newcastle and University of Canberra | Physical concept mapping, exploring relationships between each term | (Roth & Roychoudhury, 1994; Wellington & Osborne, 2001) |

| | | | |
|---|---|---|---|
| 3 Giving students opportunities to put forward their points of view in groups | All institutions | Creating a supportive atmosphere for idea exploration and debate | (Chin & Brown, 2002) |
| 4. Using online language exercises such as crosswords, gap-fill (cloze) exercises and simplified scientific readings | University of Canberra | Explicit instruction, practice, applying concepts | No research discovered in science education |
| 5. Providing stimulus questions for lecture and tutorial materials on WebCT* thus encouraging students to prepare before the lecture | University of Tasmania, The University of Newcastle | Preparation or reflection, just in time learning, online feedback | (Zhang & Lidbury, 2006) |
| 6. Breaking down long words to aid memory by identifying prefixes and suffixes, and exploring the roots and origin of words | The University of Newcastle | Explicit instruction on how to acquire new vocabulary and how to see patterns in the roots and origins of words | (Wellington & Osborne, 2001) |
| 7. Using warm up activities such as matching scientific terms to definitions for revision purposes | The University of Newcastle | Categorising and systematising terms | (Richardson & Zhang, 2008; Richardson, Zhang, & Lidbury, 2008) |
| 8. Using of flashcards for vocabulary revision, creating a glossary | The University of Newcastle, University of Canberra | Metalinguistic maintenance | (Zhang & Lidbury, 2006) |

* Now called Blackboard LMS

## 2.5 Building on existing knowledge of pedagogical advances

Research into why students did so poorly in tertiary level physics courses has been going on since 1985. The ‘common sense theory’ of the physical world, which the students brought with them into the classroom, had long been blamed as one of the major causes for instructional failure in introductory physics (Halloun & Hestenes, 1985; Hestenes & Wells, 1992; Hestenes, Wells, & Swackhamer, 1992; Jacobs, 1989; Touger, 1991). Work has been carried out on two fronts: (1) to establish diagnostic instruments to diagnose students misconceptions such as concept inventories; and (2) to explore different ways of organising learning activities in order for students to learn.

Since the publication of the ‘Mechanical baseline Test’ (Hestenes & Wells, 1992) and the ‘Force Concept Inventory’ (FCI) (Hestenes et al., 1992) appeared in 1992 in the journal *The Physics Teacher*, a large number of concept inventories have been developed and validated in different areas of science. These are the Brief Electricity Magnetism Assessment (BEMA) (Pollock, 2008) and the Conceptual Survey of

Electricity and Magnetism (CSEM) (Maloney, O'Kuma, Hieggelke, & Van Heuvelen, 2001), the Chemistry Concept Inventory (CCI) (Krause, Birk, Bauer, Jenkins, & Pavelich, 2004), Genetics Concept Inventory (Elrod, 2007) and Biology Concept Inventory (BCI) (Klymkowsky & Garvin-Doxas, 2008). While these inventories are useful, they have essentially been established as diagnostic instruments to diagnose students' misconceptions or conceptual understanding. Data from such diagnostic tools, while informing educators what the problem areas are, do not offer advice on how these problem areas can be addressed in teaching.

In the meantime, many researchers have also invested a great deal of energy into investigating 'how' problem areas identified by the diagnostic tools cited above can be taught better or how learning activities can be organised better to enable better learner outcomes in science education.

In chemistry, radical suggestions for reform have been about whether to teach introductory level chemistry from the macro and tangible, then the sub-micro atomic and molecular and then the representational use of symbols and mathematics (Johnstone, 2000). However, judging from the popular chemistry textbooks published by leading publishers, this debate is clearly having little impact. The textbooks used in the two chemistry cohorts involved in this project are *Chemistry* by Blackman, Bottle, Schmid and Mocerino; and *Chemistry: The Molecular Science* by Stanitski and Jurs. Both follow the traditional sequence in curricular design by teaching the sub-micro atomic and molecular first in conjunction with the representational use of symbols and mathematics. They very rarely teach the macro level of chemistry. Some researchers argued for a complete departure from the traditional sequencing of chemistry content in introductory courses (Dreyfus, Jungwirth, & Eliovitch, 1990), However, other researchers utilised planned cognitive conflicts by confronting students with a phenomenon that cannot be explained with their prior knowledge (Dreyfus et al., 1990; Nieswandt, 2001).

In physics, many studies in designing instructional sequences in teaching concepts such as force, motion and Newton's Third Law have been carried out (Alonzo & Steedle, 2008; Halloun, 1998; Savinainen, Scott, & Viiri, 2005). Analogies have also been used extensively to remediate misconceptions in physics since the early 1990s. (Brown, 1992; Dupin & Johsua, 1989).

Interactive Engagement (IE) strategies have been shown to enhance the gain in learning. In an IE class, the lecturer sets up a demonstration and asks the students to predict and write down, with consultation among themselves, their prediction of how the demonstration will work out. Then the demonstration is carried out, the results discussed and the relevant theory presented. The central idea is to offer students opportunities to engage with each other, commit to a position, confront this with reality and then use the event to trigger reflection and foster understanding. Extensive research has been done using IE strategies and the finding is that the 'use of Interactive Engagement (IE) strategies can increase the effectiveness of conceptually difficult courses well beyond that obtained with traditional methods' (Hake, 2007). Professor Hake's claim is based on the achievement scores obtained using standardised tests such as the FCI (see above).

Harvard's physics professor Eric Mazur implemented 'Peer Instruction' (PI) which also uses interactive-engagement strategies. Data obtained in classes using PI in a variety of disciplines show that learning gains nearly triple. Most importantly, students not only perform better on a variety of conceptual assessments, but also improve their traditional problem-solving skills (Crouch & Mazur, 2001).

In recent years, IE and PI, in various scientific disciplines, have been enhanced by the use of computer technology such as concept mapping tools, visualisation tools (Wu, Krajcik, & Soloway, 2001) audience response devices such as clickers and other web-enhanced strategies (Martyn, 2007; McDaniel, Lister, Hanna, & Roy, 2007; Odom & Kelly, 2001).

In the late 1990s, studio classes replaced straight lecturing in a number of universities in the US. Studio teaching consisted of a mixture of student exercises, instructor coaching, and sometimes laboratory experiments. It drew inspiration from the idea of interactive learning and generally taking advantage of modern technology to deliver instructional materials (Cummings, Marx, Thornton, & Kuhl, 1999; Pipes & Wilson, 1996; Roy, 2003).

## 2.6 Contribution of previous research to the project

The project leader/educationalist visited four institutions in semester one and semester two, 2008 to observe lectures and tutorials. These were The University of Sydney, the University of Technology, Sydney, the University of Tasmania and The University of Newcastle. Several factors emerged as inhibiting factors preventing the teaching of first year sciences in the form of studio classes or IE classes from the observation sessions:

- Physical space: lecture theatres restricted movement. Perhaps due to the impersonal nature of such physical space, the student body tended to be less engaged and lecturers tended to deliver lectures in a more transmissive mode.
- The large number of students in the classes (which ranged from less than 100 to 500 students per class) affected not only course delivery but also assessment. In order to manage such large numbers, assignments and tests were mainly conducted online and involved multiple-choice questions so that the LMS system could automatically calculate and assign grades to each student.
- Difficulty of the class tests is another factor. For instance, in the mid-semester test for Chemistry 1A at the University of Tasmania, students were required to answer some 50 questions in fifty minutes. Class tests generally involve short answer questions which require calculation and transformation of items such as from a chemical formula to a diagram and so on. Therefore, in order to pass the test, students really need to know the answers automatically without thinking. The difficulty of the test was confirmed by 26% of the student cohort (total n=214) failing the test.
- Coverage and the service teaching nature of the units: the coverage of the content is enormous. In a typical Physical Modelling lecture at the University of Technology, Sydney, 20 slides were covered, with about three concepts on each slide in two hours. The amount of coverage needed in each science unit is out of the control of the unit convenors because these first year units are service units. Service units such as Chemistry 1001 or Physical Modelling serve a large variety of disciplines such as mechanical engineering, electrical engineering and pharmacy. Even though reducing content to incorporate new learning strategies might be necessary to improve learning outcomes, academics in the feeder disciplines might not necessarily embrace it. Furthermore, some students in these units might only be doing Chemistry 1001 or Physical Modelling for one semester because this particular unit is a pre-requisite for other units in their degree.
- Lack of communication skills: from the class observations, students in all three institutions did not demonstrate skills in speaking and writing about science and they were not practiced at transferring or communicating what they learned to other people.

Due to these factors, these units were delivered in the traditional transmissive mode at each institution prior to 2009. Despite these inhibiting factors, the project still intended to change the teaching of these subjects in the participating institutions to a more interactive mode of teaching by incorporating a number of interactive strategies implemented by the lecturers themselves. Studio teaching and radical changes in curriculum design were simply either too expensive to implement or too disruptive to other lecturers who co-teach with the participating lecturers. Detailed implementation will be reported below.

# 3 The project methodology

## 3.1 Protocols and procedures

The project protocols were developed through collaboration among all stakeholders. These included a specialist in language learning and science subject specialists who were also E-learning developers and students. Designs built on the team members' knowledge of research into online learning (Schulte, 2006), computer-assisted language learning (Zhang & Barber, 2008), linguistics (Zhang, 2006), empirical research in science (Ellem & McLaughlin, 2005) and pedagogical practice. A student-centred approach was emphasised in the design process and in the design itself.

The subjects in this project were taught by lecturers who hold broadly constructivist views of learning as described by Bruner (1986). In this view of learning, learners are considered to bring different conceptualizations, intentions, styles and approaches to the learning situation (Kolb, 1984; Marton, Hounsell, & Entwistle, 1984; Perry, 1988). Students' active engagement in learning activities was also an essential ingredient.

Furthermore, these activities should be based on direct experience as far as possible (Boud, 1993) and reflection was seen as important in building understanding (Schon, 1987). Finally, the project was also informed by Lave and Wenger's ideas of situated learning (Lave & Wenger, 1991). Students and staff were participating in academic communities of practice. Therefore, the classroom is no longer a site for the transmission of knowledge but rather a site for social practice. To be included in such a social practice environment, the language of that environment must be learnt.

In this process, the roles of teaching and lecturers were changing too. Science lecturers worked alongside an educationalist and contributed to educational research and scholarship. Just as experiencing change in how they learned took place over two years for the students involved in this study, academics' teaching also experienced changes. The science academics involved in this project were extremely accomplished and knowledgeable individuals in their own disciplines. By participating in this project, they were positively recognizing the possible contribution education theories and practices could make to their teaching. The involvement of the educationalist is a way of establishing a mutually beneficial learning relationship so that science academics and the educationalist can gain new knowledge from each other. The educationalist involved in the project had very little scientific background in the targeted disciplines. She, in a sense, was like a student who chooses to do science without the necessary pre-requisites.

In this model, changes in teaching approaches were explored through a co-teaching or peer coaching approach (Ladyshewsky, 2006; Roth, 1998; Roth, Tobin, Zimmermann, Bryant, & Davis, 2002) in which the education/language expert shared with the science academic techniques and strategies used in teaching in a constructivist model. The science academics taught the education expert the content and pedagogy used in a particular science discipline. This coaching practice before lectures and tutorials in private between the educationalist and the lecturers was an essential element in successfully implementing the change in science academics' lecturing styles in the face to face context. During the coaching practice in private, the educationalist and the lecturers worked together to anticipate areas that students might not understand. This preparedness enhanced the delivery of the content using the new face to face protocol.

The staff project participants were instrumental in ensuring the sustainability of the project processes and findings. At each participating university, the staff project participants involved were instrumental in disseminating the outcome and findings of this project in higher education to colleagues within their own disciplines in their own universities and across the sector. Teaching project staff participants consulted with staff in units for the promotion of teaching and scholarship in higher education such as the Teaching and Learning Centre at the University of Canberra. Teaching staff project participants also conducted workshops to train lecturers in their disciplines in using the online and face to face protocols. Project participants were also involved in a peer-mentoring program organised at each individual institution. During the peer mentoring program, project participants mentored colleagues who intended to adapt and implement the strategies tested in this project and they also conducted workshops and seminars to showcase the processes and outcomes of this project at their own institutions.

We undertook to do the following:

- conduct an online language difficulty survey to ascertain the problems students might have with scientific language;
- implement the following two protocols in teaching in all five universities

1. During each lecture, the lecturer built into the lecture materials short survey questions made available on Votapedia <*http://www.votapedia.com*> or audience response devices such as clickers <*www.keepadinteractive.com*> to offer feedback on lecture content

2. During tutorials, interactive activities were introduced. Such interactive activities could include small group discussions involving the linking of concepts learned (Techniques 2 in Table 2) and activities related to technique 1 or 3 in Table 2.

## 3.2 Ethics approval

Ethics approval for surveying and communicating with participants was given and monitored by the University of Canberra Ethics Committee; approval number: 01-119. Each participating institution also obtained ethics approval for their participation in this project.

## 3.3 Reference group

The project reference group provided feedback at key stages in the development of the project. The reference group was asked to oversee realization of the project; advocate support for the project and any appropriate follow up at the highest levels of university management provided if the project team with high level guidance and support to help it meet its obligations.

The project reference group included:

- Professor Trevor R. Anderson, Head, Science Education Research Group (SERG) School of Biochemistry, Genetics, Microbiology and Plant Pathology, University of KwaZulu-Natal, Pietermaritzburg, South Africa.
- Professor Rob Norris, President of the Australian Council of Deans of Science, Dean of Science, Monash University.
- Associate Professor Roy Tasker, School of Natural Science, University of Western Sydney
- Mr. Alex. Barthel, Director and Senior Lecturer, English Language Studies Skills Assistance centre, University of Technology, Sydney.

## 3.4 Deliverables

The key deliverables of the project are:

- A report and assessment of the language difficulties faced by first year university students published in Zhang (2008);
- A range of strategies tested and validated to allow other science academics to introduce language specific learning activities to their first year curricula.
- A set of project reports (for different disciplines and campuses);
- Sample activities will be provided with specific comments related to these activities from the project participants. Comments relate to the advantages and disadvantages of using a particular activity based on the practical implementation of that activity (refer to 'Resource 1-4 on ALTC exchange);
- Sample curriculum guidelines for a particular phase of the project (refer to 'Resource 1-4 on ALTC exchange);
- Sample language oriented online exercises (refer to the zip files on the ALTC exchange website);
- Sample language oriented tests and/or exams (refer to Resource 1 on ALTC exchange);
- Sample assessment procedures reflecting the goal of the project (refer to Resource 1 on ALTC exchange);
- Sample attitudinal questionnaires and pre-test on language issues (refer to Resource 1 on ALTC exchange);
  All sample materials can be accessed at <http://www.altcexchange.edu.au/group/language-strategies-science-teaching>. This website has been made public to anyone who is interested in science education;
- This final project evaluation and report that synthesises the project's key findings and makes recommendations on how the language needs of a diverse student body can be better catered for in these disciplines.

# 4 Implementation

## 4.1 The University of Tasmania

At the University of Tasmania, in 2008 and 2009 there were 209 and 222 students respectively in the subject Chemistry 1A. In 2009, in the implementation phase of the project, in both semester one and two of 2009, Votapedia questions (see Appendix B) were used during the lectures as well as pre-lecture multiple-choice questions with full feedback were provided to students on their Learning Management System (LMS). In order to ensure full participation by students, access to assignments (which contribute to their grades) would only open on completion of these quizzes with full feedback. In this project, students who did not wish to participate in the project had an opting out option which they could tick. Once this option was ticked, their normal assessment item would become accessible as per normal.

The Votapedia tool <www.votapedia.com> was used at the University of Tasmania in first year Chemistry in semester one, 2009. According to the main page of the website 'Votapedia is an audience response system that doesn't require issuing clickers or need specialist infrastructure. Known users can create surveys and edit the surveys on the site. Once signed on, students can participate in surveys either through mobile phones, online or through SMS. Both online and mobile phone are free to the students but there will be a charge for access through SMS <*http://www.votapedia.com/index.php?title=Main_Page*>. At the University of Tasmania, when this was implemented in the lecture theatre, because only Telstra mobile phones could get signal, only students with Telstra phones could phone through. Other students voted using a raise of hands.

## 4.2 The University of Technology, Sydney

The University of Technology, Sydney used clickers in 2008. 2007-2008 results on the use of clickers (J. Schulte, personal communication, September 28, 2009). suggested that the use of clickers enabled a sustained participation in lectures from the beginning until the end of the semesters. However, survey results suggested that even though students felt the feedback they obtained from the use of clickers aided their on-the-spot understanding, the feedback could be better used as diagnostic tools so that in the long term more structural change could be implemented to help the students to self-structure their study (personal communication, September 28, 2009). In 2009, due to a large increase in the number of students in semester one 2009 (about an increase of 100 students thus raising the final student count to 530), clickers and a raise of hands were used. This was complemented by small group student to student group discussions (Technique 3 in Table 2) and then students to teacher discussion in biweekly tutorials. Only one hour was available in these tutorials.

In the online protocol, students were presented with a number of quizzes online before each lecture each week. This protocol involves the implementation of technique 5 in Table 2. The project team involved in physics and chemistry created, implemented and collected data on a set of language specific online quizzes for the respective disciplines in 2009. In 2008 and 2009, the physics assignments deployed through the WileyPLUS website consisted mainly of calculation types of questions. Below is an example:

On a dry road, a car with good tires may be able to brake with a constant deceleration of 5.28 $m/s^2$. (a) How long does such a car, initially travelling at 24.4

m/s, take to stop? (b) How far does it travel in this time?

| | | | | |
|---|---|---|---|---|
| (a) | Number | 4.62 | Units | s |
| (b) | Number | 56.38 | Units | m |

In order to get away from the assumption that if students can correctly do the calculations, then they have understood the subject matter, we also introduced a ‘Physics concept survey’ (J, Schulte, personal communication, May 28, 2009) which tested the language used in physics (see Appendix E). At the University of Technology, Sydney, in the Physical Modelling unit, there was only a one-hour tutorial available every fortnight for the students. During these tutorials, the lecturer also incorporated into small group activities the use of multiple choice and concept questions related to language use. These concept questions were created specifically to test students’ understanding of particular concepts such as ‘force’ in physics and the use of ‘force’ in real life. For example:

> Meaning of 'force'
> Which one(s) of the following sentences containing 'force' have meanings that are close to the meaning of 'force' in Physics: 1.I forced the box into the closet. 2. Jim was forcing the nut on the bolt. 3. I forced myself to go to class every day. 4. My parents forced me to go to university. 5. The force on the ball made it move. 6. The bomb exploded with great force. 7. I was hit by the force of the 18 wheeler. 8. She used a very forceful tone of voice.
> a)1, 2, 4, 3, b)3, 4, 8 c)1, 2, and 5 d) 5,6,7

These sentences have two things in common: (1) the word ‘force’ was used as a verb linked to an agency [or an assumed agency as in (5)] and every use contains a preposition such as ‘into’ or ‘onto’ or ‘on’ and another object. This makes the verb ‘force’ a transitive verb involving the interaction of two objects. This seems to loosely fit in with the common definition of force as a push or pull on an object. At the University of Technology, Sydney, the textbook used by this group of students is *Fundamentals of Physics* ($8^{th}$ Edition) by Jearl Walker (Walker & Halliday, 2008). Unfortunately, the way it discusses ‘force’ on page 87 is a bit confusing. For instance, the sentence ‘The force is said to *act* on the object to change its velocity.’ (Italic is theirs). This gave the impression that somehow ‘force’ itself is an agency like a person causing the object to change its velocity. Such differences in interpretation were discussed in small group activities.

During semester one in 2009 at the University of Technology, Sydney, two calculation type tests and a final examination were conducted. This enabled the results of these tests and examination to be compared with similar tests and the examination used in semester one 2008. In addition to this, a Physics concept survey (Appendix E) was also administered. This survey combines 16 questions related to definitions of physics concepts such as ‘force’, ‘momentum’ and 25 questions on ‘thermodynamics’ taken from (Yeo & Zadnik, 2001). 269 students completed the survey. However, because this test was not administered in 2008, no comparison was possible.

## 4.3 The University of Canberra

Research involving the use of foreign language interventions such as the ones mentioned in Table 2 was conducted in 2005 in the unit Genetics at the University of Canberra. For example, the cloze technique, also known as "fill in the blanks" or the "gap-fill exercise" approach to reading biology texts, was used extensively to enable students to learn molecular biology language. Rather than passively reading the text, the exercise was designed to encourage students to construct the meaning of the work via filling gaps which were deliberately introduced into the text. To do this successfully, students needed to actively read the journal article text (in this example, the Materials and Methods section) to find the actual words or terms, or to find clues to answer the gap-fill question. Not only did they need to find the words, they also needed to apply their skills in synthesising and evaluating the information embedded in the passage. This task was created by free-software called Hot Potatoes ™ <http://hotpot.uvic.ca> software and allowed the designer to embed clues into the exercise. There are several other language interventions that can be used in tutorials using Hot Potatoes such as group “mix-and-match” exercises, text translation and deconstructing scientific words, expressing concepts in pictorial form and so on. Again, these examples use student action in some way to encourage active learning. This includes having students leave their seats and move around the tutorial room.

## 4.4 The University of Newcastle

At The University of Newcastle in 2008 and 2009 there were 209 and 250 students respectively in the unit: Biol 1002: Organisms to Ecosystems. In 2009, in the implementation phase of the project in semester two, Votapedia questions (Appendix B) were used during the lectures as well as online revision exercises and tutorial activities (Appendix D). These took place over a period of three weeks out of a total of 13 weeks. In semester two, 2008 in the subject Biology 1002, students were asked for their consent to participate in the project through the completion of Test 1 of the language surveys (Appendix A). However, only 18 students participated. In semester two 2009, in order to increase the number of students participating, the Tests 1 and 2 of the language surveys were built in as part of the out of class non-assessable assessment items. At the end of the second non-assessable item, a number of demographic questions were asked as well as the implementation of a Biology Self-Efficacy questionnaire which was based on Baldwin, Ebert-May and Burn’s Biology Self-efficacy instrument (Baldwin, Ebert-May, & Burns, 1999). In the last item of the out of class survey, they were asked to tick ‘yes’ or ‘no’ on their participation. By building test 1 and 2 items into the survey, the survey participation rate for the unit rose to 30.4%.

During semester two, 2009, the language strategies were implemented for three weeks over four hours per week. In the second two-hour block of each week, the language exercises (Appendix D) were administered in about half an hour each week: These tutorial exercises were also provided to students before each week’s tutorial. These exercises provided students opportunities to classify, link and reflect on the linkage of words and concepts.

## 4.5 The University of Sydney

At The University of Sydney, the first year Chemistry student body were divided into three cohorts, namely those studying Chem 1001 (Fundamental Chemistry cohort with students with no HSC Chemistry), Chem 1101 (Students with HSC Chemistry) and Chem 1901 (students with good HSC Chemistry). These three groups added up to about 1000 students. The participating lecturer only taught five of the 13 weeks of the Fundamental Chemistry unit in semester 2, 2009. This arrangement corresponded to six lectures per week and two tutorials a week. The remaining eight tutorials were taken by tutors.

To build in language support, the lecturer used 2-4 clicker questions in most lectures in Fundamental Chemistry. Concept development handouts for the students to read and work on in groups during the lectures were also used. In tutorials, tutors were asked to use group work activities (see Appendix D) rather than ‘mini lectures’ for at least 25 minutes in each class. In the labs, the lecturer also introduced a written report and an online research exercise as assessed activities. He was particularly keen to develop the students’ ability to write properly structured scientific reports in place of the ‘fill in the box’ activities used elsewhere.

## 4.6 Language difficulty surveys across the five universities in 2008 and 2009

In the first six months of the project, the initial baseline surveys were conducted. Test 1 was distributed at The University of Sydney, the University of Tasmania and the University of Technology, Sydney by the end of April, 2008 (see Appendix A). Test 1 consisted of 10 multiple choice questions and corresponding confidence questions and Test 2 consisted of a fill-in-the blank exercise or cloze passage in which students had to fill in the blanks with appropriate terms chosen from the 10 terms tested in Test 1. Test 2 tested the application of the same terms as in Test 1. The project leader/educationalist visited the University of Technology, Sydney, the University of Tasmania and The University of Sydney in April, 2008 to observe classes and discuss the questionnaire data. For the Genetics unit at the University of Canberra and first year Biology at The University of Newcastle, the data was collected in this phase of the project in semester two, 2008 and 2009 when the participating lecturers were teaching.

## 4.7 Description of the surveys

In this project, we adopted a model which varied slightly from that of Jacobs (1989). We distributed one or two tests through the Learning Management System (LMS) of the participating institutions. In Test 1, we tested comprehension of ten common terms. The examined terms were; ‘research’, ‘power’, ‘concentration’, ‘equilibrium’, ‘graph’, ‘system’, equation’, ‘experiment’, ‘model’ and ‘significant’. The criteria for selection of the words were that they had to be:

- Words used as basic currency in physics, chemistry and biology lectures and for which definitions would be assumed unnecessary; and
- Words which, in lay contexts, acquire more flexible and approximate meanings.

For example, in the question related to ‘research’, the following was provided:

> "We carry out research to find out the answers to scientific questions." What is meant by the word "research" in the sentence above? (There may be more than one correct answer).

They were then provided with five answers for this question:

| | **Student response** | **Correct answer** | **Value** |
|---|---|---|---|
| A | observing the results of a series of chemical reactions | yes | 33.33% |
| B | Answering an exam question. | No | -10% |
| C | Looking for information in the library or on-line | Yes | 33.33% |
| D | Copying information out of a textbook | No | -10% |
| E | Testing a hypothesis | yes | 33.33% |

Each correct answer was allocated five marks each. If a student chose the three correct answers, she/he should score 15/15. This indicated a complete understanding of the term in different contexts. Any score less than 15 suggested an incomplete understanding of the term. All 10 terms followed a similar format. Then in the second part following each question is a related confidence question which assessed how confident a student is of the choice(s) he/she made:

| | Student response | Value |
|---|---|---|
| A | Yes, I understand the meaning of this word | 100% |
| B | No, I do not understand the meaning of the word | -100% |
| C | I have some idea of the meaning of this word. | 0% |

Please see Appendix A for the survey instruments used in the project.

## 4.8 Questionnaire Response Rate

At the University of Technology, Sydney's first year Physics Modelling unit, Tests 1 and 2 were distributed voluntarily to all students in the unit. Consent was obtained online from each student before completing the tests. A similar procedure was followed at the University of Tasmania. At The University of Sydney, Test 1 was distributed to 969 students in first year Chemistry. These students had been divided into three cohorts of students (see Table 1). At all institutions, students self-selected to do the tests. The response rates from these cohorts from all institutions were as follows:

Table 3: Questionnaire response distribution from the universities in 2008 and 2009.

| Institutions | Units | Test 1 responses | Total no. distributed | Response rate (%) Test 1 |
|---|---|---|---|---|
| University of Technology Sydney (UTS) | Physical Modelling | 40 | 412 | 9.7%, |
| University of Tasmania (UTAS) | Chemistry 1A | 29 | 272 | 10.7%, |
| The University of Sydney (Sydney) | Chemistry 1001 | 60 | 388 | 15.5%, |
| | Chemistry 1101 | 95 | 465 | 20.5%, |
| | Chemistry 1901 | 19 | 116 | 16.4%, |
| The University of Newcastle (UoN) | Biology 1002, 2008 | 18 | 237 | 7.6% |
| | Biology 1002, 2009 | 74 | 250 | 30.4% |
| University of Canberra (UC)* | Genetics 6531 | 66 | 75 | 88% |
| Total | | 243 | 1653 | 15.83% (average) |

* At the University of Canberra, the surveys were distributed to second year students simultaneously in a computer laboratory. Therefore, the compliance rate was much higher. Please note that the response rate figure for the University of Canberra was therefore excluded from the average for the response rate. For this reason the response rate is 15.83%.

The University of Sydney and the University of Tasmania were using the Blackboard LMS (formerly WebCT) which allowed printable statistics for a cohort of students to be obtained for each questionnaire. From the printable statistics, the percentage of students who demonstrated a complete understanding of a term in different contexts and of how confident they were of their understanding could be obtained. By dividing the 'Yes' confidence level (column 2) by the percentage of students demonstrating a 100% understanding (Table 4, column 3), we were able to establish a 'delusion index'. A high value in the 'delusion index' column suggests that students were highly delusional about their understanding of a particular term.

For instance, for the term 'power' in Table 4, a delusion index of 1.29 suggests that students are more realistic about their understanding of this term when compared to their understanding of the term ‘significant’ which had a delusion index of 29.95. If we look at the term ‘significant’ with a delusion index of 29.95, it means that students were highly delusional in their understanding. This was demonstrated by only 1.9% of the student body understanding this term completely but 56.9% of students thought they understood the term completely (indicated by the value in the corresponding ‘Yes’ column). A ranking of the difficulty of the terms (from the easiest=1 to the hardest=10) also determined understanding of each term by examining the percentage of students who achieved 100% understanding. In the next section are the tables showing the results of this questionnaire from The University of Sydney, the University of Tasmania, the University of Technology, Sydney, The University of Newcastle and the University of Canberra.

## 4.9 Analysis of the questionnaire data

### *4.9.1 Chemistry discipline*

Table 4: Chemistry 1001 (Fundamental students with no previous HSC chemistry) at The University of Sydney

| **Terms** | **‘Yes’ response for confidence in %** | **100% understanding** | **Delusion index** | **Ranking (easiest=1, hardest=10)** |
|---|---|---|---|---|
| Significant | 56.90 | 1.90 | 29.95 | 10 |
| Model | 64.70 | 15.40 | 4.20 | 9 |
| Power | 31.70 | 24.60 | 1.29 | 8 |
| System | 45.10 | 26.90 | 1.68 | 7 |
| Equilibrium | 59.30 | 32.10 | 1.85 | 6 |
| Research | 64.10 | 36.90 | 1.74 | 5 |
| Concentration | 80.40 | 43.90 | 1.83 | 4 |
| Graph | 84.90 | 49.10 | 1.73 | 3 |
| Equation | 82.70 | 53.80 | 1.54 | 2 |
| Experiment | 78.80 | 75.00 | 1.05 | 1 |

Table 5: Chemistry 1101 (students with HSC chemistry) at The University of Sydney

| **Terms** | **‘Yes’ response for confidence in %** | **100% understanding** | **Delusion index** | **Ranking (easiest=1, hardest=10)** |
|---|---|---|---|---|
| Significant | 51.80 | 4.80 | 10.79 | 10 |
| Model | 67.50 | 18.10 | 3.73 | 9 |
| Power | 41.60 | 19.30 | 2.16 | 8 |
| Research | 62.40 | 20.00 | 3.12 | 7 |
| System | 53.00 | 28.60 | 1.85 | 6 |
| Equilibrium | 83.50 | 50.60 | 1.65 | 5 |
| Concentration | 80.20 | 51.20 | 1.57 | 4 |
| Graph | 83.30 | 53.60 | 1.55 | 3 |
| Equation | 78.30 | 57.80 | 1.35 | 2 |
| Experiment | 67.10 | 68.70 | 0.98 | 1 |

Table 6: Chemistry 1901 (students with HSC chemistry and high UAI) at The University of Sydney

| **Terms** | **'Yes' response for confidence in %** | **100% of understanding** | **Delusion index** | **Ranking (easiest=1, hardest=10)** |
|---|---|---|---|---|
| Significant | 64.70 | 5.60 | 11.55 | 10 |
| Research | 60.00 | 28.60 | 2.10 | 9 |
| Power | 26.30 | 28.60 | 0.92 | 8 |
| System | 50.00 | 31.60 | 1.58 | 7 |
| Model | 64.70 | 50.00 | 1.29 | 6 |
| Graph | 94.40 | 52.60 | 1.79 | 5 |
| Equation | 94.10 | 55.60 | 1.69 | 4 |
| Equilibrium | 88.90 | 57.90 | 1.54 | 3 |
| Concentration | 84.20 | 60.00 | 1.40 | 2 |
| Experiment | 82.40 | 77.80 | 1.06 | 1 |

Table 7: Chemistry 1A (mixed cohort) at the University of Tasmania

| **Terms** | **'Yes' response for confidence in %** | **100% understanding** | **Delusion index** | **Ranking (easiest=1, hardest=10)** |
|---|---|---|---|---|
| Significant | 48.40 | 3.20 | 15.13 | 10 |
| Research | 73.50 | 9.10 | 8.08 | 9 |
| Model | 48.40 | 12.90 | 3.75 | 8 |
| System | 58.10 | 19.40 | 2.99 | 7 |
| Power | 48.40 | 22.60 | 2.14 | 6 |
| Concentration | 87.10 | 25.80 | 3.38 | 5 |
| Equilibrium | 76.70 | 32.30 | 2.37 | 4 |
| Equation | 77.40 | 35.50 | 2.18 | 3 |
| Graph | 87.10 | 41.90 | 2.08 | 2 |
| Experiment | 83.90 | 71.00 | 1.18 | 1 |

The data in Tables 4-7 suggest that terms such as 'model', 'significant', 'research', 'power' and 'system' were the most difficult for science students. Note that 'research' was one of the most problematic terms. From the example which described the question on 'research', we can see that in order to achieve a 100% complete understanding of this term, students had to tick all the correct answers (a, c and e). The three answers referred to the understanding of the term in scientific and non-scientific contexts. Out of the four groups of chemistry students, from both the University of Tasmania and The University of Sydney, students who chose all three correct answers for the question on 'research' (i.e. a, c, and e) ranged from 36.9% to 9.1%. The more popular choice ticked was e (Testing a hypothesis) which was the scientific definition with which they might be most familiar. This could be interpreted as symptomatic of students' ability to transfer knowledge gained in science to other realms of knowledge.

### *4.9.2 Physics discipline*

The surveys were constructed slightly differently at the University of Technology, Sydney. Only five terms were used and no confidence questions were posed. Out of the five terms, 'concentration' (which was used in chemistry surveys at The University of Sydney and the University of Tasmania), had been changed to 'density' as this is more suited to the physics context. However, it was not possible to derive a 'delusion index'.

Table 8: Physical Modelling students at the University of Technology, Sydney

| Terms | 100% understanding | Ranking (easiest=1, hardest=5) |
|---|---|---|
| Research | 15 | 5 |
| Equilibrium | 17.5 | 4 |
| Power | 25 | 3 |
| Density | 27.5 | 2 |
| Graph | 42.5 | 1 |

### *4.9.3 Biology and Genetics discipline*

The surveys were also distributed to first year students at The University of Newcastle and second year students at the University of Canberra in both 2008 and 2009. Since both these universities are involved in the discipline of biology, the same language difficulty questionnaire appropriate to biology was distributed.

Table 9: Biology 1002 students at The University of Newcastle in semester two, 2008

| Terms | 'Yes' response for confidence in % | 100% understanding | Delusion index | Ranking (easiest=1, hardest=10) |
|---|---|---|---|---|
| Significant | 44.44 | 33.33 | 1.33 | 9 |
| Equation | 72.22 | 38.89 | 0.54 | 8 |
| Research | 77.78 | 44.44 | 0.57 | 7 |
| Equilibrium | 66.67 | 50.00 | 0.75 | 6 |
| Concentration | 77.78 | 61.10 | 0.79 | 5 |
| Power | 44.44 | 66.67 | 1.50 | 4 |
| Graph | 88.89 | 77.78 | 0.88 | 3 |
| Experiment | 66.67 | 83.30 | 1.25 | 2 |
| System | 72.22 | 88.89 | 1.23 | 1 |

Note: at The University of Newcastle, one item (significant) was repeated and the item on 'model' was not included. Therefore the table shows the data for nine items rather than ten.

Table 10: Biology 1002 students at The University of Newcastle in semester two, 2009

| Terms | 'Yes' response for confidence in % | 100% understanding | Delusion Index | Ranking (easiest=1, hardest=10) |
|---|---|---|---|---|
| Research | 80 | 5 | 16 | 9 |
| Equilibrium | 47 | 11 | 4.27 | 8 |
| Equation | 73 | 15 | 4.87 | 7 |
| System | 73 | 24 | 3.04 | 6 |
| Model | 34 | 26 | 1.31 | 5 |
| Experiment | 83 | 40 | 2.08 | 4 |
| Concentration | 76 | 43 | 1.77 | 3 |
| Graph | 83 | 48 | 1.73 | 2 |
| Control | 87 | 74 | 1.18 | 1 |

Table 11: 2nd year Genetics 6531 at the University of Canberra in 2008

| Terms | 'Yes' response for confidence in % | 100% understanding | Delusion Index | Ranking (easiest=1, hardest=10) |
|---|---|---|---|---|
| Model | 9.50 | 4.00 | 2.38 | 10 |
| Equation | 21.90 | 15.00 | 1.46 | 9 |
| Power | 25.70 | 15.00 | 1.71 | 8 |
| Equilibrium | 25.00 | 18.00 | 1.39 | 7 |
| Research | 66.80 | 33.00 | 2.02 | 6 |
| System | 65.00 | 36.00 | 1.81 | 5 |
| Significant | 57.10 | 40.00 | 1.43 | 4 |
| Experiment | 64.40 | 43.00 | 1.50 | 3 |
| Concentration | 72.00 | 46.00 | 1.57 | 2 |
| Graph | 69.40 | 48.00 | 1.45 | 1 |

Table 12: 2nd year Genetics 6531 at the University of Canberra in 2009 at the beginning of the semester

| Terms | 'Yes' response for confidence in % | 100% understanding | Delusion Index | Ranking (easiest=1, hardest=10) |
|---|---|---|---|---|
| Model | 39 | 3.9 | 10 | 10 |
| Power | 51 | 10.5 | 4.86 | 9 |
| Equilibrium | 65 | 15.8 | 4.11 | 8 |
| Equation | 80 | 15.8 | 5.06 | 8 |
| Research | 78 | 22.4 | 3.48 | 6 |
| Experiment | 80 | 23.7 | 3.38 | 5 |
| Significant | 57 | 27.6 | 2.07 | 4 |
| System | 74 | 31.6 | 2.34 | 3 |
| Concentration | 86 | 38.2 | 2.25 | 2 |
| Graph | 87 | 55.3 | 1.57 | 1 |

Table 13: 2nd year Genetics 6531 at the University of Canberra in 2009 at the end of the semester

| Terms | 'Yes' response for confidence in % | 100% understanding | Delusion Index | Ranking (easiest=1, hardest=10) |
|---|---|---|---|---|
| Model | 50 | 15.6 | 3.21 | 10 |
| Power | 61 | 17.2 | 3.55 | 9 |
| Experiment | 29.7 | 19 | 2.69 | 8 |
| Equation | 70 | 20.3 | 3.45 | 7 |
| Equilibrium | 66 | 25.0 | 2.64 | 6 |
| Research | 83 | 34.4 | 2.41 | 5 |
| System | 73 | 35.9 | 2.03 | 4 |
| Significant | 61 | 39.1 | 1.56 | 3 |
| Concentration | 75 | 39.1 | 1.92 | 2 |
| Graph | 83 | 46.9 | 1.77 | 1 |

Genetics data from the University of Canberra in 2009 further revealed that for both the beginning and end of semester language tests, “model” was the worst understood word, as judged by the percentage of students who scored “0” for this question (as well as it being the median and mean scores of the cohort) in Table 14. Comprehension of “model” improved significantly by the end of the semester (Wilcoxon Signed Ranks test), but was still the worst understood. “Equilibrium” and “equation” also caused problems in terms of language comprehension for both tests. As judged by “% 0 Score”, “significant” had worse comprehension for the end of semester test, compared to the early test, but median/mean scores for both comprehension and confidence did not differ. This indicated that while more students got the answer wrong, the students who got this correct were more likely to score full marks for their understanding of “significant”. “Concentration” also had an increase of “% 0 Score” for the end of semester test. It seemed comprehension of some words/terms deteriorated over the semester.

Table 14: 2009 cohort’s performance in Test 1(MCQ) at the beginning of the semester, at the University of Canberra in 2009

| **Word** | **Median/Mean (Comprehend)** | **Median/Mean (Confidence)** | **% 0 Score** | ***r* (Comprehend vs. Confidence)** |
|---|---|---|---|---|
| Model # | 0/2.4 | 0/3.9 | 63.8 | -0.028 |
| Equilibrium | 5/3.8 | 10/6.4 | 40.6 | 0.259* |
| Equation | 5/4.3 | 10/7.8 | 29.0 | 0.094 |
| Power | 5/4.5 | 10/5.1 | 18.8 | 0.053 |
| Experiment | 8/6.2 | 10/8.0 | 15.9 | 0.105 |
| Significant | 5/5.8 | 10/5.1 | 8.7 | 0.154 |
| System | 5/6.4 | 10/7.4 | 2.9 | 0.146 |
| Research | 7/6.3 | 10/7.8 | 1.5 | 0.028 |
| Concentration | 7/6.9 | 10/8.4 | 1.5 | -0.038 |
| Graph | 10/7.9 | 10/8.6 | 1.5 | 0.109 |

* $p < 0.05$ (Spearman’s Correlation)

Table 15: 2009 cohort’s performance in Test 1 (MCQ) at the end of semester at the University of Canberra in 2009

| **Word** | **Median/Mean (Comprehend)** | **Median/Mean (Confidence)** | **% 0 Score** | **r (Comprehend vs. Confidence)** |
|---|---|---|---|---|
| Model # | 4/4.2 | 5/5.0 | 42.2 | 0.370** |
| Equilibrium | 5/4.3 | 10/6.6 | 39.1 | 0.157 |
| Equation | 4/4.3 | 10/7.0 | 31.3 | 0.320* |
| Power | 2.5/4.1 | 10/6.1 | 28.1 | 0.211 |
| Significant | 5/5.7 | 10/6.1 | 23.4 | 0.171 |
| Experiment | 8/6.3 | 10/8.0 | 20.3 | 0.268* |
| Concentration | 7/6.5 | 10/7.5 | 10.9 | 0.416** |
| Research | 7/6.5 | 10/8.3 | 7.8 | 0.061 |
| System | 7/6.9 | 10/7.3 | 4.7 | 0.146 |
| Graph | 7/7.1 | 10/8.3 | 4.7 | 0.359** |

* $p < 0.05$
** $p < 0.005$ (Spearman’s Correlation)
\# $p = 0.012$ (Wilcoxon Signed Ranks test) – 100% complete understanding of the word “model” improved significantly from the early to the later test. Confidence for “model” was not significantly different (Wilcoxon Signed Ranks test).

## 4.10 Relationship between Test 1(MCQ) and Test 2(Cloze)

We also calculated the correlation between the scores of Test 1 and Test 2 from students at the University of Technology, Sydney, The University of Sydney and the University of Tasmania. Due to the non-parametric nature of the data in the samples, Spearman's rho is calculated. A significant correlation between Test 1 and Test 2 suggested students demonstrated not only understanding, but also application of the terms. In Table 16, only the eight students in Chemistry 1901 at The University of Sydney demonstrated both understanding and application of the terms as reflected by the high correlation of results between Test 1 and Test 2.

Table 16: Correlation between language Test 1(MCQ) and Test 2 (Cloze) for the three institutions

| University | No. of students | Test 1 mean | Test 2 mean | Spearman's rho |
|---|---|---|---|---|
| Sydney (Chemistry 1001) | 25 | 80.52 (SD: 7.16) | 9.04 (SD: 1.67) | 0.082 |
| Sydney (Chemistry 1101) | 38 | 81.63 (SD:16.28) | 8.96 (SD: 1.73) | 0.169 |
| Sydney (Chemistry 1901) | 8 | 83.37 (SD:14.27) | 9.81(SD:0.372) | 0.768* |
| UTAS | 12 | 71.04 (SD:21.36) | 9.37 (SD: 0.80) | 0.181 |
| UTS | 23 | 136.96 (SD:40.42) | 6.3 (SD: 2.494) | -.0.272 |

* p<0.05

At the University of Canberra, from comparing students' performance in Test 1 at the beginning and end of the semester in 2009, only one term (equilibrium) had a significant correlation between the 100% understanding of the term and its corresponding confidence (Table 14). For the end of semester test, five words/terms had significant (positive) correlation between comprehension and confidence, according to Table 15. This indicated that by the end of the semester students were better able to judge their scientific language competency.

For the data collected from the University of Canberra, a decision tree analysis and a multiple regression analysis were used to further analyse the role of language in the learning of genetics. It was found that the grade point average (GPA) is a very powerful factor in predicting student examination and overall performance. This confirmed the conclusion reached in the pilot to this project published in 2006 (Zhang & Lidbury, 2006). However, after removing the GPA from consideration, a conclusion that could be reached was that, for the best students, the control of language or confidence in language use was a factor in their success. Similarly, after removing the GPA from the regression model, pre-test language confidence (as demonstrated by students' performance on language questionnaire Test 1) is a significant (p=0.024) predictor of final overall performance in genetics.

In conclusion, the results reported above show that (1) the students from the five institutions had problems with the ten terms tested. This signaled an urgent need for language-focused training in the teaching of first year science; (2) students with more disciplinary experiences tended to be able to better apply language in real situations; (3) confidence in language use (especially as indicated in the fill in the blank tests) might have an important role to play in second or third year level science units. While a causal relationship between the control of language and achievement could not be established, the control of language seemed certainly to be a factor in influencing later achievements in science.

# 5 Evaluation

## 5.1 Evaluation strategy

Evaluation was carried out at each stage of the project, through the design phases to pilot testing and final implementation. All stakeholders were involved in evaluation. Student users, in particular, played a major role in this process. Evaluation design was informed by the practical experience of team members. It was also informed by recent research in the areas of evaluation of online learning, educational theory and interactive approaches to the teaching of science which were identified in literature cited in this report. In this project, typical evaluation practices used included different institutional student unit satisfaction or evaluation surveys, pre- and post-test language-oriented performance data, and examination results.

## 5.2 Results of implementation at the University of Technology, Sydney

The final examinations in Physical Modelling at the University of Technology, Sydney in 2008 and 2009 consisted of eight sections. These were on 'Kinetics', 'Forces', 'Momentum and energy', 'Equilibrium', 'Thermal', 'Electricity', 'Oscillations, Waves' and 'Optics'. In 2008, the physics unit was taught entirely by the staff member who was participating in this project. However, in 2009, the same unit was taught by three different staff. Only the sections on 'kinetics', 'forces' and 'momentum and energy' were taught by the same participating academic. Consequently, only questions in these sections in both 2008 and 2009 final examinations could be used for comparative purposes.

Table 17: Physical Modelling at the University of Technology, Sydney: semester 1, 2008 and semester 1, 2009 data comparison

| Year | No. of students | Kinetics, %of full marks | Momentum, % of full marks | Forces, % of full marks | Energy, % of full marks |
|---|---|---|---|---|---|
| 2008 | 388 | 79.77 | 69.3 | 32.2 | 63 |
| 2009 | 478 | 83.33 | 75.1 | 46.3 | 53.5 |
| % change | 23.19 | 4.46 | 8.37 | 14.1 | -9.5 |
| p-value | | 0.57 | 0.32 | 0.0 | 0.07 |

The "% of full marks" in each section indicated the % of students who obtained full marks for the section. The information in Table 17 informs us that in the 'kinetics', 'momentum' and 'forces' sections, students in 2009 in this unit outperformed the students in the 2008 cohort. For instance, in the 'kinetics' section, in 2009 83.33% of the students achieved full marks for this section as compared to only 79.77% of students in 2008. For the 'momentum' section, the increase was 8.37%. In the 'forces' section, the 2009 cohort of students outperformed the 2008 cohort by 14.1%. In the 'energy conservation' section, the 2008 students outperformed the 2009 students by 9.5%. We also used the Z test to compare the 2 independent proportions and it was found that only the change in the 'forces' section was highly significant (p=0.000 to three decimal points).

Table 18: Achievement results by students attending lectures (n=108) and students who did not attend lectures (n=85) in Physical Modelling at the University of Technology, Sydney in semester 1, 2008 and semester 1, 2009.

| Assessment tasks | Non-clicker group mean | Clicker group mean | Sig. (2-tailed) |
|---|---|---|---|
| Total/100 | 38.41 | 56.20 | .000** |
| Final exam | 12.01 | 19.38 | .000** |
| Lab | 14.84 | 17.49 | .000** |
| Test A | 4.85 | 4.92 | .016* |
| Test B | 2.28 | 2.99 | .003** |
| Wiley | 5.15 | 8.46 | .000** |
| Quiz | 0.52 | 0.69 | .001* |

* $p<0.05$,
** $p<0.005$

The lecture and non lecture attendance groups were self-selected. Students who attended lectures used clickers as each clicker was registered under the students' student number. This also made it possible to collect information on who performed in the in class clicker questions on a weekly basis. For a significance level of $p < 0.05$; Table 18 suggests that the 'clickers' group performed significantly better than the non-clickers group in all assessment items. Furthermore, only 18% of the students in the 'clicker group' failed the unit compared to 68% in the non-clicker group

In 2008, semester one, the question 'I received constructive feedback when needed' on the Student feedback results (SFR) only received a rating of 2.70/5 and this lack of satisfaction was confirmed by the open ended questions section of the SFR which showed that 50% of students' complaints centered on how and where the tutorials were run. Students tended to see them as basically just another extension of the lecture. As one student put it:

> The idea of a single tutorial for the whole subject in the lecture theatre was terrible. It basically turned into a tedious lecture on how to do questions which went too fast to grasp and didn't give any value since we weren't actually doing the questions. Proper tutorials are needed.

In 2009, semester one, the tutorial classes were renamed as 'workshops' and language strategies were consistently and extensively included. These interventions not only improved the rating on feedback to 3.56/5 but hardly any complaints were received about the workshops. In fact one student suggested the following:

> I reckon it will help the students if there were more workshops than lectures. To be successful in this subject, students must understand physics concepts inside out. In order for this to happen, problem solving workshop is the key. I felt that the workshops helped me more than lectures as it is more hands-on. What I suggest is that instead of having 3 hour lectures and 1 hour workshop a week, why not have 2 hour workshops and 2 hour lectures instead.

Clearly physics students liked workshops involving the small group work introduced through this project. However, such arrangements are resource intensive. Nevertheless, students have obviously clearly identified this as a preferred mode of learning as a result of this project.

## 5.3 Results of implementation at the University of Tasmania

At the University of Tasmania, results on the final examination and the distribution of the final grades in semester one and two in 2008 and 2009 are reported.

Table 19: Distribution of grades for the unit in semester one, 2008 and semester one, 2009 at the University of Tasmania

| grades | % 2008 | % 2009 | Difference in % |
|---|---|---|---|
| HD | 9.7 | 9.9 | 0.2 |
| DN | 10.2 | 17.6 | 7.4 |
| CR | 25.2 | 23.0 | -2.2 |
| PP | 31.4 | 23.0 | -8.4 |
| TS | 10.2 | 12.2 | 2.0 |

Table 19 illustrates the distribution of the grades for semester one in 2008 and semester one 2009. It can be seen that the % of failures has increased slightly from 10.2% in 2008 to 12.2% in 2009, a rise of 2%; the % of Passes has dropped from 31.4% to 23%, a drop of 8.4%; the % of Credits has dropped slightly from 25.2% in 2008 to 23% in 2009, a drop of 2.2%; the % of Distinctions has increased from 10.2% in 2008 to 17.6% in 2009, an increase of 7.4%; and finally the % of High Distinctions has increased from 9.7% in 2008 to 9.9% in 2009, an increase of 0.2%. Distribution of grades for the continuation of the unit in semester two further reinforces this view as shown in Table 20.

Table 20: Distribution of grades for Chemistry 1A them in semester two, 2008 and semester two, 2009 at the University of Tasmania

| grades | % 2008 | % 2009 | Difference in % |
|---|---|---|---|
| HD | 10 | 10.4 | 0.4 |
| DN | 13.9 | 21.6 | 7.7 |
| CR | 29.2 | 23.0 | -6.2 |
| PP | 22.5 | 20.3 | -2.2 |
| TS | 10.5 | 8.62 | -1.9 |

According to Table 21, the % of failures decreased from 10.5% in 2008 to 8.62% in 2009, a fall of 1.9%; the % of Passes has dropped from 22.5% to 20.3%, a drop of 2.2%; the % of Credits dropped slightly from 29.2% in 2008 to 23% in 2009, a drop of 6.2%; the % of Distinctions increased from 13.9% in 2008 to 21.6% in 2009, an increase of 7.7%; and finally the % of High Distinctions increased from 10% in 2008 to 10.4% in 2009, an increase of 0.4%.

The consistent increase in the number of students obtaining Distinctions in both semesters in Chemistry 1A at the University of Tasmania seems to suggest that students who achieved above pass level tended to benefit from the language strategies implemented. This confirms the findings found in similar studies conducted at the University of Canberra in subjects such as genetics and molecular biology from 2005 to 2009 (Zhang & Lidbury, 2006).

In the Student Evaluation of Teaching and Learning (SETL) surveys conducted at the end of semesters one and two in 2009, the use of 'Votapedia' concept tests (Appendix B) and the extensive feedback for the online non-assessable 'concept tests' (Appendix C) were evaluated.

Table 21: SETL survey results for Chemistry 1A and Chemistry 1B in 2009 at the University of Tasmania

| Items | Subject | N | No answer % | Strongly agree % | Agree % | Neutral % | Disagree % | Strongly disagree % |
|---|---|---|---|---|---|---|---|---|
| 1. I value the feedback on my understanding gained by the use of in lecture 'votapedia' questions | Chemistry 1A | 139 | 8 | 12 | 38 | 33 | 7 | 2 |
| | Chemistry 1B | 117 | 21 | 5 | 27 | 34 | 9 | 4 |
| 2. The non-assessable 'concept tests' conducted on MyLo helped me answer the weekly assignment questions | Chemistry 1A | 139 | 0 | 23 | 42 | 20 | 13 | 2 |
| | Chemistry 1B | 117 | 0 | 16 | 53 | 18 | 11 | 2 |
| 3. The extensive feedback available when I make an incorrect response in the non-assessable 'concepts tests' are helpful | Chemistry 1A | 139 | 0 | 37 | 46 | 11 | 5 | 1 |
| | Chemistry 1B | 117 | 3 | 31 | 48 | 16 | 1 | 1 |

Most students agreed that Votapedia concept questions were useful during lectures. However, some 15% of the students would like more connection between the online concept questions and the Mylo assignments. This view was also confirmed by comments in the open-ended section of the SETL surveys.

## 5.4 Results of implementation at the University of Canberra

The results of the study conducted in 2005 were published (Zhang & Lidbury, 2006), and in short showed no significant increase in performance for either the theory examination or overall performance across the student cohort, compared to earlier student cohorts who had traditional transmissive teaching. Nor was there significant movement of students from Pass to Credit, or Credit to Distinction/High Distinction levels of overall attainment in the 2005 language cohort compared to earlier traditionally-taught genetic student cohorts. For all student cohorts compared, the final theory examination was identical and the continuous assessment tasks similar. Therefore, there was no significant impact on overall student cohort performance obtained from language-centred instruction.

However, when examining student performance at an individual level, an interesting association was found between performance in genetics and individual student performance across their whole degree measured by grade point average (GPA). There was a significant correlation (r = 0.64, p = 0.045) between student performance for genetics and degree GPA, but only for the Distinction students. Furthermore, this association between specific academic performance in genetics and overall degree performance (GPA) was only seen for the 2005 language cohort, and not any previous genetics distinction cohort taught under a traditional regime between 2001-2004 (Zhang & Lidbury, 2006). This finding was confirmed by the data for the same unit in 2006-2009. In 2008, on the University of Canberra's Unit satisfaction scale (USS) for the question 5: 'I received feedback that assisted my learning', the unit scored 5.6/7 and overall the unit scored 6/7 for overall satisfaction. The participating lecturer did not teach the unit in 2009. However, the implementation of the strategies used in this project was so easy that another lecturer implemented them successfully in 2009.

## 5.5 Results of implementation at The University of Newcastle

The examinations for this unit in 2008 and 2009 were comparable. However, at the time of completing this report, the only reportable data available was the grade distribution for both years

Table 22: Distribution of grades for Biology 1002 in semester two, 2008 and semester two, 2009 at The University of Newcastle

| grades | %08 | %09 | Difference in % |
|---|---|---|---|
| HD | 0.84 | 12.96 | 12.12 |
| DI | 8.02 | 20.65 | 12.63 |
| CR | 16.88 | 32.39 | 15.51 |
| P | 50.21 | 21.46 | -28.75 |
| F | 24.05 | 12.55 | -11.50 |

As shown in Table 22, significant increases in HD, DI and CR grades were achieved and the number of P grades drastically reduced by 28.75% and F grades by 11.5%. The trend of change was similar to the patterns demonstrated by the data at the University of Tasmania in Chemistry and Genetics at the University of Canberra.

Student evaluation data will be forthcoming in the near future.

## 5.6 Results of implementation at The University of Sydney

The content of the examination in 2009 was very different from that in 2008. Consequently, only a number of multiple choice questions in both exams were common and therefore could be compared. There was no common item between examinations for the Fundamental Chemistry unit (Chemistry 1001) and other two higher level Chemistry units (Chemistry 1101 and Chemistry 1901). Consequently, only results on Fundamental Chemistry are reported below.

Table 23: Distribution of marks in the multiple choice questions of the examinations in Chemistry 1001 in semester one, 2008 and semester one, 2009 at The University of Sydney

| MCQ question no. | average marks 2008 | average marks 2009 | Difference in marks |
|---|---|---|---|
| 19 | 35 | 41 | 6 |
| 20 | 56 | 60 | 4 |

| | | | |
|---|---|---|---|
| 21 | 79 | 82 | 3 |
| 22 | 68 | 66 | -2 |
| 23 | 91 | 92 | 1 |
| 24 | 54 | 83 | 29 |
| 25 | 80 | 84 | 4 |
| 26 | 75 | 78 | 3 |
| 27 | 92 | 91 | -1 |
| 28 | 78 | 86 | 8 |
| 29 | 32 | 47 | 15 |
| 30 | 92 | 93 | 1 |
| 31 | 81 | 94 | 13 |
| 32 | 60 | 72 | 12 |

Questions 24, 28, 29, 31 and 32 covered various topics such as acids/bases, transition metal complexes, periodicity, phase changes and metal complexes respectively and were taught by the participating lecturer. As shown in Table 23, the increases on these questions are quite large and can probably be attributed to the intervention strategies deployed.

According to The University of Sydney's Unit of study evaluation (USE), there was a marked improvement in Q3 ("This unit of study helped me develop valuable blue graduate attributes") from 3.30 to 3.51/ 5. This is most likely to be due to the report writing activity in the labs. Even though the score of 3.51/ 5 on Q3 attracted the lowest rating on the evaluation, it was still much higher than for other units across the faculty. Trying to embed graduate attributes in the students' first year and in a concept heavy course has always been a struggle.

There was also an improvement in Q12 ("Overall I was satisfied with the quality of this unit of study") from 4.16 to 4.23 /5. On this question, the 2008 score was very high in the Fundamentals of Chemistry unit (Chemistry 1001), which traditionally had been hated by the students, as almost all of whom would not have to take any more chemistry. Improving the score in Q12 again in 2009 was very pleasing. By comparison, this question averages about 3 – 3.5 /5 in other units in the Chemistry Faculty. From the lecturer's personal evaluation, on the question 'what did you like most in this unit?', comments from students include:

- "daily work sheets very effective in learning concepts"
- [positive] "questions to reinforce understanding"
- "we learnt concepts through thinking. Better than being told"
- "use of problem sheets engaged students. I'm used to falling asleep"
- "made everyone involved to increase learning, especially with work sheets and clickers"
- "interactive, made us do working/exercises during lectures!"
- "I liked the sheets he gave. More like a tutorial than a lecture. Liked having prizes – especially the chocolates"
- "made learning interesting"
- "the sheets and clickers were great for consolidation"
- "interactive learning"
- "critical thinking questions were awesome"
- "make other subjects – and other chemistry lecturers – use critical thinking questions and clickers"

- “liked working with my friends rather than listening/sleeping”
- “getting feedback from clickers every lecture:”
- “those clickers poll things were good.”

## 5.7 Project evaluation

Formative and summative evaluation processes were used. Formative evaluation was carried out at each stage of the project, through the design phases to pilot testing and final implementation to assess the day to day running of the project. The project leader and the project team were involved in the formative evaluation. Results of the formative evaluation were reported in progress reports to the ALTC.

All stakeholders were involved in summative evaluation. Student users, in particular, played a major role in this process. Evaluation design was informed by the practical experience of team members. It was also informed by recent research in the areas of evaluation of online learning, educational theory and interactive approaches to the teaching of science which were identified in literature cited in this report. In this project, typical summative evaluation practices used included different institutional student unit satisfaction or evaluation surveys, pre- and post-test language-oriented performance data, and examination results.

Evaluation of the implementation of project interventions showed:

- Students have demonstrated better achievement scores at every university and in every discipline with significant improvement in some universities;
- the retention rate for each subject in the discipline has improved;
- passing, credit, distinction and high distinction rates have improved dramatically;
- students’ perceptions of lecturers’ ability to teach has dramatically improved (as demonstrated by the end of semester student feedback forms);

The factors that were critical to the success of the project were:

- Skilled and motivated personnel: both the research team members and the research assistants employed came to the project with a high level of specialised discipline knowledge, networks and interest.
- An already established working relationship between the project leader Zhang and Lidbury, a relationship that is collaborative and productive in this and other projects.
- The support offered by the five universities: University of Canberra, The University of Sydney, University of Tasmania, University of Technology, Sydney and The University of Newcastle, in the form of: travel allowances and time; infrastructural support including space, technological and communication support, and administrative staff assistance; and also the interest and encouragement offered by colleagues and Deans. The project Leader, Dr Felicia Zhang and Dr Brett Lidbury have won a University of Canberra Award for Programs that Enhance Learning. University of Canberra for 2010.
- Strong leadership of project members who deliberately included postgraduate students in disciplines to provide input, and who have taken up some of the research and implementation work at some sites.
- Undergraduate students in disciplines who generously participated in the project thus contributing to the shaping of their study.
- The support and flexibility shown by ALTC staff in approving changes, and providing advice, throughout the project.
- High level of public presentation and publishing during the process meant that the ideas and knowledge developed have been subject to peer review

and discussion throughout the project.

Factors that impeded its success:

- Since the project leaders and project members also are senior academics/researchers, all were required to be heavily involved in this and other concurrent research projects and this ate into available time and energy.
- The five universities used different learning management systems (LMS) which made the construction and implementation of the language surveys and the language oriented exercises very time-consuming and difficult to implement. A consistent LMS such as Moodle for all universities involved would have been ideal but was not attainable during the project. For instance, hot potatoes exercises included in Attachment G are very easy to create and deploy. However, at this stage, they can only be easily deployed through Moodle. As UC is the only Moodle user, this meant that in order to deploy these exercises online in institutions using Blackboard (the other four institutions), these exercises had to be re-created onto that specific version of Blackboard. This was time consuming for the participating lecturers involved. Consequently, we adopted all MS Word document based exercises as these do not require redesigning to suit different versions of the Blackboard LMS.

General lessons learnt, including a reflection on the challenges and unexpected successes:

- Ensuring that project participants are familiar with their Learning Management System in their institutions.
- Use of current postgraduate students as RAs to complete the work under close supervision, to train them in the practice, build their confidence and ability as part of their career development, and help develop the disciplines through this expertise and succession planning.
- Knowing about other ALTC projects happening contemporaneously, and dovetailing with them.
- Engaging in high level of publishing during the process so that ideas and knowledge can be subject to peer review and input.

### *5.7.1 An analysis of the extent to which the approach/outcomes are amenable to implementation in a variety of institutions or locations*

The project demonstrated having a sustainable impact in the long term on student learning through affecting lecturer expertise in using these language strategies in their institutions. In some institutions, strong leadership on the part of the project member has meant a wholesale adoption of the learning strategies into the entire first year program involving all lecturers and tutors within the program in that institution.

Furthermore, the project has achieved excellent results in building knowledge, capacity and a community of practice with regard to incorporating educational practices in the day to day practice of science teaching in first year. It provides a successful and achievable model for a sustainable professional development of academic staff and for conducting research using online surveys. Instead of only reaping the benefit of improved classroom practice using reported inquiry practices after 80 hours of professional development (Supovitz & Turner, 2000), academic staff constructed and implemented intervention strategies themselves on a weekly basis over the course of two years thus greatly increasing the amount of professional development time. These model have the capacity to be implemented in any other academic discipline.

Strategies employed in the project have already been taken up by a number of other subjects outside the ones covered in this project at, for example, The University of Newcastle. The ease of use and flexibility afforded by the strategies developed in the project meant that wider uptake of project outcomes have already happened in some contexts.

## 5.8 Dissemination strategy

The dissemination strategy for this project consisted of both engagement and information provision.

Engagement was marked by the uptake of the project by first year science programs in Australian tertiary institutions and by a wider audience: both beyond the tertiary education sector and beyond Australia. As the project was a collaborative effort, wider uptake among these programs was a measure of the project outcomes and, in itself, was both a process and a mode of dissemination.

Information provision took place throughout the project: reports were written at the conclusion of each stage and distributed to the partner and reference group universities for their perusal and comment. Papers and conference presentations on the progress and findings of the project were reported at conferences to the wider academic community.

The project's website (see below) fulfilled both modes of dissemination: the online information repository supported the uptake of the project and promoted greater networking among educators nationally in the tertiary sector. Its resources will continue to open the project to the world, with overseas universities encouraged to link to it.

## 5.9 Dissemination of project outcomes

The major part of the dissemination process focuses on the higher education sector. The outcomes, in terms of knowledge generated, were and are being shared through publications and presentations (see section 6.4 below). This has put new knowledge into the literature on science education in general and especially in the areas of investigating the role of language in science education, curriculum design issues (such as assessment) and creating new and innovative models to design curricula.

## 5.10 ALTC Exchange

Another way through which these outcomes were shared was through the ALTC Exchange website. Educators within the higher education sector and other education systems.

The purpose-built interactive website of the project is on ALTC Exchange <http://www.altcexchange.edu.au/group/language-strategies-science-teaching> under the group: Language Strategies in Science Teaching. This website has been made public to anyone who is interested in science education.

A list of materials will be made available through ALTC Exchange at <http://www.altcexchange.edu.au/group/language-strategies-science-teaching>. These include:

- Project's final report.
- Downloadable zip files of the survey instruments used in each institution (Resource 1).
- Downloadable zip files of Votapedia concept questions in each discipline (Resource 2).
- Downloadable zip files of full feedback online Chemistry MCQs (Resource 3).
- Downloadable zip files of tutorial activity sheets for each discipline (Resource 4).
- Downloadable zip files of Hot potatoes exercises for each discipline

(Resource 5).

## 5.11 Conference presentations

The project team developed a number of materials (papers, posters and a showcase) which were presented by some members at national and international conferences in 2008 and 2009.

Published items include refereed papers from the 2008 National UniServe Science Symposium(Zhang et al., 2008), the AARE International Education Research Conference in 2009 (Zhang et al., 2009b), CONASTAS 58 in 2009 (Zhang et al., 2009a) and the 8th Teaching Matters Conference in 2009 (Yates et al., 2009) .

They also presented a showcase at the HERDSA 2009 conference (Zhang et al., 2009) and a refereed poster paper at the 2009 International East Asian Science Education conference (Zhang, 2009).

Accepted presentations to be delivered in 2010 include a refereed paper to be presented at the 2010 FYHE conference *Catering for the language needs of diverse first year science students,* see http://www.fyhe.com.au/, in addition to a paper *Integrating language learning practices in first year science disciplines* to be presented at the The International Conference on Learning and published in the International Journal of Learning, see <http://l10.cgpublisher.com/program-detail.html>.

## 5.12 Other methods

In addition to formal presentations, project information has been widely disseminated by provision of materials and engaging in conversations at the UniServe and other national conferences and a number of overseas conferences.

In September, 2009, Dr Felicia Zhang presented a workshop at the University of Canberra *The Use of clickers to promote institutional reform.* This workshop provided more evidence for the efficacy of using audience response devices in large class learning and thus leading to the wholesale adoption of using clickers in all first year science units at UC.

Printed copies of the report will be available for members to peruse and a PDF version of the report will be publicly available on the ALTC-Exchange website.

Forthcoming Book: Dr Felicia Zhang successfully secured a book contract from IGI Global, to publish a book based on this project's outcomes. The title of the book is *Sustainable Language Support Practices in Science Education: Technologies and Solutions*. All project members and other academics who are already adopting the strategies in their teaching have agreed to contribute book chapters for this book. The manuscript of the book will be finished by December, 2010 and will probably be out by June 2011.

## 5.13 Links with other ALTC-funded projects

This project also shared personnel and knowledge with an ALTC-funded project on leadership entitled: *Developing leaders of change in the teaching of large university chemistry classes*. Professor Brian Yates, Dr Michael Gardiner and Associate Professor Adam Bridgeman are on both teams. Strategies and ideas concerning the writing of science laboratory reports from the above project have also been incorporated into Associate Professor Adam Bridgeman's first year classes involved in this project.

Similarly, through the reference group, linkages were made with Professor Trevor Anderson, Head of the Science Education Research Group at the University of KwaZulu-Natal, South Africa; Professor Rob Norris from the Australian Council of Deans of Science; Associate Professor Roy Tasker from Royal Australian Chemical Institute (RACI) and Mr. Alex Barthel, director of the English Language Study Skills Assistance Centre at the University of Technology, Sydney. Alex Barthel is also the inaugural president of a new professional body, the Association for Academic Language and Learning. These international and national linkages will assist in the long term dissemination of the project's findings and deliverables.

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