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Embedding in-discipline language support for first year students in the sciences

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Abstract: This paper reports on a 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. These strategies consist of active learning skills which are widely used in language learning. 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. This project is funded by the Australian Learning and Teaching Council (ALTC). The paper discusses the background to the study and reports on 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. It will also report on the results on the implementation of the learning strategies at UTS and UTAS in Physics and Chemistry disciplines in 2009.

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

Introduction

This study reports on a project which aims at addressing the need to cater for the language needs 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 (Table 1) 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. One distinctive feature of this project is that the llanguage expert did not teach any of the classes unlike similar support programs which aimed in providing language support to International students (Murray, 2007). The language expert worked collaboratively with lecturers in the disciplines closely but she was never 'positioned by academic staff as being responsible for the students' learning and language development'(Murray, 2007). Nor Zhang asserts her position as an 'epistemological authority rest(mine: ing) on an understanding of second language acquisition (SLA)' (Wai, 2008). Instead, she was position as a novice first year student with no previous HSC experience (but an expert in language learning and teaching). In this project, the language expert 'learned' the content of the disciplines by direct experience and in this process, attempts to (a) make lectures more accessible; (b) look for opportunities for small group participation; (c) look for opportunities to develop students' communication skills in communicating scientific knowledge to lay communities; (d) create opportunities for providing formative feedback both face-to-face and through online activities through negotiating and collaborating with the disciplinary lecturers. Some of the activities focused on language issues, others focused on active learning strategies.

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. (UTAS, Usyd, Newcastle)
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. (Newcastle)
4. Using online language exercises such as crosswords, gap-fill (Cloze) exercises.	9. Using of flashcards for vocabulary revision (Newcastle, Usyd)
5. Providing stimulus quizzes for lecture and tutorial materials on WebCT thus encouraging students to prepare before the lecture.	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 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 (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 (see Zhang, Lidbury, Bridgeman, Yates, Rodger, & Schulte, 2008 for details). The language expert (FZZ) also discussed with lecturers appropriate places to implement the intervention in year 2 of the project.

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). 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 was a related confidence question which assessed how confident a student was 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%

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 3, 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.
For instance, for the term 'power' in Table 3, a delusion index of 2.14 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 15.13. If we look at the term 'significant' with a delusion index of 15.13, it means that students are highly delusional of their understanding. This is demonstrated by only 3.2% of the student body understood this term completely but 48.40% 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 questionnaire data

Chemistry discipline

Table 2: Chem1001/1101/1901 at USyd

Terms	Ranking (easiest=1, hardest=10)
Significant	10
Model	9
Power	8
System	7
Equilibrium	6
Research	5
Concentration	4
Graph	3
Equation	2
Experiment	1

Key:
Chem1001 (Fundamental students with no previous HSC chemistry) at USyd
Chem1101 (Students with HSC Chemistry) at USyd.
Chem1901 (students with HSC chemistry and high UAI) at USyd

Table 3: 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
Research	73.50	9.10	8.08	9
Model	48.40	12.90	3.75	8
System	58.10	19.40	2.99	7
Power	48.40	22.60	2.14	6
Concentration	87.10	25.80	3.38	5
Equilibrium	76.70	32.30	2.37	4
Equation	77.40	35.50	2.18	3
Graph	87.10	41.90	2.08	2
Experiment	83.90	71.00	1.18	1

Table 2 is a composite table of the rankings obtained from the three cohorts from USyd. The data in Tables 2-3 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' on page 3 of this paper , 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. 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 5 terms were used and no confidence questions were posed (Table 4) due to technical difficulties with the questionnaires. 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' because the confidence questions were not deployed at UTS.

Table 4: 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. See Table 5. At the University of Newcastle, one item (significant) was repeated (which was due to human error) and the item on 'model' was not included. Therefore the table shows the data for nine items rather than ten.

Table 5: University of Newcastle, Biology 1002

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

Table 6: University of Canberra, 2nd 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 focused training in the teaching of first year science.

Methods

The project is to be carried out in two years. During the control part of the project in 2008, no intervention took place except the implementation of language difficulty questionnaires. 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. 2008 student cohorts constitute the Control groups of students. Students, in 2009, in the participating universities constitute the Experimental groups of students. At the time of submitting this paper for refereeing, interventions have taken place at UTS in Physics and UTAS in Chemistry.

The next stage 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 year 1 of the project that there is a gap in students' understanding of common scientific words, we intend to enhance student awareness of the language used in each disciplines 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 alert students that (1) precision of these terms in science is important and (2) 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. 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 stage of the project.

The FTF protocol consists of the following phases:

1. During each lecture, the lecturer build into the lecture materials, short survey questions made available on votapedia (http://www.votapedia.com) or audience response devices such as clickers (www.keepadinteractive.com) to offer feedback on lecture content
2. During tutorials, interactive activities are introduced. Such interactive activities can include small group discussions involving the linking of concepts learned (Techniques 2 in Table 1) and activities related to technique 7, or 8 or 10 in Table 1.

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. Both online through mobile phones are free to the students but there will be a charge through SMS' (http://www.votapedia.com/index.php?title=Main_Page). At UTAS, when this was implemented in the lecture theatre, because only Telstra mobile phones can get signal, only students with Telstra phones could phone through. Other students voted using a raise of hands.

UTS used clickers in 2008. 2007-2008 results on the use of Clickers at UTS (Schulte, 2008) suggested that the use of clickers enabled a sustained participation in lectures from the beginning till the end of the semesters. However, survey results suggested that even though students felt the feedback they obtained from the use of clickers aided their on-the-spot understanding, the feedback could be better used as diagnostic tools so that long term more structural change can be implemented to help the students to self-structure their study (Schulte, 2008). In 2009, 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. This was complemented by small group student to student group discussions (Technique 3 in Table 1) 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. This protocol involves the implementation of technique 5 in Table 1. 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. Below is an example:

On a dry road, a car with good tires may be able to brake with a constant deceleration of 5.28 m/s^2. (a) How long does such a car, initially travelling at 24.4 m/s, take to stop? (b) How far does it travel in this time?

(a) Number 4.62 Units s

(b) Number 56.38 Units m

In order to get away from the assumption that if students can correctly do the calculations, then they have understood the subject matter, we also introduced a 'Physics concept surveys' which tested the language used in Physics (see Appendix 1). 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. 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 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.
>
> a)1, 2, 4, 3, b)3, 4, 8 c)1, 2, and 5 d) 5,6,7

During the 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. 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. However, since this Physics concept test tests students' ability to differentiate everyday use of physical terminology from the specific meaning of these terminologies in Physics, it is worthwhile to analyse the answers to ascertain *where* students are still having difficulties even after instruction.

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 (which contribute to their grades) would only open on completion of these quizzes with full feedback. 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 will become accessible as per normal.

Evaluation

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

1. Pre- and post tests focused on language issues (at the beginning and end of 2008);
2. Institutional teaching evaluation questionnaires from semester 1 and 2 in 2009;
3. Examination and test marks in 2008 and 2009.

However, at the time of submission of this paper, only some of the examination results are available for UTS and UTAS. Results of institutional teaching evaluation results and staff and student focused group interviews have not yet been made available. 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. 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', '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 same participating academic. Consequently, only questions in these sections in both 2008 and 2009's final exams can be used for comparative purposes.

Table 7: UTS Physics, semester 1, 2008 and 2009 data comparison

Year	Number 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 7 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 14.1%. In the 'Energy conservation' section, 2008 students outperformed the 2009 students by 15%. 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 3 decimal points) and with the change in the 'Energy' section approaching statistical significance with p=0.07.

Analysis of the Physics Concept survey (see Appendix 1)

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 importance of precise use of language, particularly in introductory teaching of physics, has been emphasized by Arons (1990):

> Since the words, to begin with, are metaphors, drawn from everyday speech, to which we give profoundly altered scientific meaning, only vaguely connected to the meaning in everyday speech, the students remain unaware of the alteration unless it is pointed to explicitly many times-not just once' .

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 were focused on concepts in 'Mechanics' and questions 17-41 focused on concepts in 'Thermodynamics'. For the 2009 group of students, achievement in concepts in 'Mechanics' is much higher than that in the 'Thermodynamics' section. For instance, in order to check students' understanding of the definition of 'impulse', responses to question 2 is compared to that of question 3. It seems that while 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 was a bit 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.

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). The correct sentences:

(1) I forced the box into the closet.
(2) Jim was forcing the nut onto the bolt and
(5) The force on the ball made it move.

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 is 'Fundamentals of Physics' by Walker, Jearl (8th extended edition). 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) (Walker, 2008). This gives the impression that somehow 'force' itself is an agency like a person causing the object to change its velocity'.

Students also seemed not to have understood the definition of 'mass' (Question 11). This is demonstrated by 3% of the students choosing (d: sensation one has when trying to kick a football) the correct answer whereas 50% of the students chose (b: density) as the correct answer. The writer of the textbook 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). 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'.

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, as we know 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.

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 emphasizes ‘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.

Table 8: Questions answered with a high degree of correctness (greater than 70% correct) in semester one in 2008

UTS question	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 9: Questions answered with a medium degree of correctness (between 48%-70% correct) in semester one in 2008

UTS question	Concepts	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

The rest of the Physics Concept survey (Question 17-41) concerns concepts in Thermodynamics. Questions 17-41 were taken from (Yeo, 2001). Unfortunately, all students only 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). At the time of submitting this paper, we are still waiting on student feedback on the unit in 2009.

Results of Test 1 for Chemistry at the UTAS

At UTAS, no Chemistry concept test was administered and therefore only results on the results of the tests are reported.

Table 10: Descriptive statistics in Test 1 of Chemistry 1A semester 1 2008 and semester 1 2009

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

Table 10 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 11: Independent samples t-test comparing descriptive statistics of Test 1 in semester 1 08 with semester 1 09 Test 1 respectively

Test 1	Unit	N	Mean	Std. Deviation	Std. Error Mean	Unit	N	Mean	Std. Deviation	Std. Error Mean	MEAN Change	Significance (Equal assumed)
A1	Ch1aS108	192	6.84	1.59	0.11	Ch1aS109	193	8.00	1.66	0.12	1.16	**0.000****
A2	Ch1aS108	192	6.20	2.28	0.16	Ch1aS109	193	6.99	1.86	0.13	0.79	**0.000****
A3	Ch1aS108	192	6.97	2.11	0.15	Ch1aS109	193	6.88	2.11	0.15	-0.09	0.666
A total	Ch1aS108	192	20.02	4.80	0.35	Ch1aS109	193	21.88	4.64	0.33	1.85	**0.000****
B1	Ch1aS108	192	6.12	2.34	0.17	Ch1aS109	193	6.10	2.61	0.19	-0.02	0.949
B2	Ch1aS108	192	5.80	2.48	0.18	Ch1aS109	193	5.04	2.20	0.16	-0.76	**0.002***
B total	Ch1aS108	192	11.92	4.13	0.30	Ch1aS109	193	11.15	4.31	0.31	-0.77	0.073
total	Ch1aS108	192	31.94	7.90	0.57	Ch1aS109	193	33.02	8.06	0.58	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.

Table 11 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:

1. there is an increase in marks of 1.16 points for Question A1 of the paper and this change between the two cohorts is highly significant (p=0.000 to 3 decimal point).
2. Similarly for Question A2, an increase of 0.79 was achieved from 2008 to 2009 and this change is also highly significant (p=0.000 to 3 decimal point).
3. 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 much harder. This signals an area of the curriculum for further development.

Table 12: The distribution of grades for Test 1 in semester 1 2008 and semester 1 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 12 illustrates the distribution of the grades for Test 1 in semesters 1 in 2008 to 2009. It can be seen that the % of failures has dropped from 19.3% in 2008 to 14.5% in 2009, a drop of 4.8%; the % of Passes has dropped from 34.9% to 29.5%, a drop of 5.4%; the % of Credits has increased from 18.8% in 2008 to 19.7% in 2009, an increase of 0.9%; the % of Distinction has increased from 16.1% in 2008 to 23.3% in 2009, an increase of 7.2%; and finally the % of High Distinctions has increased from 10.9% in 2008 to 13.0% in 2009, an increase of 2.1%. Data contained in Table 10 lend further support that the interventions in Chemistry 1A at UTAS improved student learning in 2009.

Discussion

In each of the Science discipline under investigation, there are an enormous amount of resources at the students' disposal in 2008. However, do any students make use of these enormous arrays of resources in the past? The short answer is 'no' due to lack of time and energy. Consequently, they chose what they concentrate on without any or much guidance. Limited data contained in this paper from UTS and UTAS Physics and Chemistry subjects show that even with large cohorts, learning intervention can be successful. The data clearly supports the use of Votapedia and Online full feedback questions as useful support mechanisms. 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 could 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 at UTS and UTAS. The results from both sites also highlighted particular areas of difficulties for students such as the understanding of Newtonian laws in Physics and in Chemistry, organic Chemistry seems to be of particular difficulty for students. It is hoped that this project signals the beginning of a dialogue among science lecturers about how to deal with difficult content areas as well as deciding what we expect from our students in the first year science curriculum.

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Appendix 1

1. Definition 1
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.
a. linear momentum
b. momentum
c. angular momentum
d. both a and b

2. Definition 2
I equal the change in an object's momentum, i.e. the product of the total mass and the velocity of the center of mass.
a. momentum
b. acceleration
c. impulse

3. Meaning of 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.
a. 2, 3,
b. 1
c.4

4. Meaning of momentum (Taken from Itza-Ortiz, Rebello, Zollman, & Rodriguez-Achach, 2003)
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.
a. 3 and 4
b. 1 and 2

5. Meaning of 'force' (Taken from Itza-Ortiz et al., 2003)
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.
a. 1, 2, 4, 3,
b. 3, 4, 8
c. 1, 2, and 5
d. 5, 6, 7

6. Definition 7
This is the force that is acting along the normal (perpendicular) to the contact surface.
a. kinetic friction
b. Normal force
c. static friction

7. Definition 6
These are forces that are acting parallel to the contact surface. This force exists when the surfaces are not moving relatively to each other.
a. kinetic friction
b. static friction
c. dynamic force

8. Definition 5
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.
a. gravitational force
b. net force
c. frictional force

9. Definition 4
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
a. gravitational force
b. centripetal acceleration
c. average acceleration

10. Definition 3
This is a vector force with which Earth is pulling on an object with.
a. mass
b. weight
c. density

11. Definition 2
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?
a. weight
b. density
c. body size
d. sensation one has when trying to kick a football

12. Definition 1
This is the vector describing the interaction between two objects (pull or push). The unit of force is Newton, N.
a. Displacement
b. Acceleration
c. Force

13. Newton's first law:
An object cannot continue to move with the same speed and in the same direction. It will eventually stop.
a. True
b. False

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.
a. continues, constant, straight, net
b. continues, uniform, straight, net
c. stops, constant, straight,
d. both a and b.

15. Net force
When will an object accelerate?
a. When there is a net force on the object.
b. When the net force is more than 0 N.
c. When the net force on the object is zero N

16. Newton's 3rd 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.
a. 1 and 3
b. 2
c. All the above

The following questions have been taken from (Yeo, 2001)
17. ThermalConcepts2
2. Ken takes six ice cubes from the freezer and puts four of them into a glass of water. He leaves two on the counter top. He stirs and stirs until the ice cubes are much smaller and have stopped melting. What is the most likely temperature of the water at this stage?
a. -10°C
b. 0°C
c. 5°C
d. 10°C

18. ThermalConcepts1
1. What is the most likely temperature of ice cubes stored in a refrigerator's freezer compartment?
a. -10°C
b. 0°C
c. 5°C
d. It depends on the size of the ice cubes.

19. ThermalConcepts3
3. The ice cubes Ken left on the counter have almost melted and are lying in a puddle of water. What is the most likely temperature of these smaller ice cubes?
a. -10°C
b. 0°C
c. 5°C
d. 10°C

20. ThermalConcepts4
4. On the stove is a kettle full of water. The water has started to boil rapidly. The most likely temperature of the water is about:
a. 88°C
b. 98°C
c. 110°C
None of the above could be right.

21. ThermalConcepts5
5. Five minutes later, the water in the kettle is still boiling. The most likely temperature of the water now is about:
a. 88°C
b. 98°C
c. 110°C
d. 120°C

22. ThermalConcepts6
6. What do you think is the temperature of the steam above the boiling water in the kettle?
a. 88°C
b. 98 °C
c. 110 °C
d. 120 °C

23. ThermalConcepts7
7. Lee takes two cups of water at 40°C and mixes them with one cup of water at 10°C. What is the most likely temperature of the mixture?
a. 20°C
b. 25°C
c. 30°C
d. 50°C

24. ThermalConcepts8
8. Jim believes he must use boiling water to make a cup of tea. He tells his friends: ‘I couldn't make tea if I was camping on a high mountain because water doesn't boil at high altitudes’ Who do you agree with below?
a. Joy says: 'Yes it does, but the boiling water is just not as hot as it is here'
b. Tay says: 'That's not true. Water always boils at the same temperature'
c. Lou says: 'The boiling point of the water decreases, but the water itself is still at 100 degrees'
d. Mai says: 'I agree with Jim. The water never gets to its boiling point'

25. ThermalConcepts9
9. Sam takes a can of cola and a plastic bottle of cola from the refrigerator, where they have been overnight. He quickly puts a thermometer in the cola in the can. The temperature is 7°C. What are the most likely temperatures of the plastic bottle and cola it holds?
a. They are both less than 7°C.
b. They are both equal to 7°C.
c. They are both greater than 7°C.
d. The cola is at 7° C but the bottle is greater than 7°C.
e. It depends on the amount of cola and/or the size of the bottle.

26. ThermalConcepts19
19. Pat believes her Dad cooks cakes on the top shelf inside the electric oven because it is hotter at the top than at the bottom. Which person do you think is right?
a. Pam says that it's hotter at the top because heat rises.
b. Sam says that it is hotter because metal trays concentrate the heat.
c. Ray says it's hotter at the top because the hotter the air the less dense it is.
d. Tim disagrees with them all and says that it's not possible to be hotter at the top.

27. ThermalConcepts18
18. Ron reckons his mother cooks soup in a pressure cooker because it cooks faster than in a normal saucepan but he doesn't know why. [Pressure cookers have a sealed lid so that the pressure inside rises well above atmospheric pressure.] Which person do you most agree with below?
a. Emi says: 'It’s because the pressure causes water to boil above 100°C.'
b. Col says: 'It's because the high pressure generates extra heat.'
c. Fay says: 'It’s because the steam is at a higher temperature than the boiling soup.'
d. Tom says: 'It's because pressure cookers spread the heat more evenly through the food.'

28. ThermalConcepts17
17. Dan simultaneously picks up two cartons of chocolate milk, a cold one from the refrigerator and a warm one that has been sitting on the counter top for some time. Why do you think the carton from the refrigerator feels colder than the one from the counter top? Compared with the warm carton, the cold carton?
a. contains more cold.
b. contains less heat.
c. is a poorer heat conductor.
d. conducts heat more rapidly from Dan's hand.
e. conducts cold more rapidly to Dan's hand.

29. ThermalConcepts16
16. Amy took two glass bottles containing water at 20°C and wrapped them in washcloths. One of the washcloths was wet and the other was dry. 20 minutes later, she measured the water temperature in each. The water in the bottle with the wet washcloth was 18°C, the water in the bottle with the dry washcloth was 22°C. The most likely room temperature during this experiment was:
a. 26°C
b. 21°C
c. 20°C
d. 18°C

30. ThermalConcepts15
15. Kim takes a metal ruler and a wooden ruler from his pencil case. He announces that the metal one feels colder than the wooden one. What is your preferred explanation?
a. Metal conducts energy away from his hand more rapidly than wood.
b. Wood is a naturally warmer substance than metal.
c. The wooden ruler contains more heat than the metal ruler.
d. Metals are better heat radiators than wood.
e. Cold flows more readily from a metal.

31. ThermalConcepts14
14. Jan announces that she does not like sitting on the metal chairs in the room because "they are colder than the plastic ones." Who do you think is right below?
a. Jim agrees and says: "They are colder because metal is naturally colder than plastic."
b. Kip says: "They are not colder, they are at the same temperature."
c. Lou says: "They are not colder, the metal ones just feel colder because they are heavier."
d. Mai says: "They are colder because metal has less heat to lose than plastic."

32. ThermalConcepts12
12. Mel is boiling water in a saucepan on the stove top. What do you think is in the bubbles that form in the boiling water? Mostly:
a. Air
b. Oxygen and hydrogen gas
c. Water vapour
d. There's nothing in the bubbles.

33. ThermalConcepts11
11. Pam asks one group of friends: 'If I put 100 grams of ice at 0°C and 100 grams of water at 0°C into a freezer, which one will eventually lose the greatest amount of heat?' Which of her friends' opinion below do you most agree with?
a. Cat says: 'The 100 grams of ice.'
b. Ben says: 'The 100 grams of water.'
c. Nic says: 'Neither because they both contain the same amount of heat.'
d. Matt says: 'There’s no answer, because ice doesn't contain any heat.'
e. Jed says: 'There's no answer, because you can't get water at 0°C.'

34. ThermalConcepts10
10. A few minutes later, Ned picks up the cola can and then tells everyone that the counter top underneath it feels colder than the rest of the counter.
a. Jon says: 'The cold has been transferred from the cola to the counter.'
b. Rob says: 'There is no energy left in the counter beneath the can.'
c. Sue says: 'Some heat has been transferred from the counter to the cola.'
d. Eli says: 'The can causes heat beneath the can to move away through the counter top.'
Whose explanation do you think is best?

35. ThermalConcepts13
13. After cooking some eggs in the boiling water, Mel cools the eggs by putting them into a bowl of cold water. Which of the following explains the cooling process?
a. Temperature is transferred from the eggs to the water.
b. Cold moves from the water into the eggs.
c. Hot objects naturally cool down.
d. Energy is transferred from the eggs to the water.

36. ThermalConcepts20
20. Bev is reading a multiple-choice question from a textbook: 'Sweating cools you down because the sweat lying on your skin: Which answer would you tell her to select?
a. 'wets the surface, and wet surfaces draw more heat out than dry surfaces.'
b. 'drains heat from the pores and spreads it out over the surface of the skin.'
c. 'is the same temperature as your skin but is evaporating and so is carrying heat away.'
d. 'is slightly cooler than your skin because of evaporation and so heat is transferred from your skin to the sweat.'

37. ThermalConcepts21
21. When Zack uses a bicycle pump to pump up his bike tires, he notices that the pump becomes quite hot. Which explanation below seems to be the best one?
a. Energy has been transferred to the pump.
b. Temperature has been transferred to the pump.
c. Heat flows from his hands to the pump.
d. The metal in the pump causes the temperature to rise.

38. ThermalConcepts22
22. Why do we wear sweaters in cold weather?
a. To keep cold out.
b. To generate heat.
c. To reduce heat loss.
d. All three of the above reasons are correct

39. ThermalConcepts23
23. Vic takes some Popsicles from the freezer, where he had placed them the day before, and tells everyone that the wooden sticks are at a higher temperature than the ice part. Which person do you most agree with?
a. Deb says: 'You're right because the wooden sticks don't get as cold as ice does.'
b. Ian says: 'You're right because ice contains more cold than wood does.'
c. Ross says: 'You're wrong, they only feel different because the sticks contain more heat.'
d. Ann says: 'I think they are at the same temperature because they are together.'

40. ThermalConcepts24
24. Gay is describing a TV segment she saw the night before: 'I saw physicists make super-conductor magnets, which were at a temperature of 260°C.' Who do you think is right?
a. Joe doubts this: 'You must have made a mistake. You can't have a temperature as low as that.'
b. Kay disagrees: 'Yes you can. There's no limit on the lowest temperature.'
c. Leo believes he is right: 'I think the magnet was near the lowest temperature possible.'
d. Gay is not sure: 'I think super-conductors are good heat conductors so you can't cool them to such a low temperature.'

41. ThermalConcepts25
25. Four students were discussing things they did as kids. The following conversation was heard: Ami: 'I used to wrap my dolls in blankets but could never understand why they didn't warm up.' Who do you agree with?
a. Nick replied: 'It's because the blankets you used were probably poor insulators.'
b. Lyn replied: 'It's because the blankets you used were probably poor conductors.'
c. Jay replied: 'It's because the dolls were made of material which did not hold heat well.'
d. Kev replied: 'It's because the dolls were made of material which took a long time to warm up.'
e. Joy replied: 'You're all wrong.'