Embedding in-discipline language support for first year students in the sciences: outcomes and future directions

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Abstract: *This paper reports on an Australian Learning and Teaching Council (ALTC) funded project which aims at addressing the need to cater for the language needs of a diverse student body (both domestic and international student body) by embedding 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 semester one 2009, active learning strategies such as the use of Votapedia (www.votapedia.com), online pre-lecture questions and group work in tutorials were implemented at both UTS and UTAS. The paper reports on student achievement results obtained from first year Chemistry and Physics student cohorts in 2009 from UTAS and UTS. This data has been compared to data obtained in semester 1 2008. Early data analysis suggests that the combination of techniques listed above, introduced in lectures and tutorials, has led to improved achievement in students' overall grades*

Introduction

Specialist terminology in Biology, Chemistry and Physics has proved difficult for most students (Wellington & Osborne, 2001). 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 (Zhang, Lidbury, Bridgeman, Yates, Rodger & Schulte 2008). Due to lack of space, this paper will report on results of the intervention strategies applied to first year teaching in Physics (UTS) and Chemistry (UTAS).

Context

The project is being conducted over 2008 and 2009, with 2008 as the study baseline and control phase. In 2008, no intervention took place except the implementation of language difficulty questionnaires. During this phase in 2008, lecturers taught the subject matter as how 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. At the time of submitting this paper (June, 2009) for refereeing, language support had taken place at UTS in Physics and UTAS in Chemistry. This included: (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:

The Votapedia tool (www.votapedia.com) and a show of hands were used at UTAS in first year Chemistry in semester one. Votapedia is a free audience response system that allows known users to create surveys and edit pages on the site. To become a known user, you need to sign up an account and obtain permission from Ken Taylor to create questions. Please visit the website for more details. UTS used clickers in 2008. However, due to a large increase students in semester 1 2009 (about an increase of 100 students thus raising the final student count to 530) clickers were not used but a raise of hands were used. At UTS, this was followed by small group, student to student group discussions and then students to teacher discussion in biweekly tutorials. Only one hour was available in these tutorials. However, at UTAS, due to institutional constraints, small group activities could not be built into the weekly tutorials.

In the ONLINE protocol, students are presented with a number of quizzes online before each lecture each week. The research team involved in Physics and Chemistry created, implemented and collected data on a set of language specific online quizzes for the respective disciplines in 2009. In 2008 and 2009, the Physics assignments deployed through the *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' which tested the language used in Physics. During the biweekly tutorials, the lecturer also incorporated multiple choice and concept questions related to language use. These concept questions were created specifically to test students' understanding of particular concepts such as 'force' in Physics and the use of 'force' in real life.

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 the exam to be compared with similar tests and exam used in semester one 2008. In addition to this, a Physics Concept survey was also administered. This survey combines 16 questions related to definitions of physics concepts such as 'force', 'momentum' and 25 questions on thermodynamics taken from Yeo (2001). 269 students completed the survey. However, because this test was not administered in 2008, no comparison is possible. At UTAS, 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 was made conditional on the completion of these quizzes. The decision to implement these pre-lecture multiple-choice questions with full feedback at UTAS was based on research carried out by the first year Chemistry coordinator who trialled a set of similarly constructed conditional self-tests in second semester 2008 (Zhang et al. 2008; Zhang, Lidbury, Schulte, Bridgeman, Yates & Rodger, 2009).

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);
- Institutional teaching evaluation questionnaires from semester 1 and 2 in 2009;
- Examination, test marks and assignment marks; and
- Student and staff focused group interviews.

However, at the time of submission of this paper, only some of the examination results are available for UTS and UTAS. Other qualitative data is not yet available. We will report on some of the data collected from UTS and UTAS next.

Results

UTS in Physics

The final exams in Physics at UTS in 2008 and 2009 consisted of 8 sections. These were on 'Kinetics', 'Forces', 'Momentum and Energy', 'Equilibrium and Force', 'Thermal', 'Electricity', 'Oscillations, Waves' and 'Optics'. In 2008, the Physics unit was taught entirely by the staff member who is 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 participating academic. Consequently, only questions in these sections in both 2008 and 2009's final exams can be used for comparative purposes.

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	-15
p-value		0.57	0.32	0.0	0.07

Table 1: UTS Physics, semester 1, 2008 and 2009 data comparison

The % of full marks in each section indicates the % of students who obtained full marks for this section. The information in Table 1 informs us that despite an increase in student number of 23.19%, 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 14.1%. In the 'Energy conservation' section, 2008 students outperformed the 2009 students by 15%. This may be caused by the uneven number of questions in this section in 2008 and 2009's exams. We also used the Z test to compare the 2 independent proportions and it is found that only the change for the 'Forces' section is statistically significant at $p<0.01$ with the change for the 'Energy' section approaching statistical significance at $p=0.07$.

Analysis of the Physics Concept survey at UTS

Williams (1999) suggested that

> Part of the difficulty (of Physics), perhaps even a large part, lies in language and the way we use it in the practice of physics, and in the teaching of physics…..we simply do not spend enough time with our students for us to use the laboratory vernacular and expect them to assimilate it (Williams, 1999)

The construction of the Physics Concept survey took the advice of Williams (1999) and refined the definitions of many concepts in physics. Questions 1-16 of the survey were focussed on concepts in 'Mechanics' and questions 17-41 focussed on concepts in 'Thermodynamics'. For the 2009 group of students, achievement in concepts in 'Mechanics' is much higher than that in the 'Thermodynamics' section.

'Impulse': For instance, in order to check students' understanding of the definition of 'impulse', responses to question 2 are compared to those of question 3. It seems that while the majority of the students (74%) chose the correct response for number 2 (c), when the meaning of 'impulse' gets mixed up with nominal and adjectival uses of 'impulse' (common in everyday use of the word) students were confused. This was demonstrated by 49% of the student body choosing (b) as the correct answer (which is not) and 41% choosing (a) the correct answer.

'Force': Similarly, students seemed to be confused about the definition of 'force' (Question 5), 55% of the students chose (c) as the correct definition and only 36% chose the correct answer (b) which contains the following correct sentences:

- I forced the box into the closet;
- Jim was forcing the nut onto the bolt; and
- The force on the ball made it move.

These sentences have two things in common: (1) the word 'force' was used as a verb linked to an agency (or an assumed agency as in (5) and every use contains a preposition such as 'into' or 'onto' or 'on' and another object. This makes the verb 'force' a transitive verb involving the interaction of two objects. This seems to loosely fit in with the common definition of force as a push or pull on an object. At UTS, the textbook used by this group of students is 'Fundamentals of Physics' by Walker (2008) (8th extended edition). Unfortunately the way, it discusses 'force' on page 87 is 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'.

'Mass': Students also seemed not to have understood the definition of 'mass' (Question 11). This is demonstrated by 3% of the students choosing (d) the correct answer whereas 50% of the students chose (b) density as the correct answer. The textbook authors tried their best to clear up the confusion between the use of 'mass' in everyday language with the concept of 'mass' in physics by saying 'you can have a physical sensation of mass only when you try to accelerate a body, as in the kicking of a baseball or a bowling ball' (Walker, 2008, page 91). However, since most students might not have read the textbook in detail, this useful discussion is likely to be missed totally. Question 14 is a question on the definition of Newton's first law. However, the key to get the correct answer lies in the students' understanding of the words 'constant' and 'uniform'. On page 88 of the textbook, the writer writes 'we can conclude that a body will keep moving with constant velocity if no force acts on it'. However, from students' answers, only 28% chose (a) the correct answer, 18% chose (b), 4% chose (c) and 48% chose both (a) and (b). This means 48% of the student body thought 'constant' has the same meaning as 'uniform'.

'Net force': Question 15 on the understanding of 'net force' tests students' precise understanding of the cause of an object's acceleration. The fact that 50% of the students chose (a) as the correct answer ((b) is the correct answer) suggests that students lacked the ability to use this concept precisely. Of course, if the vector sum of the forces is zero, there will be no acceleration. Only when the vector sum of the forces is larger than 0 N, will there be acceleration.

'Action and reaction': Williams (1999) suggested that students often associate the terms 'action' and 'reaction' improperly in the physics context. This is because the normal definitions of action and reaction often suggest a 'temporal delay between action and reaction' (p.676). In fact, the physics definition of Newton's third law emphasises 'the simultaneity of the forces or the symmetry of the force relationship'. This group of students did not fall into this trap with 68% of students choosing (a) as the correct answer.

UTS Q no.	Concepts	Content	% Correct
2	Impulse	I equal the **change** in an object's **momentum**, i.e. the product of the total mass and the velocity of the centre of mass.	74
4	Momentum	Which one(s) of the following sentences containing 'momentum' have meanings that are close to the meaning of 'momentum' in Physics: 1.After their touchdown, the other team had the momentum. 2. The football player has a lot of momentum when he tacked his opponent. 3. Our team gained momentum in the game after intercepting the ball. 4. As the car rolled down the hill it gained momentum.	76
6	Normal force	This is the force that is acting along the normal (perpendicular) to the contact surface.	83
7	Static friction	These are forces that are acting parallel to the contact surface. This force exists when the surfaces are not moving relatively to each other.	74
8	Gravitational force	It is the force that the earth exerts on any object. It is directed towards the centre of the earth. Its magnitude is given by Newton's second law.	88
9	Centripetal acceleration	This is the acceleration that is due to change in direction, not speed (in uniform circular motion) and it points toward the centre. a=v2/R	88
10	Weight	This is a vector force with which Earth is pulling on an object with.	83
12	Force	This is the vector describing the interaction between two objects (pull or push). The unit of force is Newton, N.	86

Table 2: Questions answered with a high degree of correctness (greater than 70% correct) in semester one in 2009

UTS Q no.		Content	% Correct
1	Momentum	I am a vector quantity of a particle which is defined as product of the mass of the particle and its velocity. The SI unit for me is kg. m/s.	49
3	Impulse	Which one(s) of the following sentences containing 'impulse' have meanings that are close to the meaning of 'impulse' in Physics: 1.An impulse made her change her mind. 2. My first impulse was to kick him. 3. In time of crisis we act on our impulses. 4. My sister is an impulsive shopper.	49
5	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 everyday. 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.	36
11	Mass	This is a scalar quantity which describes how difficult it is to change an object's velocity (sluggishness or inertia of the object). Which one of the statements below describes the Physics definition of mass?	49
13	Newton’s first law	An object cannot continue to move with the same speed and in the same direction. It will eventually stop.	65
14	Newton’s first law	Every object ________ in its state of rest or _______ velocity in a _________ line, unless it is compelled to change that state by _____ force acting on it.	28
15	Net force	When will an object accelerate?	45
16	Newton’s third law	Which of the following statements about Newton's 3rd law are correct? 1. For every action there is an equal and opposite reaction simultaneously. 2. For every action there is an equal and opposite reaction but a time delay is allowed. 3. Forces occur in the action-reaction pairs simultaneously.	68

Table 3: Questions answered with a medium degree of correctness (between 48%-70% correct) in semester one in 2009

The rest of the Physics Concept survey (Question 17-41) concerns concepts in Thermodynamics. Questions 17-41 were taken from Yeo (2001). All students achieved a low degree of correctness (less than 48%) with this part of the survey. This is much lower than the results reported in Yeo (2001). The same staff member did not teach Thermodynamics in 2009 and therefore, it is hard to comment on students’ low degree of achievement here.

Results of Test 1 for Chemistry at the UTAS

In Semester 1 2008, 210 participants participated in this study. Similarly, in Semester 1 2009 the final number of students was 218.

Test 1	Unit	N	Mean	Std. Deviation	Std. Error Mean
Total	Ch1aS108	210	19.40	5.340	.369
	Ch1aS109	218	20.79	5.513	.373

Table 4: Descriptive statistics of Test 1 of Chemistry 1A semester 1 2008 and semester 1 2009

Table 4 shows that the mean increased by 1.39 points, rising from 19.40 to 20.79. An Independent Samples T-test was done on the data for the corresponding first semesters of 2008 and 2009. This finding is 99% reliable with $p = 0.009$. Therefore, the conclusion can be reached that the two groups achieved significantly different results in this test.

Table 5 summaries a comparison of the descriptive statistics of each of the questions in both 2008 and 2009 test 1 papers respectively. For instance, independent samples t-test showed that there is a increase in marks of 1.16 points for Question A1 of the paper and this change between the two cohorts is significant at $p=0.000$ level. Similarly for Question A2, an increase of 0.79 was achieved from 2008 to 2009 and this change is also significant at $p<0.01$ level. On the other hand for Question b2, a decrease of -0.76 was achieved from 2008 to 2009 and this change is also significant at $p=0.002$ level. This shows that while 2009 cohort of students performed better in section A: structure and bonding, they still found section B: organic chemistry difficult. This signals an area of the curriculum for further development.

Test 1	Unit/2008	N	Mean	Std. Devi.	Unit/2009	N	Mean	Std. Devi.	MEAN Change	Significance (Equal assumed)
A1	Ch1aS108	192	6.84	1.59	Ch1aS109	193	8.00	1.66	1.16	0.000**
A2	Ch1aS108	192	6.20	2.28	Ch1aS109	193	6.99	1.86	0.79	0.000**
A3	Ch1aS108	192	6.97	2.11	Ch1aS109	193	6.88	2.11	-0.09	0.666
A total	Ch1aS108	192	20.02	4.80	Ch1aS109	193	21.88	4.64	1.85	0.000**
B1	Ch1aS108	192	6.12	2.34	Ch1aS109	193	6.10	2.61	-0.02	0.949
B2	Ch1aS108	192	5.80	2.48	Ch1aS109	193	5.04	2.20	-0.76	0.002*
B total	Ch1aS108	192	11.92	4.13	Ch1aS109	193	11.15	4.31	-0.77	0.073
total	Ch1aS108	192	31.94	7.90	Ch1aS109	193	33.02	8.06	1.08	0.185

Key: A: Structure and Bonding; B: Organic Chemistry; The numbers 1, 2, 3 etc stands for the number for the questions
**: statistically significant at p=0.01 level *: statistically significant at p<0.01

Table 5: Independent samples t-test comparing individual questions in Test 1 semester 1 08 with that in semester 1 09 Test 1 respectively

Table 6 illustrates the distribution of the grades for Test 1 in semesters 1 in 2008 to 2009. It can be seen that the % of failures and passes have dropped by 4.8% and 5.4%; while the % of Credits, Distinctions and High distinctions have increased by 0.9%, 7.2%; and finally 2.1%. Together with data contained in Table 3, this demonstrates that the interventions in Chemistry 1A at UTAS improved student learning in 2009.

			Grade					Total
			FAIL	P	CR	DI	HD	
Unit	Ch1aS108	Count	37	67	36	31	21	192
		% within Unit	19.3%	34.9%	18.8%	16.1%	10.9%	100.0%
	Ch1aS109	Count	28	57	38	45	25	193
		% within Unit	14.5%	29.5%	19.7%	23.3%	13.0%	100.0%

Table 6: The distribution of grades for test 1 in semester 1 2008 and semester 1 2009.

Discussion

Data contained in this paper from UTS and UTAS Physics and Chemistry subjects show that with large cohorts, learning intervention can be successful. The analysis clearly supports the use of Votapedia and Online full feedback questions as useful support mechanisms. 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. Results reported in this paper have just illustrated this. This project has already create a framework for lecturers to provide students with more cognitively and pedagogically sound guidance with specific examples of what such guidance might look like in each of the disciplines. Some of them have already been provided in this paper. Further information will be made available in the final report and on a dedicated website. This project is already influencing the way first year Chemistry and Physics are taught in a fundamental way.

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