Integrating Language Learning Practices in First Year Science Disciplines

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Abstract: One of the emerging issues is the changing nature and diversity of students in science. The project, 'A cross-disciplinary approach to language support for first year students in the physical sciences', commenced in October, 2007 and was funded by the Australian Learning and Teaching Council (ALTC), 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 (rather than for science students to write grammatically correct sentences or improve language use for ESL students) and the implicit teaching of meta-cognitive skills required in doing science. Eight strategies were employed in five universities and a number of positive outcomes have been obtained. Most noticeably, the demonstrable gains achieved by students at every university and in every discipline. Students' perception of lecturers' ability to teach has dramatically improved. The project is sustainable on student learning through affecting lecturer expertise in using these language strategies. It provides a successful and achievable model for sustainable professional development of academic staff.

Keywords: Science Education, Language and Meta-cognition

Introduction

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) in Australia. There is also a substantial body of literature concentrating on the first year experience at university (for example, in the Australian context, see Krause, Hartley, James, McInnis, & Centre for the Study of Higher Education. University of Melbourne, 2005). One of the particular concerns is that the diversity of the student body is rapidly increasing. Of course, with diversity comes with differentiated level of preparation for academic study within the student body.

Currently, there are two broad approaches to providing extra *academic (rather than language)* support to help students succeed during their first semester at university: (1) targeting all students who wish to participate in extra learning opportunities; or (2) 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

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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, S. Britton, A. George, S. Franklin, & A. 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 assumes 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 aim to offer language support to all students who attend lectures and tutorials thus developing an approach of academic support that supports *all* students.

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, 1975; Gardner & Australian Science Education Project, 1972; Pickersgill & Lock, 1991; Wandersee, 1988) further suggests that students have problems with both technical and non-technical vocabulary, especially with the logical connectives such as 'and', 'or', 'but', and 'although'. In other words, students have difficulty recognizing where a concept begins and ends and therefore cannot put different concepts into relation (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 and therefore pose fewer difficulties than vocabulary used in normal English as well as in a science context. For example, 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 thus causing confusion in students with scientific terms. Researchers have studied semantics of such words in physics (Touger, 1991; Williams, 1999).

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 what students 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 analyze data, how we formulate hypotheses and conclusions, how we connect theories, models, and data, how we relate our work and result 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 (Lemke, 1998) dialogues 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 also argue that the dialogues also involve the use of meta-language of learning such as checking, problem solving, reflecting and so on; students also learn how to synthesis, monitor, critique and reflect on the information gathered in the process of learning. Furthermore, acquiring scientific terms is, of course, a fundamental part of scientific literacy education which would include the ability to read and write science texts, a dominant genre used by practicing scientists (Yore, Hand, & Prain, 2002).

In this project, 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 *explicitly model* (a verb) how to test reality 'by checking, monitoring, coordinating, and controlling deliberate attempts to execute learning activity (Koch, 2001, p. 760). 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 promotes 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 the three-language (home language, instructional language, science language) problem that exists for most science language learners is acknowledged as parallel to that of English language learning. Like in foreign language learning, learners also need to move across many discourse communities of their family, school, science and foreign language cultures. However, as pointed out by Yore (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 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. This project also documents the effects on student learning as well as 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 meta-cognition is central to constructivist perspectives of learning. This idea was reaffirmed and embraced by Yore (2006). Meta-cognition 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).

The eight strategies outlined in Table 1 below all promote some aspects of meta-cognition.

Table 1: Strategies Implemented in the Project and the Research that Supported them

Strategies	Experimental Sites	Meta-cognitive Skills Practiced	Research Supporting the 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 & Tobin, 2001)
2. Students are provided with a list of terms and, through the process of group work, place these terms in relation	University of Newcastle, University of Canberra.	Physical concept mapping, exploring relationships between each term	Wellington and Osborne (2001), (Roth & Roychoudhury, 1994)
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, 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	University of Newcastle	Explicit instruction on how to acquire new vocabulary and how to see patterns in the roots and origins of words.	Wellington and Osborne (2001)

7. Using warm up activities such as matching scientific terms to definitions for revision purposes	University of Newcastle	Categorising and systematising terms	(Richardson & Zhang, 2008; Richardson, Zhang, & Lidbury, 2008)
8. Using of flashcards for vocabulary revision, creating a glossary	University of Newcastle, University of Canberra	Metalinguistic maintenance	(Zhang & Lidbury, 2006)

Building on Existing Knowledge on Pedagogical Advances

Research into why students did so poorly in college level physics course has been going on since 1985 and 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. Work has been carried out on two fronts: (1) to establish diagnostic instruments to diagnose students misconceptions using tools such as concept inventories; (2) to explore different ways of organizing 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 *Physics*, 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 and learning.

In the meantime, many researchers have also invested a great deal of energy in investigating 'how' problem areas identified by the diagnostic tools cited above can be taught better (a teaching perspective) or how learning activities can be organised better to enable better learner outcome in science education. In chemistry, some radical suggestions for reform have been about whether to teach introductory level of 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 not having much impact. The textbooks used in the two chemistry cohorts involved in this project, Chemistry by Blackman, Bottle, Schmid and Mocerino; and Chemistry: The Molecular Science by Moor, 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 and very rarely then teach the macro level of chemistry. However, other researchers, rather than arguing for a complete departure from the traditional sequencing of chemistry content in introductory courses, utilised planned cognitive conflicts by confronting students with a phenomenon that cannot be explained with their prior knowledge (Dreyfus, Jungwirth, & Eliovitch, 1990; Nieswandt, 2001).

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

Interactive Engagement (IE) strategies have been shown to enhance learning gains in physics. 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 and 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.

Harvard's physics Professor Eric Mazur (Crouch & Mazur, 2001) implemented 'Peer Instruction'(PI) which also used interactive-engagement strategies. Data obtained in classes using PI in a variety of disciplines show that learning gains nearly tripled. Most importantly, students not only performed better on a variety of conceptual assessments, but also improved 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 tool, visualization 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 United States. Studio teaching consisted of a mixture of student exercises, instructor coaching, and sometimes laboratory experiments, drawing their inspiration from the idea of interactive learning and generally taking advantage of modern technology to deliver instructional materials (Cummings, Marx, Thornton, & Kuhl, 1999; Pipes, 1996; Roy, 2003).

Contribution of Previous Research into the Project

From lecture and tutorial observations, several factors emerged as inhibiting factors preventing the teaching of first year sciences in the form of studio and IE classes in this project. These factors were:

- Physical space: lectures 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 (ranged from less than 100 to 500) affected not only delivery but also assessment. In order to manage such large numbers, assignments and tests are mainly conducted online and involved multiple-choice questions so that

the Learning Manage System (LMS) in each institution could automatically calculate and assign grades to each student.

- Time pressure of tests was another factor. For instance, in mid-semester test for Chemistry 1A at the University of Tasmania in 2008, students were required to answer some 50 questions in fifty minutes. These questions included short answer questions which required 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 needed 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 in 2008.
- Coverage and the service teaching nature of the units: the coverage of the content in each discipline was enormous and often beyond the control of the unit convenors.
- Lack of communicative skills: from the class observations, students in all 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 had been delivered in the traditional transmissive mode at each institution prior to 2009. In 2009, the implementation period of the project, studio teaching and radical changes in curriculum design are simply too expensive to implement or too disruptive to other lecturers who co-teach with the participating lecturers. 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 the eight interactive strategies, listed in Table 1, implemented by the lecturers themselves.

In this project, activities were designed to be based on direct experience as far as possible (Boud, 1993) and reflection was seen as important in building understanding (Schon, 1987). Finally, students and staff were participating in academic communities of practice (Lave & Wenger, 1991).

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 are extremely accomplished and knowledgeable individuals in their own disciplines. By participating in this project, they are positively recognizing the possible contribution education theories and practices can make to their teaching. The involvement of the educationalist was a way of establishing a mutually-beneficial learning relationship so that science academics and the educationalist could 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 chose to do science without the necessary pre-requisites.

In this model, changes in teaching approach were explored through a co-teaching or peer coaching approach (Ladyshewsky, 2006; Roth, 1988; Roth, Tobin, Zimmermann, Bryant, & Davis, 2002) in which the education/language expert shared with the science academic techniques and strategies used in language teaching in a constructivist model while the science academic 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.

In the project, we undertook to do the following:

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

The FTF protocol consists of the following phases:

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

Implementation at Each University

University of Tasmania

At UTAS, 2008 and 2009 had 209 and 222 students respectively. In 2009, in the implementation phase of the project, in both semester one and two of 2009, Votapedia questions were used during the lectures as well as pre-lecture multiple-choice questions with full feedback were provided to students on their LMS. In order to ensure full participation by students, access to assignments (which contributed 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 UTAS 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 (*http://www.votapedia.com/index.php?title=Main_Page*). At UTAS, when this was implemented in the lecture theatre.

University of Technology, Sydney

UTS used clickers in 2009. This was complemented by small group student to student group discussions (Technique 1 and 3 in Table 1) 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 involved the implementation of technique 5 in Table 1. The research team involved in physics 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 Wiley plus website consisted mainly of calculation types of questions.

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 surveys' (J, Schulte, personal communication, May 28, 2009) which tested the language used in physics. At UTS in this unit, there was only a one-hour tutorial available every fortnight for the students. During these tutorials, the lecturer also incorporated multiple choice and concept questions related to language use through small group activities. 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 college. 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 had two things in common: (1) the word 'force' was used as 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 UTS, the textbook used by this group of students was *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 gives 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 at UTS.

During semester one in 2009 at UTS, two calculation type tests and a final exam were conducted. This enabled the results of these tests and exam to be compared with similar tests and exam used in semester one 2008.

University of Canberra

Research involving the use of foreign language interventions such as the ones mentioned in Table 1 was conducted in 2005 in the unit Genetics at UC. For example, the cloze technique, also known as the fill in the blanks or gap-fill exercise, to reading biology texts was used extensively to enable students to learn molecular biology language. Rather than simply passive reading the text, the exercise was designed to encourage students to construct the meaning of the work via filling gaps, deliberately introduced into the text. To do this successfully, students needed to actively read the journal article text 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 synthesizing and evaluating the information embedded in the passage. This kind of tasks was created by free-software called Hot Potatoes ™ 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, group "mix-and-match" exercises, text translation and deconstructing scientific words, expressing concepts in pictorial form can be created. Again, these examples used student action in some way to encourage active learning. This included having students leave their seats and move around the tutorial room.

University of Newcastle

At Newcastle, in the subject Biology 1002, 2008 and 2009 had 209 and 250 students respectively. In semester 2, 2009, in the implementation phase of the project, Votapedia questions were used during the lectures as well as online revision exercises and tutorial activities over a period of three weeks out of a total of thirteen 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). However, only 18 students participated. In semester two 2009, in order to increase the number of students participating, the Test 1 and 2 of the language surveys were built as part of the out of class non-assessable assessment items. At the end of 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 .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 participation rate for the unit rose to 30.4%.

During semester two in 2009, the language strategies were implemented for three weeks over 4 hours per week. In the second two hour block of each week, the language exercises 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.

University of Sydney

At USyd, the first year Chemistry student body consisted of three different cohorts, namely 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 add up to about 1000 students. The participating lecturer only taught 5 of the 13 weeks of the Fundamental Chemistry unit. This corresponded to 3 lectures per week (i.e. 6 per week altogether) and 2 tutorials a week. The remaining 8 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 hand outs 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, 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 students' ability to write properly structured scientific reports in place of the 'fill in the box' activities used elsewhere.

Ethics approval for surveying and communicating with participants was given and monitored by the UC Ethics Committee; project no 07-441. Each participating institution had also obtained Ethics approval for their participation in this project.

Results of Implementation from each Institution

Results of Implementation at the University of Technology, Sydney

The final exams in physics at UTS in 2008 and 2009 consisted of 8 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's final exams could be used for comparative purposes.

Table 2: UTS Physics, Semester 1, 2008 and 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
% of 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 indicates the % of students who obtained full marks for this section. The information in Table 2 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. From the 'momentum' section, the increase is 8.37%. In the 'forces' section, the 2009 cohort of students outperformed the 2008 cohort by 9.5%. In the 'energy conservation' section, 2008 students outperformed the 2009 students by 9.5%. We also used the Z test to compare the 2 independent proportions and it is found that only the change in the 'forces' section is highly significant ($p=0.000$ to three decimal points) and with the change in the 'energy' section approaching but not reaching statistical significance with $p=0.07$.

Table 3: Achievement Results by Students Attending Lectures (n=108) and Students who did not Attend Lectures (n=85) at UTS

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	0.016*
Test B	2.28	2.99	0.003**
Wiley	5.15	8.46	.000**
Quiz	0.52	0.69	.001*
Key: *p<0.05, **p<0.005			

The lecture and non lecture attendances groups were self-selected. Students who attended lectures used clickers as each clicker was registered under each student's student number. This also made it possible to collect information on who performed in the in class clicker questions on a weekly basis. Setting the significance level as $p < 0.05$; the above table 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 'attendance group' failed the unit compared to the 68% in the non-attendance 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 Student Feedback Results which showed that 50% of students complaint 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. (from open ended questions section of the Student Feedback Results)

In 2009, semester one, the tutorial classes were renamed as 'workshops' and language strategies were consistently and extensively included. These interventions improved the rating on feedback to 3.56/5 with hardly any more complaints 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 small group work and they were introduced to this through this project. However, such arrangements are resource intensive. Nevertheless, students have obviously clearly identified the preferred mode of learning as a result of this project.

Results of Implementation at the University of Tasmania

At UTAS, results on final exam and the distribution of the final grades in semester one and two in 2008-9 are reported.

Table 4: Distribution of Grades for the Unit in Semester One, 2008 and 2009 at UTAS

Grades	**%08**	**%09**	**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

Table 4 illustrates the distribution of the grades for semesters 1 in 2008 to 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 Distinction 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 5.

Table 5: Distribution of Grades for the Unit in Semester Two, 2008 & 2009 at UTAS

Grades	**%08**	**%09**	**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 5, the % of failures has 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 has dropped slightly from 29.2% in 2008 to 23% in 2009, a drop of 6.2%; the % of Distinction has increased from 13.9% in 2008 to 21.6% in 2009, an increase of 7.7%; and finally the % of High Distinctions has 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 at UTAS seems to suggest that students who are above pass level tended to benefit from the language strategies implemented. This confirms the findings found in similar studies conducted at UC in subjects such as genetics and molecular biology from 2005 to 2009.

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

Table 6: SETL Survey Results for Chemistry 1A and Chemistry 1B in 2009 at UTAS

Items	**Subject**	**N**	**No Answer %**	**Strongly Agree %**	**Agree %**	**Neutral %**	**Disagree %**	**Strong 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.

Results of Implementation at the University of Canberra

The results of the study conducted in 2005 had been published (Zhang & Lidbury, 2006), and in short 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 in the same unit in 2006-2009. In 2008, on UC'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.

Results of Implementation at the University of Newcastle

The exams for Biology 1002 in 2008 and 2009 were comparable.

Table 7: Distribution of Grades for Biology 1002 in Semester Two, 2008 and 2009 at 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	-11.5

As show in Table 7, significant increases in HD, Di and Cr grades had been achieved and the number of P grades drastically reduced by 28.75% and Fail grades by 11.5%. The trend of change was similar to the patterns demonstrated by the data at UTAS in Chemistry and Genetics at UC.

Results of Implementation at the University of Sydney

The content of the exam 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 exams for the Fundamental Chemistry unit and other two higher level Chemistry units. Consequently, only results on Fundamental Chemistry are reported below.

Table 8: 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 08	Average Marks 09	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

Q24, 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 8, the increases on these questions are quite large and can probably be attributed to the intervention strategies deployed.

According USyd's Unit of Study Evaluation (USE), there was a marked improvement in Q3 ("This unit of study helped me develop valuable graduate attributes") from 3.30 to 3.51/ 5. This was 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 is still much higher than other units across the faculty. Trying to embed graduate attributes in first year and in a concept heavy course was always a struggle.

There was also a marked 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 and improving it again in 2009 was very pleasing. In the Fundamentals of Chemistry unit (Chem 1101) and traditionally has been hated by the students, as virtually all of whom would not have to take any more chemistry. 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 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."

Conclusion

In conclusion, the evaluation of the implementation of project interventions showed:

- Students demonstrated better achievement scores at almost every university and in every discipline with significant improvement in some universities;
- the retention rate for most subject in the discipline (as demonstrated by lower failure and higher passing, credit, distinction and high distinction rates) also improved dramatically;
- students' perception of lecturers' ability to teach had dramatically improved (as demonstrated by the end of semester student feedback forms);
- strategies employed in the project have already been taken up by a number of other subjects outside the units 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.

The project has demonstrated as having sustainable impact, in the long term, on student learning through affecting lecturer expertise in using these language strategies. 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 regards 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 models have the capacity to be implemented in any other academic disciplines.

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