Language difficulties in first year Science - an interim report

Dr. Felicia Zhang and **Dr. Brett Lidbury,** University of Canberra, Australia,
Jurgen Schulte, University of Technology, Sydney, Australia,
Dr. Adam Bridgeman, The University of Sydney, Australia, **Dr. Brian Yates,** University of Tasmania, Australia and **Dr. John Rodger,** University of Newcastle, Australia
Felicia.Zhang@canberra.edu.au

***Abstract**: 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 Carrick Institute for Learning and Teaching in Higher Education, 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, reports on some of the preliminary results on the language difficulties faced by first year student cohorts in science from data collected in 2008, and describes the framework we have established for the organization and delivery of first year science courses to be implemented in semester one 2009.*

Introduction

Specialist terminology in Biology, Chemistry and Physics has proved difficult for most students (Wellington and 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. These pedagogical methods, as outlined in Table 1 (below), have resulted from interdisciplinary negotiations between the fields of Applied Linguistics and Molecular Biology but are practices which could assist students of other scientific disciplines.

Table 1. Proposed Language oriented Techniques to be implemented in the project

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

Context and characteristics of the students

Students undertaking tertiary studies in science are a highly diverse group. For instance, 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 (>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 a number of Australian universities.

Progress of the project

In the first six months of the project, three initial baseline questionnaires (Test 1, Test 2 and Test 3) have all been distributed in University of Technology, Sydney (UTS),University of Tasmania (UTAS) and USyd by the end of April, 2008. The project leader/educationalist visited UTS, UTAS and USyd to observe classes and discuss the questionnaire data 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 these institutions in Semester 2, 2008 when the participating lecturers are teaching.

Description of the questionnaires

In this project, we adopted a model which varied slightly from that of Jacobs (1989). We distributed three tests through the Learning Management System (LMS) of the participating institutions. In Test 1, 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', the following is 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 are 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 is allocated 5 marks each. 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 10 terms followed a similar format. Then in the second part following each question is a related confidence question which assesses 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%

In Test 2, a fill-in-the blanks passage utilizing the ten terms was provided for students to complete. This is designed to see whether a demonstrated confidence in the terms in Test 1 would mean a correct application of the terms in Test 2. In Test 3, students were asked to write down short definitions of a different set of words in each disciplinary context.

Questionnaire response rate

At UTS's first year Physics Modelling unit, Test 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 UTAS. At USyd, Test 1 and 2 were distributed to about 1000 students in first year Chemistry. The 969 students have been divided into three cohorts of students (see Tables

2). Test 3 has not been graded yet at any of the institutions. At all institutions, students self-selected to do the tests. The response rates from these cohorts from all three institutions are as follows:

Table 2. Questionnaire response distribution from the three universities

Institutions	Units	Test 1 responses	Test 2 responses	Total number distributed	Response rate (%)	
					Test 1	Test 2
UTS	Physical Modelling	40	23	412	9.7%,	5.6%
UTAS	Chemistry 1A	29	16	272	10.7%,	5.9%
USyd	Chem1001	60	32	388	15.5%,	8.2%
	Chem1101	95	47	465	20.5%,	10%
	Chem1901	19	11	116	16.4%,	9.5%
Total		243	129	1653	14.7%,	7.8%

Analysis of the questionnaire data

USyd and UTAS are using the *Blackboard* learning management system (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 percentage of students demonstrating a 100% understanding by the 'Yes' confidence level (Table 3, 100% understanding column/Yes column), we are able to establish a 'delusion index'. A high value in the 'delusion index' column suggests that students' confidence (indicated by the value in the 'Yes' column) is closely demonstrated by the percentage of students who understood a particular term 100%. For instance, for the term 'power' in Table 3, a delusion index of 0.78 suggests that students are realistic about their understanding of this term. However, in this case it means that they are very unsure of this term. The percentage of students who attained 100% of understanding of the term 'power' was 24.6%. Similarly, if we look at the term 'significant' with a delusion index of 0.03, it means that students are highly delusional of their understanding. This is demonstrated by only 1.9% of the student body who 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 Test 1 from USyd and UTAS.

Table 3. Chem1001 (Fundamental students with no previous HSC chemistry) at USyd

Terms	Yes	100% understanding	Delusion index	Ranking (easiest=1, hardest=10)
Significant	56.9	1.9	0.03	10
Model	64.7	15.4	0.24	9
Power	31.7	24.6	0.78	8
System	45.1	26.9	0.60	7
Equilibrium	59.3	32.1	0.54	6
Research	64.1	36.9	0.58	5
Concentration	80.4	43.9	0.55	4
Graph	84.9	49.1	0.58	3
Equation	82.7	53.8	0.65	2
Experiment	78.8	75	0.95	1

Table 4. Chem1101 (students with HSC chemistry) at USyd

Terms	Yes	100% understanding	Delusion index	Ranking (easiest=1,hardest=10)
Significant	51.8	4.8	0.09	10
Model	67.5	18.1	0.27	9
Power	41.6	19.3	0.46	8
Research	62.4	20	0.32	7
System	53	28.6	0.54	6
Equilibrium	83.5	50.6	0.61	5
Concentration	80.2	51.2	0.64	4
Graph	83.3	53.6	0.64	3
Equation	78.3	57.8	0.74	2
Experiment	67.1	68.7	1.02	1

Table 5. Chem1901 (students with HSC chemistry and high UAI) at USyd

Terms	Yes	100% understanding	delusion index	Ranking (easiest=1, hardest=10)
significant	64.7	5.6	0.09	10
Research	60	28.6	0.48	9
Power	26.3	28.6	1.09	8
System	50	31.6	0.63	7
model	64.7	50	0.77	6
Graph	94.4	52.6	0.56	5
Equation	94.1	55.6	0.59	4
Equilibrium	88.9	57.9	0.65	3
Concentration	84.2	60	0.71	2
Experiment	82.4	77.8	0.94	1

Table 6. Chemistry 1A (mixed cohort) at UTAS

Terms	Yes	100% understanding	Delusion index	Ranking (easiest=1,hardest=10)
Significant	48.4	3.2	0.07	10
Research	73.5	9.1	0.12	9
Model	48.4	12.9	0.27	8
System	58.1	19.4	0.33	7
Power	48.4	22.6	0.47	6
Concentration	87.1	25.8	0.30	5
Equilibrium	76.7	32.3	0.42	4
Equation	77.4	35.5	0.46	3
Graph	87.1	41.9	0.48	2
Experiment	83.9	71	0.85	1

The questionnaires were constructed slightly differently at UTS. Only 5 terms were used and no confidence questions were posed. Out of the five terms, 'concentration' which was used in the Chemistry tests at USyd and UTAS, has been changed to 'density' as this is more suited in a physics context. However, it was possible to work out the percentage of students who attained 100% understanding of the terms:

Table 7. Physical Modelling students at UTS

Terms	100% understanding	Ranking (easiest=1,hardest=10)
Research	15	5
Equilibrium	17.5	4
Power	25	3
density	27.5	2
Graph	42.5	1

The above tables suggest that terms such as 'model', 'significant', 'research', 'power' and 'system' are the most difficult for science students. Note that 'research' is one of the most problematic terms. From the example on page 2 which describes the question on 'research', we will 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 refer 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 is 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.

Relationship between Test 1 and Test 2

We also calculated the correlation between the scores of Test 1 and Test 2 from students in all three institutions. 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 suggests students have demonstrated not only understanding, but also application of the terms. In Table 8, only the 8 students in chem1901 at USyd demonstrated both understanding and application of the terms as reflected by the high correlation of results between test 1 and test 2.

Table 8. Correlation between Language Test 1 and Test 2 for the three institutions

University	No. of students	Test 1 mean	Test 2 mean	Spearman's rho
USYD (chem1001)	25	80.52 (: ± 7.16)	9.04 (SD:1.67)	0.082
USYD (chem1101)	38	81.63 (SD:16.28)	8.96(SD: 1.73)	0.169
USYD (chem1901)	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

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

Observation of lectures in Semester 1, 2008

The project leader/educationalist (FZZ) visited the three institutions in semester one, 2008. During the lectures, the project leader sat and observed the teaching from a student's point of view. The same procedure was used during all observation sessions in each institution. She also filled in a form that contained the same set of questions about the physical surroundings and contexts of the lectures and tutorials. 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: 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 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 LMS system can automatically calculate and assign grades to each student.
- Difficulty of the class tests is another factor. 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 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 Physics Modelling lecture at UTS, 20 slides will be covered with about 3 concepts on each slide in 2 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 or pharmacy. Even though reducing content to incorporate new learning strategies might be necessary to improve learning outcomes, it might not be necessarily embraced by academics in the feeder disciplines. Furthermore, some students in these units might only be doing Chem1001 or Physical Modelling for one semester because this particular unit is a pre-requisite for other units in their degree.

- Lack of communicative skills: from the class observation, students in all the 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 next phase

The next step in the project is for the educationalist to work alongside the science lecturers to find the best possible ways of implementing the strategies listed in Table 1. Discussion on learning space is of top priority. Secondly, having identified in this phase 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). It is hoped that this will lead to improved transfer of learning from first year subjects to subjects in other year levels in science degrees. The team will also work at developing knowledge and skills in the design and development of online learning and face-to-face environments with a particular focus on language issues in science. It is envisaged that by the end of 2008, a range of activities and online materials will be available for use in 2009. These materials will be used and evaluated so that practical guides and exemplars are available to assist other tertiary education providers to integrate such language learning strategies in the various disciplines in 2009. These documents will be made available through the Carrick Institute (Australian Learning and Teaching Council).

Acknowledgement

The project team would like to thank the Australian Learning and Teaching Council (formerly the Carrick Institute for Learning and Teaching in Higher Education) for funding this project. In addition they would like to thank the staff and students in the three institutions for participating in the project.

References

Jacobs, G. (1989) Word usage misconceptions among first-year university physics students. *International Journal of Science Education*, **11**(4), 395–399.

Wellington, J. and Osborne, J. (2001) *Language and Literacy In Science Education*. Buckingham, Philadelphia: Open University Press.

Zhang, F. and Lidbury, B. (2006) It's all foreign to me: learning through the language of genetics and molecular biology. Paper presented at the UniServe Science Assessment Symposium, University of Sydney, Australia.