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

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A key goal of the study entitled ‘A cross-disciplinary approach to language support for first-year students in the science disciplines’, funded by the Australian Learning and Teaching Council, is to examine the role of language in the learning of science by first-year university students. The disciplines involved are physics, chemistry and biology. This national project also aims to transfer active learning skills, which are widely used in language teaching, to the teaching of science in first year. The paper discusses the background to the study and reports preliminary results on the language difficulties faced by first-year science student cohorts from data collected in 2008 as well as qualitative data was also collected on 2008 students’ attitudes towards online science learning.

Keywords: first-year science teaching, role of language in science teaching, active learning skills

Introduction

This study reports on a project that aims to address the need to cater for the language requirements of a diverse student body by investigating strategic approaches to learning and teaching in first-year sciences in tertiary education. The disciplines covered by the project are biology, chemistry and physics and involves the University of Canberra (UC), University of Sydney (USyd), University of Tasmania (UTAS), University of Technology, Sydney (UTS) and University of Newcastle (Newcastle) in Australia.

Specialist terminology in biology, chemistry and physics has proved difficult for most students (Wellington & Osborne, 2001). Students have difficulty recognizing where a concept begins and ends and therefore cannot differentiate concepts. Zhang and Lidbury (2006) identified difficulties with language as contributing significantly to problems students experience in studying science (specifically genetics). In this study, we seek to implement language-oriented strategies developed by Zhang and Lidbury (2006) for first-year biology, chemistry and physics lectures and tutorials with the aim of evaluating the benefits of those methods.

Table 1: Proposed language-oriented techniques to be implemented in the project

1.	Small-group work in tutorials using guided questions.
2.	Students are provided with a list of terms and, through the process of group work, place these terms in relation.
3	Giving students opportunities to put forward their points of view in groups.
4.	Using online language exercises such as crosswords, gap-fill (Cloze) exercises.
5.	Providing stimulus quizzes for lecture and tutorial materials on WebCT thus encouraging students to prepare before the lecture.
6.	Attaching sound files to vocabulary
7.	Breaking down long words to aid memory by identifying prefixes and suffixes, and exploring the roots and origin of words. (UTAS, USyd, Newcastle)
8.	Using warm up activities such as matching scientific terms to definitions for revision purposes. (Newcastle)
9.	Using of flashcards for vocabulary revision (Newcastle, Usyd)
10.	Role playing: students practise conveying complex scientific discoveries to the public. (Newcastle)

Context and characteristics of the students

Students undertaking tertiary studies in science are a highly diverse group. For example, at the University of Sydney (USyd) in 2008 there are 969 students from various faculties in the first-year chemistry cohort. Three-hundred and eighty eight students have little or no HSC chemistry; while 116 students have very high UAI chemistry scores (greater than 98 for veterinary science students). With such a diverse group there is, naturally, a wide range of interest in and aptitude for the subject. Such diversity is typical in cohorts in biology, chemistry and physics at the participating Australian universities in this project.

Progress of the project

In the first six months of the project, an initial baseline language difficulty questionnaire was distributed in UTS, UTAS and USyd by the end of April, 2008. The language expert visited UTS, UTAS and USyd to observe classes and implemented the questionnaire in April, 2008. For the genetics unit at the University of Canberra (UC) and first-year biology at the University of Newcastle, it was decided to replicate this phase of the project in Semester 2, 2008 when the participating lecturers were teaching. This constitutes Stage 1 of the project in Figure 1.

Stage 1.1 Identifying content in 2008

In 2008, the language expert (FZZ) in the project, who is an academic but not in science, visited each partner institution and collected disciplinary content. This included textbooks, lecture slides, tutorial materials and laboratory materials. Access to the learning management system (LMS) was also obtained from each institution. Information on the teaching context was also collected. Due to lack of space, this information will not be provided here. The language expert (FZZ) then proceeded to 'learn' the collected materials with the help of the disciplinary lecturers. During the process of learning, she noted down difficulties encountered and inconsistencies of information. She also created language-oriented exercises as templates for future development. In subsequent meetings, the team discussed appropriate strategies and a plan of action for implementing them.

Stage 1.2 Observation of lectures in Semester 1, 2008

The language expert (FZZ) visited three institutions (UTS, UTAS and USyd) in semester one, 2008. During the lectures, the language expert observed the teaching. The same procedure was used during all observation sessions in each institution. Several main factors emerged as inhibiting factors preventing the teaching of first-year sciences in a more interactive mode 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 affected assessment as well as delivery. In order to manage such large numbers, assignments and tests are mainly conducted online and involve multiple-choice questions, so that the LMS can automatically calculate and assign grades to each student.
- Difficulty of the class tests. For instance, in mid-semester test for Chemistry 1A at UTAS, students were required to answer some 50 questions in fifty minutes. Class tests generally involve short answer questions, which required calculation and transformation of items such as from a chemical formula to a diagram and so on. 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 physics modelling lecture at UTS, 20 slides will be 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 unit convenors because these first-year units are service units.
- Lack of communicative skills: from the class observation, students in all three institutions did not demonstrate skills in speaking and writing about science and they are not practiced at transferring or communicating what they have learned to other people.

The language expert (FZZ) also discussed with lecturers appropriate places to implement the intervention in Stage 2 of the project. Stage 2 of Figure 1 illustrates the teaching contexts in which interventions are to be implemented.

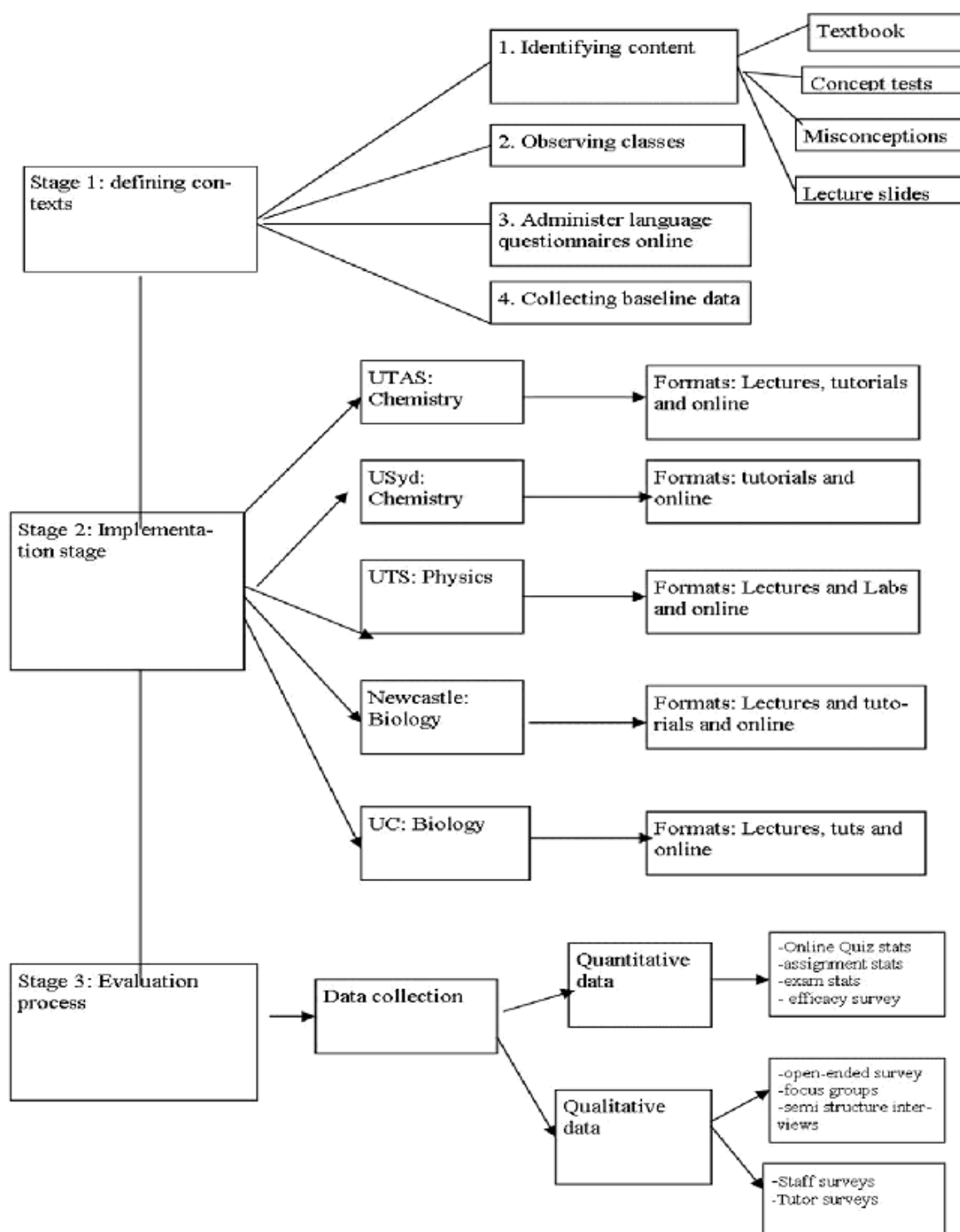


Figure 1: Stages of the project 2008–2009

Stage 1.3 Administration of the language difficulty questionnaires

In this project, we adopted a model which varied slightly from that of Jacobs (Jacobs, 1989). We distributed one questionnaire through the LMS of the participating institutions. In this questionnaire, we tested comprehension of ten common terms. The examined terms are; ‘research’, ‘power’, ‘concentration’, ‘equilibrium’, ‘graph’, ‘system’, ‘equation’, ‘experiment’, ‘model’ and ‘significant’. The criteria for selection of the words were that they have 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’ for the chemistry and physics disciplines, 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).

Students were then provided with five answers for this question as shown in Table 2.

Table 2: Student responses

	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 is allocated five marks. If a student chose the three correct answers, she/he should score 15/15. This indicates a *complete* understanding of the term in different contexts. Any score less than 15 suggest an incomplete understanding of the term. All ten terms followed a similar format. Then in the second part following each question was a related confidence question which assessed how confident a student was of the choice(s) he/she made, as shown in Table 3.

Table 3: Confidence responses

	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%

Questionnaire response rate

At UTS’ first-year Physics Modelling unit, this questionnaire was distributed voluntarily to all students in the unit. A similar procedure was followed at UTAS. At USyd, the questionnaire was distributed to about 1000 students in first-year chemistry. The 969 students have been divided into three cohorts of students (see Table 4).

USyd and UTAS are using the *Blackboard* LMS (formerly *WebCT*) which allows printable statistics for a cohort of students to be obtained for each questionnaire. From the printable statistics, the percentage of students who have demonstrated a complete understanding of a term in different contexts and how confident they are of their understanding can be obtained. If we divide the ‘yes’ confidence level (column 2) by the percentage of students demonstrating a 100% understanding (Table 5, column 3), we are able to establish a ‘delusion index’. A high value in the ‘delusion index’ column suggests that students are highly delusional about their understanding of a particular term.

Table 4: Questionnaire response distribution from the five universities

Institutions	Units	Questionnaire responses	Total no. distributed	Response rate (%)
UTS	Physical Modelling 68037	40	412	9.7
UTAS	Chemistry 1A	29	272	10
USyd	Chem1001	60	388	15.5
	Chem1101	95	465	20.5
	Chem1901	19	116	16.4
NEWCASTLE	Biology 1002	18	237	7.6
UC*	Genetics 6531*	66	75	88
Total		243	1653	13.4 (average)

*At UC, the questionnaires were distributed to second-year students at the same time in a computer laboratory. Therefore, the compliance rate was much higher. The response rate figure for UC has been excluded from the average for response rate.

For instance, for the term ‘power’ in Table 5, 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 has delusion index of 29.95. If we look at the term ‘significant’ with a delusion index of 29.95, it means that students are highly delusional of their understanding. This is demonstrated by only 1.9% of the student body understood 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) is also provided by examining the percentage of students who achieved 100% understanding of any terms. Below are the tables showing the results of this questionnaire from USyd, UTAS, Newcastle and University of Canberra.

Analysis of data

Chemistry discipline

Table 5: Chem1001 (Fundamental students with no previous HSC chemistry) at USyd

Terms	Yes	100% understanding	Delusion index	Ranking (easiest=1, hardest=10)
Significant	56.90	1.90	29.95	10.00
Model	64.70	15.40	4.20	9.00
Power	31.70	24.60	1.29	8.00
System	45.10	26.90	1.68	7.00
Equilibrium	59.30	32.10	1.85	6.00
Research	64.10	36.90	1.74	5.00
Concentration	80.40	43.90	1.83	4.00
Graph	84.90	49.10	1.73	3.00
Equation	82.70	53.80	1.54	2.00
Experiment	78.80	75.00	1.05	1.00

Table 6: Chem1101 (students with HSC chemistry) at USyd

Terms	Yes	100% understanding	Delusion index	Ranking (easiest=1,hardest=10)
Significant	51.80	4.80	10.79	10.00
Model	67.50	18.10	3.73	9.00
Power	41.60	19.30	2.16	8.00
Research	62.40	20.00	3.12	7.00
System	53.00	28.60	1.85	6.00
Equilibrium	83.50	50.60	1.65	5.00
Concentration	80.20	51.20	1.57	4.00
Graph	83.30	53.60	1.55	3.00
Equation	78.30	57.80	1.35	2.00
Experiment	67.10	68.70	0.98	1.00

Table 7: Chem1901 (students with HSC chemistry and high UAI) at USyd

Terms	Yes	100% of understanding	delusion index	Ranking (easiest=1, hardest=10)
Significant	64.70	5.60	11.55	10.00
Research	60.00	28.60	2.10	9.00
Power	26.30	28.60	0.92	8.00
System	50.00	31.60	1.58	7.00
Model	64.70	50.00	1.29	6.00
Graph	94.40	52.60	1.79	5.00
Equation	94.10	55.60	1.69	4.00
Equilibrium	88.90	57.90	1.54	3.00
Concentration	84.20	60.00	1.40	2.00
Experiment	82.40	77.80	1.06	1.00

Table 8: Chemistry 1A (mixed cohort) at UTAS

Terms	Yes	100% understanding	Delusion index	Ranking (easiest=1,hardest=10)
Significant	48.40	3.20	15.13	10.00
Research	73.50	9.10	8.08	9.00
Model	48.40	12.90	3.75	8.00
System	58.10	19.40	2.99	7.00
Power	48.40	22.60	2.14	6.00
Concentration	87.10	25.80	3.38	5.00
Equilibrium	76.70	32.30	2.37	4.00
Equation	77.40	35.50	2.18	3.00
Graph	87.10	41.90	2.08	2.00
Experiment	83.90	71.00	1.18	1.00

The data in Tables 5–8 suggest that terms such as ‘model’, ‘significant’, ‘research’, ‘power’ and ‘system’ are 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 UTAS and USyd, 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.

Physics discipline

The questionnaires were constructed slightly differently at UTS. Only five terms were used and no confidence questions were posed. Out of the five terms, ‘concentration’ which was used in chemistry questionnaires at USyd and UTAS, had been changed to ‘density’ as this is more suited in the physics context. However, it was not possible to derive a ‘delusion index’.

Table 9: Physical Modelling students at UTS

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

Biology discipline

The questionnaires were also distributed to first-year students at the University of Newcastle and second-year students at UC. Since both these universities are involved in the discipline of Biology, the same language difficulty questionnaire appropriate to Biology was distributed.

Table 10: University of Newcastle, Biology 1002

Terms	Yes	100% understanding	Delusion index	Ranking (easiest=1,hardest=10)
Significant	44.44	33.33	1.33	9.00
Equation	72.22	38.89	0.54	8.00
Research	77.78	44.44	0.57	7.00
Equilibrium	66.67	50.00	0.75	6.00
Concentration	77.78	61.10	0.79	5.00
Power	44.44	66.67	1.50	4.00
Graph	88.89	77.78	0.88	3.00
Experiment	66.67	83.30	1.25	2.00
System	72.22	88.89	1.23	1.00

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 11: University of Canberra, second-year Genetics 6531, 2008

Terms	Yes	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

In conclusion, the results reported above show that the students from the five institutions had problems with the ten terms tested. This signals an urgent need for language focussed training in the teaching of first-year science.

Methods

The project is to be carried out in two years. In 2008, the control part of the project, no intervention took place except the implementation of language difficulty questionnaires. During this phase, lecturers taught the subject matter as they would normally deliver the material and students were assessed in the normal fashion. Assessment data collected during this phase constitutes baseline data to which data from the experimental phase of the project in 2009 will be compared. 2008 students constitute the control groups of students. Students, in 2009, in the participating universities constitute the experimental groups of students.

The next step in the project is for the language expert to work alongside the science lecturers to find the best possible ways of implementing the strategies listed in Table 1. Having identified in phase 1 of the project that there is a huge gap in students' understanding of common scientific words, we intend to enhance student awareness of the language used in each disciplines perhaps by *inspiring* them 'to recognise that scientific discourses are a specialised subset of ordinary language, requiring constant alertness to precision and the possibility of idiosyncratic meaning' (Jacobs, 1989). In order to 'inspire' students, we intend to implement a range of language-specific education techniques to (1) alert students that precision of these terms in science is important and (2) explain how to check that they are being precise when using these terms. Zhang and Lidbury (2006) implemented a range of language-specific educational techniques to encourage such thinking. Results of Zhang and Lidbury (2006)'s study suggested that students favoured the use of small-group work to acquire difficult and abstract genetic concepts.

Small-group work is one of the active learning practices under study. The benefits of small-group work have been established for a wide range of applications in science (see (Fagen, 2003) for a review). In connection with language problems, Wellington and Osborne (2001) suggest that time needs to be spent discussing and explaining the meaning of the words by the students, themselves (in small groups), rather than relying on the meaning of the words to be 'caught' haphazardly. Small-group work is also the keystone of *communicative language teaching* methodology (that being the dominant language teaching method). Yager (1983) stated that the amount of new vocabulary students encounter in an introductory biology

course often exceeds that in a beginning foreign language course and this represents a significant stumbling block for many students (Wandersee, 1988). In this project, unlike lecturing, small-group work is used as it is a dialogical process promoting the negotiation of meaning and thus capable of responding to diverse student needs and identities. Furthermore, small-group work provides a privileged opportunity for the contextualization of concepts, which is to say the organization of concepts into holistic schema. However, in some institutions such as UTS, it might be difficult to build in small-group activities in the learning process due to institutional constraints. This issue is still being explored.

Consequently, based on the literature review, we decided to implement (1) a face-to-face (FTF) learner-centred, interactive lecturing protocol and (2) online content and language support for learners (ONLINE) in the experimental phase of the project.

The FTF protocol consists of the following phases:

1. During each lecture, the lecturer builds into the lecture materials, short survey questions made available on votapedia (<http://www.votapedia.com>) to offer feedback on lecture content. This tool will be used at UC, Newcastle, UTAS and possibly USyd. UTS currently uses clickers and therefore the use of clickers will continue there. This might be followed by small-group student-to-student group discussions (technique 3 in Table 1) and then students-to-teacher discussion. On average, in a two-hour lecture block, eight survey questions will be used.
2. During tutorials, interactive activities are introduced. Such interactive activities can include small-group discussions involving the linking of concepts learned (technique 2 in Table 1) and activities related to technique 7, 8 or 10 in Table 1.

In the ONLINE protocol, students are presented with a number of quizzes online before each lecture each week. This protocol involves the implementation of techniques 4 and 9. The research team involved in each discipline will create, implement and collect data on a set of language specific online quizzes for the respective disciplines. These quizzes can be designed for students to think about the lecture materials in the next lecture or as a checking mechanism for what they already know or do not know. They can be in a variety of forms such as multiple-choice questions, matching, fill in the blanks, jumbled up sentences. They will be constructed to suit the LMS of each individual institution. In order to ensure full participation by students, access to an assignment will be conditional on the completion of these quizzes.

Evaluation

The project draws on the following data collection methods to evaluate the research:

- pre- and post-tests focussed on language issues (at the beginning and end of 2008 and 2009);
- efficacy questionnaires from students in the experimental groups regarding the students' perceived ability in each discipline will be administered at the end of semester 1 and 2 in 2009;
- examination , test marks and assignment marks; and
- student and staff focused group interviews.

It is envisaged that the FTF and ONLINE protocols will improve experimental groups of students' understanding in the various disciplines as demonstrated by their better examination and test marks when compared to the control groups' results.

Conclusion and implications

One of the major issues we encountered in conducting this research is student participation, especially online. We distributed the first language questionnaires on a voluntary basis in 2008, resulting in fairly low response rate (Table 4 with the exception of UC's genetics data). Due to the low participation rate at the end of semester 1 and 2 in 2008, no analysis was carried out on the data. In order to increase participation online, the team decided to make questionnaires and online exercises conditional, so that they must be completed before an assessment item which counts towards marks would be made available to students. This is already part of the normal assessment practice in most participating institutions except UTAS.

In second semester 2008, the first-year chemistry coordinator at UTAS trialled a conditional self-test which needed to be completed before an actual assessment could be accessed by students. The lecturer deliberately and explicitly linked items in the self-test to the content of the following assessment. He also conducted a survey on the efficacy of this type of self-test.

Table 12: Data collected on the efficacy of the non-assessable self-test at UTAS

Questions	Strongly agree (%)	Agree (%)	Neutral (%)	Disagree (%)
1. The non-assessable Self-Test was useful and worth the time as a preliminary to the assignment?	4.9	22.7	37.4	22.7
2. I feel that the time I spent on the Self-Test was made up in the speed that I could complete the assignment.	4.9	22.7	37.4	22.7
3. Even though I didn't put effort into the Self-Test, I used the answers to help me in the assignment.	30.2	33.3	7.4	29
4. Cross-referencing the Self-Test questions with the relevant assignment questions was good as I knew where to look for "hints".	13.6	43.8	26.5	3.7
5. Were there too many questions in this trial Self-Test, even though each one introduced a new concept required for the assignment questions?	9.4	33/8	27.5	21.2
6. The Self-Test, with full feedback provided, is a good compromise to the limited feedback that can be provided for the assignment itself (which we have chosen to limit in order to maximise the independent completion of the assignments).	24.2	47.8	20.5	3.7
7. I liked the "exam time equivalent" information given at the start of the questions this week as a guide for the expectations in this topic.	35.6	43.8	19.6	1.2

From the response to the question "If Self-Tests was implemented each week for this unit next year, accessing the assignment should be conditional on you attempting the Self-Test?" 42.9% responded with 'true' and 57.1% responded with 'false. Similarly, students felt the number of questions contained in such a test should be between 10–15 questions and they

should be open for about an hour for students to complete. Similarly, students preferred that an achievement of 50% on the self-test should lead to access to the assignment.

The data in Table 12 clearly shows that students liked the links between this self-test to the assignment (item 1, 2, 3 4 and 7 of Table 12). They clearly liked to have full feedback rather than limited feedback. This reinforces the need to enable connections between pieces of knowledge to be made by students. Take Biology 1002 at the University of Newcastle, for instance, in a total three hours of face-to-face lecture and tutorials, there is not much interaction between the lecturer and students. Students are required to do three practice tests and an assignment, which is graded, and a final exam for the component that is part of this project. However, the practice tests and the assignment consist of multiple-choice questions, while the final exam consists of short-answer questions. Consequently, it is hard to predict whether students who perform well in MCQ questions in practice tests and assignment can perform equally well in the final exam. However, a third of the student body clearly did not like to be compelled to do tests. In this project, students who do not wish to participate in the project have an opting out option which they can tick. Once this option is ticked, their normal assessment item becomes accessible as per normal.

In each of the science disciplines under investigation, there is an enormous array of resources at the students' disposal. However, do any students make use of them? The short answer is 'no' due to lack of time and energy. Consequently, they choose what they concentrate on without any or much guidance. This project places a language expert (an academic with expert knowledge in language teaching) in the position of a first-year student so that they can 'look through their eyes' to create a framework for lecturers that enables them to provide students with more cognitively and pedagogically sound guidance. The framework includes specific examples of what such guidance looks like in each of the disciplines. The implications of this project are wide ranging. It has the capacity to influence the way first-year science disciplines are taught in a fundamental way.

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