Peer Assisted Study Sessions (PASS) in first year chemistry and statistics courses: insights and evaluations

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Introduction

First level Science students are faced with a bewildering array of courses at university, many of them with densely structured, modular, and multi-streamed curricula. While such curricula are designed to give students the advantage of studying a large number of topics in separate modules within the one course structure, they also have the potential to alienate rather than engage students. This is especially so if students lack the ability to interpret confusing messages concerning learning requirements. Any lack of coherence between teaching, learning and assessment may be exacerbated if there is non-alignment between student learning and progressive assessment. If students lack an overarching perspective of the critical appraisal inherent in the discipline, they may be forced to adopt a surface learning approach, especially if they have done so in the past.

Students' prior educational experiences are known to influence their current conceptions of learning (Marton and Saljo 1997). However, while students' approaches to learning can be influenced by their perceptions of the teaching and learning environments (Biggs 1999b), assessment criteria (Laurillard 1997), or motivation and anxiety levels (Fransson 1977), their learning orientations may be positively re-directed. This can be achieved if they are encouraged to become personally involved with their own learning (Beaty, Gibbs and Morgan 1997); for example, by increasing students' level of learning related activity with the coursework (Biggs 1999a).

To provide an active learning environment which can also support the alignment of learning objectives and assessment with student learning, peer assisted study sessions (PASS) have been introduced into the curricula of eleven first level courses within the Faculty of Biological and Chemical Sciences. The aim of this paper is to discuss features, or insights, that have been identified as contributing to the successful implementation of PASS in chemistry and statistics, and to evaluate the effect of PASS on student performance and subsequent recruitment into the discipline.

Rationale: The PASS Model

The essence of PASS pedagogy, not unlike Supplemental Instruction, is designing well-organised study sessions consisting of small groups of first year students who undertake self-directed learning (Martin and Arendale 1993). These hour-long, weekly, voluntarily attended study sessions are facilitated by two, course competent second or third year undergraduate student leaders. PASS is a mainstream service: it pro-actively targets large, high-risk, first year courses rather than reactively assisting high-risk students.

The aim of these sessions is to create a collaborative learning environment where students can integrate traditional methods of teaching with learning from student centred discussions in a relaxed yet intellectually stimulating environment. Students are thus able to admit ignorance and misconceptions, and seek information, advice and remediation, without fear of jeopardising their academic outcome (Bulmer and Miller 2003).

The PASS paradigm epitomizes a social constructivist mode of education whereby small groups of students interact to explore concepts and values inherent in the discipline (Topping 1998). An important consideration is that students' knowledge constructs are mediated by interactions with more competent peers who are at a level of understanding just beyond that of the students themselves, so that learning can occur within a student's 'zone of proximal development' (Vygotsky 1978).

By learning with supportive mentors, students gain confidence in their own ability to practise within the discipline and are thus encouraged to take control of their own learning (Ramsden 1992). The rationale of the PASS learning model is that it allows leaders to align student learning with progressive assessment, as it provides the scaffold within which leaders can design student-directed study activities that target course learning objectives, for any instructional mode of learning.

Method

First level chemistry (CHEM1012) and statistics (STAT1201) courses during 2003 were selected to evaluate the effect of PASS attendance on student performance and attrition, and also on recruitment of students into second and third year Chemistry courses. Overall, 84% of chemistry students were enrolled in a science-based degree program. Student outcomes were recorded for chemistry from 1999 to 2003 and for statistics in 2003. Student OP (Overall Position) ratings, or university entrance scores, were recorded for each student; OP1 is the highest rating, OP25 the lowest. For science students, the lowest rating is OP8, for applied science students, the lowest rating is OP16.

Quantitative evaluation

PASS leaders recorded the attendance of students in weekly attendance rolls and numbers were checked and verified against figures collected by supervising coordinators. Individual student attendances were entered into student academic profiles on a database that contained OP (overall position) ratings, all progressive assessment marks and final course grades.

Qualitative evaluation

The Chemistry department commissioned a survey from the Tertiary Education Development Institute, of students who were enrolled in the second level chemistry course CHEM2041 in 2002. Students participating in the survey were given written questionnaires preceded by interviews in smaller focus groups, regarding the origin of their current views of proceeding with chemistry (Smith and Bath 2002). Of interest was the perceived impact of PASS on students' future study and work intentions, and their perceptions of chemistry; in particular whether attending PASS had any effect on changing their intentions to continue studying chemistry after first year.

Teaching and learning modes and assessment

For CHEM1012, there are three streams of 36 lectures supported by ten PASS sessions each semester. Assessment comprises a final MCQ exam (60%), five laboratory practicals (20%), and four progressive computer generated tests (CMTs) (20%). Each CMT is a set of twelve questions randomly and uniquely generated from a lecturer devised testbank comprising mostly MCQs, but also a limited number of short, numerical answer questions. Approximately 5,000 tests are generated and marked by the system each semester. Students are notified of the release and return dates for each test and can download and work on each set for up to one week, with the help of peers and any resource material provided in PASS.

For STAT1201, there are two streams of 36 lectures and ten practicals supported by ten PASS sessions each semester. Assessment comprises a computer based final exam (44%), a library skills based journal article review (10%), a project (individual or group) presented as a journal article (25%), a laboratory book (practical problem solving) (10%), a computer based mid-semester test (10%), and a statistically relevant photograph, or poem, or art competition (1%).

Results and evaluation

Quantitative: Chemistry course

Table 1 is a profile of Chemistry 1A (CH112/CHEM1012) student numbers, attrition rates and student performance in first semester from 1999 to 2003. Although enrolment numbers are commonly >1 000, attrition rates due to student drop-out have remained relatively constant, from 3.1% to 4.3%. The primary concern in 1999-2000 was a relatively high failure/pass conceded (grades 1-3) rate of 15-16%, with concurrent low student retention rates. Consequently, a pilot PASS program began in 2001 with groups meeting only every second week; since then, session frequency has increased to weekly, in alignment with other PASS programs.

Since 2000, there has generally been a fall in the number of students with grades 1-3, viz. a 10.1% drop between 1999 and 2003. Concurrently, there has been an increase in the number of students attaining grades 4 and 5 in 2001 (7%-8%) and grades 6 and 7 in 2002 and 2003 (8%-11%). From 1999 to 2003, the Grade Point Average (GPA) has increased from 4.34 to 4.91, and mean CMT and MCQ results have increased by an average of 8.4% and 3.8%, respectively.

Table 1. CHEM112/1012 student enrolment, assessment and performance

Category	1999	2000	2001 #	2002	2003
No. enrolled	1279	1066	1040	1118	1131
% Attrition	4.3*	3.1*	3.9	3.7	3.8
% grades 1-3	15.2*	16.0*	6.7	11.4	5.1
% grades 4-5	61.8*	62.7*	70.5	62.5	62.0
% grades 6-7	18.7*	18.2*	18.8	22.4	29.1
GPA	4.34	4.34	4.63	4.61	4.91
% Practical	92.3	93.7	88.8	91.9	92.0
% CMT	71.6	72.4	76.0	75.5	80.0
% MCQ	52.1	50.4	50.2	52.1	55.9
% Total	63.9*	63.5*	63.1	64.8	67.9

* amended to align with 2001-2003 marking scheme # pilot PASS program

Table 2 presents evidence relating to the effect on student performance for students attending PASS. Data were generated from the 2003 CHEM1012 student cohort who had completed assessment (1089 students). Students were divided into four groups: those that had never attended PASS (0 PASS), those who had attended only intermittently (1-4 PASS), those who had attended regularly (5+ PASS), and all students who had completed assessment (all students).

Table 2. Effect of PASS attendance on student performance: CHEM1012, 2003

Category	% Mean result for each category			
	All students	0 PASS	1-4 PASS	5+ PASS
Practical	92.0	90.6	92.3	93.2
CMT	80.0	74.3	76.8	83.9
MCQ	55.9	50.2	50.3	61
Total	67.9	63.1	64.1	71.8
Grade	4.91	4.51	4.57	5.29
OP	4.5*	5.3*	5.0*	3.9*

*OP range for all students was 1 to 16

There is strong evidence that students who regularly attended PASS demonstrated improved performance, not due to higher OP students self-selecting to attend PASS, as there is very little difference between the mean OP of students in each category. While the class averages in Table 1 showed overall elevated student performance after the introduction of the PASS program in 2001, the progressive (CMT) and final (MCQ) assessment results in Table 2 each showed an average rise in both CMTs (9.6%) and final exam MCQs (10.8%) results for the regular (5+ PASS) participants.

Multiple comparisons (using Tukey corrections at the 95% level) between mean grades for students attending 0, 1-4, or 5+ PASS sessions showed significant differences between the 5+ and 0 groups (+0.61 to +0.95 grade points) and the 5+ and 1-4 groups (+0.51 to +0.92 grade points), but no significant difference between the mean grades of students attending 0 sessions and 1-4 sessions.

Recruitment of students into second and third year Chemistry courses between 2000 and 2003 is shown in Table 3. There is a sustained increase in enrolment numbers of second year students since 2002, and of third year students since 2003, respectively. While there may be numerous factors that have contributed to this increase, there does not appear to be any change in the numbers of first level students during this period. Factors influencing students' decisions to continue with Chemistry in second and subsequent years of their degree program are therefore more likely to be ones that they were confronted with during their first year at University.

Table 3. Recruitment of Science students in 2nd and 3rd level Chemistry courses, 1999 - 2004

	No. students in 1st, 2nd and 3rd level Chemistry courses											
Chemistry	1999		2000		2001		2002		2003		2004	
level	1	2	1	2	1	2	1	2	1	2	1	2
1st/Semester	1279	1029	1165	874	1126	973	1125	1073	1228	1106	1160	1074
1st/Year	2308		2039		2099		2353		2334		2234	
2nd/Semester			110	95	87	106	148*	177*	173*	178*	200*	148?*
2nd/Year			205		193		325*		351*		358?*	
3rd/Semester					109	108	138	86	122*	145*	161*	158?*
3rd/Year					217		214		267*		319?*	

*2nd and 3rd level students who were offered PASS in 1st level Chemistry

Qualitative: Chemistry course

Students were categorised from two principal groupings based on their intention or non-intention to proceed with chemistry prior to commencing first year chemistry. More students in the non-intending group attended PASS sessions (93% vs. 72%) than the intending group. This 'non-intending' cohort felt that PASS was a more worthwhile part of their first year course (88% vs. 65%) than the 'intending' cohort. In terms of impact on future intentions, significantly more students in the non-intending group who now intended to complete a whole degree focussed on chemistry (C) , rather than study chemistry only to second year (NC) (40% vs. 14%), had attended PASS.

The (C) student cohort also reported that PASS had a greater positive impact on their intention to continue studying chemistry in second year than the (NC) cohort (60% vs. 40%), intention to become a professional working in the field of chemistry (40% vs. 7%), ability to imagine themselves as chemists in the future (44% vs. 8%) and ability to imagine themselves as advanced undergraduate students in chemistry (60% vs. 40%). Specifically, students felt that PASS had a great positive impact on their belief that working as a chemist could be intellectually stimulating, on their ability to succeed in chemistry, on their sense of belonging as a chemistry student, and on the quality of their learning and understanding of chemistry.

Quantitative: Statistics Course

Results for the statistics course (STAT1201) were similar to the outcomes in Chemistry. Figure 1 shows an effects plot that gives the mean grade of students in Semester 2, 2003 against how many PASS sessions they attended and what their university entrance (OP) score had been. An OP score of 1 is the highest and it would be expected that these students might perform better than those with a larger OP score. For each level of PASS attendance, the mean grade increases steadily with OP score. Multiple linear regression was used to assess the joint relationship between grades and both the OP and the number of PASS sessions attended. While the modelled relationship was not very strong (R-squared + 0.21), there was significant evidence that mean grade is related to both OP (p + >003) and PASS attendance (p + .016). For example, students in the lowest OP group (8+) who attended PASS 10 or more times had a mean grade of 4.75, higher than that of OP 1-3 students who didn't attend any PASS, who had a mean of 4.36.

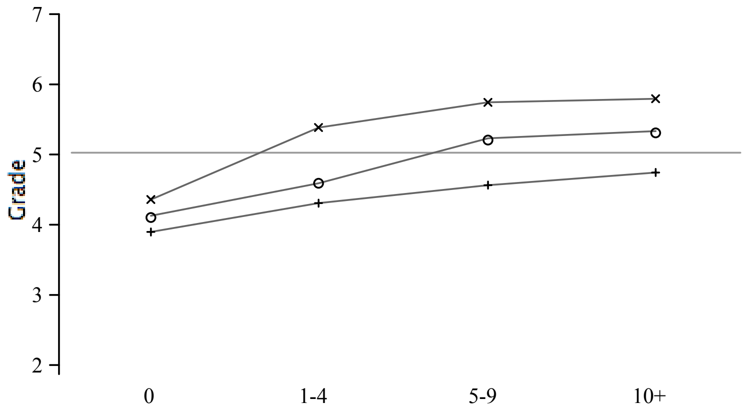

Figure 1. Mean grades for students by PASS attendance for OP 1-3 (+), OP 4-7 (*), and OP 8+ (o)

The lines in Figure 1 are roughly parallel, and a multiple regression for grade using OP score and PASS attendance shows no evidence of interaction between OP and PASS attendance on mean grade ($p = .819$), as suggested by Figure 1. It appears therefore that increase in mean grade is related to PASS attendance in a similar way regardless of student OP score which concurs with related findings by Biggs (1999b, p4). As STAT1201 is a service course for first year Biology and Chemistry based degree programs, retention of students in second year statistics courses did not apply in this instance.

Insights: creating a productive learning environment

Leaders

PASS leaders play a pivotal role in the success of PASS. They are responsible for creating a productive learning environment for their students that is both learning centred and student directed, and is thus structured to meet the diverse learning needs and styles of students. By sharing similar career interests with students, they can communicate their appreciation for the extent to which the discipline is of use to them. Explicit instruction to leaders concerning the scope of their facilitative role is therefore of paramount importance.

Selection of leaders is based on their previous academic performance in the course as well as for their enthusiasm and communication skills. They attend a workshop during which they practise their role as facilitators of learning in the context of social constructivism. They are also made aware of principles of active learning, modes of facilitation, and strategies to foster communication. Leaders re-attend at least one first level lecture every week, and are encouraged to use this time to both consolidate existing knowledge and plan an activity for their next session, based on aligning key concepts from the lecture material with learning objectives. While leaders are academically competent in the coursework, their own cultural and disciplinary backgrounds allow them to create study activities flavoured with their own cultural and interdisciplinary overtones, enriching the learning context with personal examples of authenticity.

Study Activities

While the principles of action learning are applied to PASS, the cornerstone of every session is the leader-generated study activity. These instructional activities are designed to formatively test students' understanding and to keep it aligned with progressive summative assessment. Current leaders have access to activities generated by previous leaders that facilitate not only knowledge recall and recognition but also association and deduction. These activities are made available to academic staff so that they can monitor their students' learning progress and rectify problem areas.

Alignment of teaching, learning and assessment

One of the strengths of the chemistry and statistics curricula is their learning-centred approach to teaching which encourages students to explore both the application of their course work in authentic and personally meaningful situations. In this respect, PASS provides a venue where students can practice problem solving activities from their CMTs and laboratory books, as well as critique journal articles and plan projects in collaboration with their peers. For example, students are encouraged to research personally relevant statistically based topics and thus become aware of the benefits of statistical analysis in scientific investigation. PASS can enhance student learning regardless of the instructional mode or the learning context: sessions can operate in the library, the computer-based interactive learning centre or the seminar room. Through active and authentic learning, students develop a sense of ownership with the course while they engage more deeply with the discipline.

Conclusion

Incorporating active learning into first level chemistry and statistics courses has helped to improve student performance by promoting an inquiring, analytical and creative approach to student learning. The development of students' cognitive and affective skills is thus enhanced in a peer assisted learning environment where students feel free to exercise independent judgement and practise the skills of the discipline within a collaborative learning framework. PASS participants report heightened quality of learning and understanding of the coursework, ability to succeed and proceed within the discipline, and a greater sense of belonging within a community of learners.

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Statistics—worse than a poke in the eye?

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Introduction

The majority of students studying statistics are not majoring in that subject: they are taking a service course in statistics as part of their studies in another discipline to prepare themselves for a career where statistics will be a professional component tool. Many of them find such a course difficult or even distasteful. A recent advertisement put up at Macquarie University by someone offering tutoring services began: 'If you think statistics is worse than a fork in the eye, then you need help!' We have previously reported on conceptions of statistics held by statistics major students (Reid and Petocz 2002). In this paper, we extend that study by looking at the views of statistics held by students taking service statistics courses in various areas of science. We also investigate their expectations of their use of statistics in their future studies and profession. The students' views were obtained using an anonymous, open-ended questionnaire, and we have analysed the content of the responses using our previous theoretical framework. Based on the results obtained, we discuss teaching and learning approaches and materials that can help such students to engage with the ideas of statistics and to develop an appreciation for its possible uses in their future professional lives.

Service statistics courses

Many tertiary students in a wide range of disciplines will have need of statistics as a tool in their professional life: they will be introduced to the subject in a 'service' course in statistics. Such service courses have been much studied by statistics educators, and are a continuing theme in forums such as the on-line *Journal of Statistics Education* and the four-yearly *International Conference on Teaching Statistics* (or *ICOTS*). Research on students' learning in statistics has often been oriented around investigations of learning approach and environment (Boyle 1999; Martinez-Dawson 2003), the educational effects of assessment (Garfield and Gal 1999), the impact of students' attitudes towards the subject (Gal and Ginsburg 1994) and students' statistical ideas of specific topics, particularly in the area of probability (Pfannkuch and Brown 1996; Keeler and Steinhorst 2001). Garfield (1995) lists aspects of the learning environment that seem to encourage student learning of statistics, including activity and group work, use of interactive computer software and computer simulations, and investigation of statistical 'misconceptions'. There have been several reports on the topic of enhancing statistics education for scientists by using case studies, applications and projects (Zetterqvist 1997; MacGillivray 2002). Other reports write of the positive effects of teaching using industrial collaborations, settings and applications (Morris 2000; Davies 2002).

Relatively few studies include an emphasis on students' understanding of statistics (such as Gordon 2004). Yet, focusing on students' learning, rather than on the lecturer's ideas of important content or pedagogical method, is an essential step to encourage students to develop mature approaches to learning, and an appreciation of the possible role of statistics in their professional life. We have been carrying out a project in just this area, based initially on a series of in-depth interviews with students majoring in statistics, and then extended to include students who are studying statistics as a 'minor' component of their professional studies. We have also surveyed a much larger number of students in service courses in various areas of science. An analysis of these survey results is presented later, but to provide an appropriate theoretical framework we first summarise students' conceptions of statistics from the initial interview study.

Statistics major students' conceptions of statistics

In a previous paper (Reid and Petocz 2002), we have reported on the conceptions of statistics held by students who were majoring in statistics. The conceptions were identified from a phenomenographic analysis (Marton and Booth 1997) of interviews with 20 students from first- and third-year classes in statistics, focusing on their responses to the question 'What is statistics?' or 'What do you understand statistics to be about?' The 'outcome space' is presented in Table 1 without supporting quotations from the transcripts (which can be found in the cited reference). The first three conceptions focus on techniques, mathematical and then statistical, individual and then a collection. Students holding conceptions 1 or 2 have a limited and fragmentary understanding of statistics, which is somewhat broader in conception 3 as techniques are accumulated. The next two conceptions focus on using data: conception 4 shows a view of analysing a set of data to understand the meaning hidden in it, while conception 5 explicitly includes the context of the analysis. Students describe statistics using the techniques characteristic of conceptions 1–3, but consider these techniques to be part of a coherent whole, and aim to be able to analyse and interpret a complete set of data. Conception 6, the broadest, focuses on meaning. Students use statistical methods to develop their own thinking, create new interpretations of data, and actively relate their statistical understanding to their personal and professional life. In common with many other phenomenographic outcome spaces, the conceptions are hierarchical and inclusive. They are listed in the table from the narrowest and most fragmentary to the broadest and most holistic. Moreover, students who express the broader conceptions are also aware of the narrower conceptions, and can make use of any or all of the characteristics of the previous conceptions, if their perception of the situation demands it. It is for this reason that we as educators favour the broader, most expansive conceptions over the narrower, more limiting ones.

Table 1. Statistics major students' conceptions of statistics (after Reid and Petocz 2002)

Focus	Conception of Statistics	Brief Description
Techniques	1. Numerical techniques	Limited and fragmentary understanding, statistics is a type of mathematics that uses 'boring calculations', 'numbers' or 'probability'
	2. Individual statistical techniques	Statistical rather than mathematical fragments, individual techniques used to look at data, eg graphing, line of best fit, collecting data, regression
	3. Collection of statistical techniques	Statistics is a collection or 'stockpile' of a range of techniques, accumulated by students and listed as a description
Data	4. Analysis and interpretation of data	Statistics is interpreting or making sense of a complete set of data, analysing and drawing conclusions about it
	5. Understanding using statistical models	Statistics is a way of understanding situations by examining statistical models, analysing sets of data and testing appropriateness of conclusions
Meaning	6. Making sense of the world and develop personal meaning	Statistical methods are used to understand and make sense of wider aspects of reality, develop creative and critical thinking, create new interpretations of data and life

While this model of students' understanding of statistics is interesting theoretically, it can also be used practically as a basis for developing effective pedagogical approaches. Firstly, students often believe that everyone else in the class shares their way of looking at the subject and are surprised to hear that there are alternative viewpoints: those students who previously held more limiting views are thus encouraged to consider broader conceptions of their subject (see Ho, Watkins and Kelly 2001). Students' conceptions of their own learning and the role of their teacher can also be discussed (see Petocz and Reid 2003). Secondly, we can provide activities and assessment that encourage students towards the broader conceptions. For instance, rather than simply asking students to carry out a statistical technique, we can set the problem in a real-life context and in addition ask students to explain the *meaning* of the results to a colleague or a client: this moves students' focus from facts and techniques towards the broader conceptions of statistics as a way of understanding the world. An example of such a pedagogical approach in action is given in Reid and Petocz (2003) in the context of a class in regression analysis.

The questionnaire and data collection

The background to the data collection was our desire to make practical and immediate use of results that we had obtained from the interviews with statistics major students. We wanted to discuss the range of conceptions of statistics with our other classes, and in order to provide a basis for starting a discussion we asked students to think about their ideas of statistics and how they might use it. Using an anonymous open-ended questionnaire, students were asked to write replies to the questions: What is statistics? What part do you think statistics will play in your future studies? What part do you think statistics will play in your future professional work? The replies formed the basis for general class discussions and with our students' permission we collected their responses for further analysis. We have responses from 122 students, two groups of students from sports science (one undergraduate, one honours), a group of masters students in orthodontics and two groups of masters students in human nutrition. These responses were analysed together due to the relatively small samples.

Service students' conceptions of statistics

Although enough space was left for longer responses, most people just wrote a short definition of statistics for the first question. Many responses were concerned with mathematical techniques (the study of numbers, application of mathematical formulae, calculating, a form of maths) or their application (finding probabilities, calculating reliability, correlations or trends, using mathematical methods to find results, using numbers to work out significance). Another large group of responses focused on compiling or collecting data, using data or samples and analysing, evaluating or interpreting data. Also mentioned were finding significance of results or confirming/denying a hypothesis and drawing valid conclusions. Finally, there were some isolated comments that focused on the positive aspects ('A subject helpful in research') or negative aspects ('Glorified guesswork', 'Science designed to prove that all our work is wrong'), or made comments on respondents' attitudes to statistics ('Complicated', 'A struggle for those who dislike maths').

The responses can be analysed using our previous theoretical framework and the results are shown in Table 2. Using the inclusive nature of the outcome space, each response was classified at the broadest level shown, so for instance if a student wrote 'The collection of data and the use of it', the response would be classified as conception 4 (since it showed evidence of interpreting or using the data) rather than conception 2 (collecting data as an individual statistical technique). Since there is no chance for respondents to amplify their written responses, the classification is 'generous'.

Table 2. Service statistics students' conceptions of statistics

Focus	Conception of Statistics	Freq	Example
Techniques	1. Numerical techniques	14	A lot of numbers and graphs everywhere/ A form of maths/ Maths calculations/ The study of numbers
	2. Individual statistical techniques	9	A way of displaying information in numerical format/ Studying relationships between values and data/ The measurement of a specific phenomenon with a group of subjects (or objects)
	3. Collection of statistical techniques	19	The study of probabilities and the significance of results/ Standard deviation, are the results statistically significant?/ ANOVA, Wilcoxon rank sum test, but can't remember detail
Data	4. Analysis and interpretation of data	66	Analysing numerical data and then putting them to some use/ Analysing data and making sense of it/ The collection of data, making sense of the collected data
	5. Understanding using statistical models	5	The collection and organisation of data so that it can be understood and give meaning to a particular situation/ Analysing numbers to make sense of the results of experiments
Meaning	6. Making sense of the world and develop personal meaning	0	

Table 2 shows that conception 4, analysis and interpretation of data, is the most common (and in fact was the most common in each of the three sub-groups). It is not surprising that the short written responses from this group did not display the broadest conception of statistics as 'an inclusive tool to make sense of the world and develop personal meanings'. The following extract from an interview with an honours student in sports science shows the problem. Joe's first statement, early in the interview, would indicate conception 4, statistics as analysis and interpretation of data. However, his response to a question at the end of the interview implies the broadest conception 6 of statistics:

> Joe: [Ok, can I start then by asking you, what you think statistics is?] I would think stats is about investigation of data. It can be any kind of data and it can be used for anything, but pretty much working to formulate anything they want really. /…/ [What do you think the main things are from what you have learned here in stats that you take with you when you leave?] The whole way of thinking about things differently, you know, ideas of formulation that I would have never had come up with before that maybe I could lay things out a little bit differently so it works, that I may not have thought of previously. It will just make my life easier basically. /…/ I think differently now because I can see now that it's much wider and can be used for a much wider range of things, as previously I may have been a bit more closed minded, thinking it was just nerdy stuff that we don't need to know. But now it's like, oh this really applies to everything. You know I can work out this, and whack these things together. Just thinking differently, thinking more advanced.

Service students' ideas about their use of statistics

The responses to the questions about the use of statistics in future studies and professional work are considered next. Students from the first interview study who were majoring in statistics had no doubt that they would use statistics in some form in their professional life, and some of them were already using it professionally. By contrast, the students in the service groups had less clear expectations. The most common responses for both study and work were concerned with reading and understanding research articles or results and actually carrying out research assignments or projects. This focus is not surprising given that more than half the students were enrolled in coursework masters degrees, but it was also apparent in the undergraduate group in sports science. Many respondents gave specific examples, such as sports coaching or evaluating sporting performance, investigating public health or the nutritional status of a group, or developing better dental materials. There were a small number of comments related to a broader use of statistics, for example: 'Understand better the industry where I will work' and 'It helps to derive conclusions from observations kept in everyday work in the clinic.' Despite this, there was a minority who believed that statistics would have no role, or were unsure about the role it might play, writing comments such as 'Unsure of what I'm doing, so I'll have to wait and see.' The responses are summarised in Table 3: a response could contain several ideas, so the frequencies do not sum to the total number of respondents.

Table 3. Service students' ideas of future use of statistics in their studies and work

Use of Statistics		Studies	Work
Unspecific:	- no role	3	3
	- unsure of role	9	12
	- some role	5	7
	- large role	12	9
Specific Example:		17	33
Research Use:	- organise and present data	2	4
	- analyse data, evaluate results	10	2
	- read and understanding research	28	30
	- carry out own research	48	27
Professional Use:	- explain to clients		1
	- understand the industry	1	
	- support professional judgement	2	3
	- further studies (PhD, Honours)	4	

Conclusions

Our analysis permits us to draw several conclusions concerning effective pedagogy for service classes in statistics for science students. We have already mentioned the strategy of helping students become aware of the various conceptions of statistics and the fact that other students may think differently about the subject. Given the large numbers of students who viewed statistics as isolated mathematical techniques, there seems to be potential for broadening their views of the statistics and learning statistics. However, it is important to remember that it would be as important that they expand their conceptions of their own area of science. We have also pointed out the benefits of providing learning activities and assessment that direct students towards the broader conceptions of statistics. Such an applied approach is vital even in an introductory statistics course, rather than the traditional focus on the development of basic statistical techniques. Given the large numbers of students who were aware of the role of statistics in understanding research results or carrying out their own research, this would be an obvious source of examples and assessments. The many reports of pedagogy involving projects selected in the students' own areas of interest attest to the success of this approach (e.g., MacGillivray 2002; Yesilcay 2000).

These research outcomes can be used as a basis for developing effective learning materials. As examples, we can refer to the laboratory exercises in Petocz (1998) that ask students to engage with the meaning and context of various sets of scientific data (e.g., Rayleigh's measurements of 'standard volumes' of nitrogen that led him to the discovery of argon in 1894), the video case studies in Petocz, Griffiths and Wright (1996) that take students behind the scenes of problems in statistical quality management (e.g., the problem of trichloroanisole in the corks at the Rosemount winery), and the book *Reading Statistics* (Wood and Petocz 2003) which encourages students to 'read' statistical papers, articles and research in a variety of areas of application (e.g., effects of T'ai Chi on balance), with the aim of looking beyond the data to the real life meanings. These examples fit into the problem-based learning model that has been successfully used throughout the sciences: the winning presentations at the last three UniServe Science Symposia are good examples (Kirkpatrick, McLaughlan, Maier and Hirsch 2002; Meyers, Nulty, Cooke and Rigby 2003; Batmanian, 2004). Another statistical example: we recently read a fascinating imaginary conversation with Florence Nightingale about the use of statistics in evidence-based medicine that would be an ideal resource for a medical statistics class (Maindonald and Richardson 2004). With such learning materials, the focus of the learning shifts to the broader conceptions of statistics, and supports students' own learning rather than statistics itself, or the basic techniques of the subject.

Traditionally it is assumed that science students learn about professional competencies such as statistical skills through real-life problems or experience in laboratory experimentation. However, their lecturers may have limited industry experience and thus prepare students for professional work from an institutional academic orientation (Evans 2001). This standard approach reflects a lack of appreciation of the way in which students understand the situated nature of their learning and the professional tools that are integral to their intended profession. 'Telling' students, and providing activities purporting to reflect professional work simply do not enable students to challenge their own beliefs about their learning focus and their work. Providing a space where *students* can explore their own perception of professional work and the way in which other subjects can be appreciated as component tools for scientific work enables educators to more effectively enhance the situation of learning and the students' own connections between institutional and professional learning experiences (Trigwell and Reid 1998). Another quote from an interview with another student in sports science points to the importance of changing students' conceptions:

> Karin: [What do you think might be the main things you take away with you from your stats learning when you leave university?] More understanding of it, before I thought statistics was very dry and useless. Something for academics to keep them busy. But it actually has a purpose: I changed my mind. [Why?] Because I guess I realized I might use it in the future.

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Science learning environment—outside-class experience: design, evaluation and challenge

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Introduction

Traditional university science (physics) teaching is based on the lecture-laboratory/tutorial delivery scheme. Also, this type of training is usually in the form of puzzle-solving strategy on a particular class of problems which comprises successful aspects of a topic/discipline (textbook-science). In addition to that the segmentation of teaching where the knowledge transferred has been broken up into separate courses (topics) increases tendency to omit as much as possible of the material that does not fit exactly the course objectives. As a result, some important in teaching and practice of science topics falls between and are not presented at all. This is especially true for issues related to contemporary, cutting-edge science.

Science and science-oriented students enrolled in two introductory physics courses presented by the Discipline of Physics at the University of Newcastle were/are exposed to a number of diverse topics (fundamental physics) with little time for expanding and overlapping their course-based knowledge with more and more multidisciplinary science environment. In order to encourage students to test and expand their knowledge a two-A4-page format bulletin was designed and widely distributed among about 450 students in these two level-one introductory physics courses (Figure 1). Qualitative evidence regarding student's perceived value of the bulletin shows that the proposed design was as a successful and valuable learning experience for a vast majority of the first year students.

Design

The primary design and topic selection principle was to confront student's course-based knowledge with their willingness and ability to absorb an outside-class message, carry it through and extend it beyond their prescribed degree-program experience. By reading the bulletin, students were exposed to topics from history of science, contemporary science, junk science, movies, books, etc. The following titles were distributed in our 2001-2002 first-year introductory physics courses:

- **The Law of the Farm or the Problem Based Learning Strategy in Physics.** A short presentation of scientific method linked to topics from 'First Things First' by S.R. Covey. Context: traditional perception of learning practice in science (especially in physics) and effectiveness of practice in everyday life and work environment.
- **The Hollywood Physics.** Text designed to verify popular-movie-based scientific knowledge with that discussed in introductory physics courses.
- **The Midas Formula.** Relationship between physics and finance—historical perspective and current practices. A brief introduction to econophysics.
- **The Extrapolated World of Science… Fiction?** The phenomenon of Sir Arthur Clark and his writing; a simple scheme to confront knowledge with creativity and imagination.
- **The Legacy of Cargo People.** Extended version of famous statement from Richard Feynmann regarding science and pseudoscience.
- **The Sound of Music.** One of the greatest scientific puzzles of contemporary science (origin of noise) and the unexposed discovery (1970s) about human's perception of music. Link to the origin and early days of quantum physics.

- **The Mystery of Ettore Majorana.** The genius of Italian physicist Ettore Majorana and his mysterious disappearance linked to early advances in nuclear physics and today's nuclear power related controversies.
- **Nanoscience, Nanotechnology... Nonsense?** The extraordinary carrier of Silicon and its uncertain future in tomorrow's microelectronics. A short introduction to nanoscience and nanotechnology; Moore's Law and current advances in molecular electronics.
- **The Good, The Bad or… just not too Pretty.** Confrontation between 'real' and 'junk' science in the context of the Alfred Nobel and Ig. Nobel Prize winning achievements.
- **The Guessing Game.** A view on science as a 'guessing game'; selected facts from the most important moments in history of science.
- **Have You Seen a Beautiful Mind?** John Nash's life story and achievements in Ron Howard's Oscar winning movie.
- **Science in the Sandbox.** Cutting-edge research a 3-year-old can do and some unexpected, surprising and intriguing outcomes.
- **The Missing Link.** Student's uni-life experience in a poster-cartoon format.

Adapted distribution strategy was based on an easy-to-catch graphical form of the bulletin (see Figure 1) and easy-to-access policy (lectures, laboratory sessions, tutorial classes, library, and the Web). While students were encouraged to read the distributed texts, they were also aware of the fact that reading the bulletin was not 'a course prescribed activity'. Students (and academics) were also encouraged to contribute to the forthcoming editions of the bulletin.

Evaluation

Surveys of students and evaluations of their responses were carried out to determine in what ways the described design was succeeding. Two distinctive groups of first-year and one group of former first-year students were targeted in the conducted surveys. Both groups of first-year students—Biotechnology, Biomedical Science, and Science students enrolled in the Introductory Physics course (lower level course with approximately 200 students), and approximately 160 students in the higher level Advanced Physics course—completed identical, end-of-semester evaluation questionnaire. Former first-year students (in 2002) completed the evaluation questionnaire. The end-of-semester first-year student's evaluation form contained the following questions:

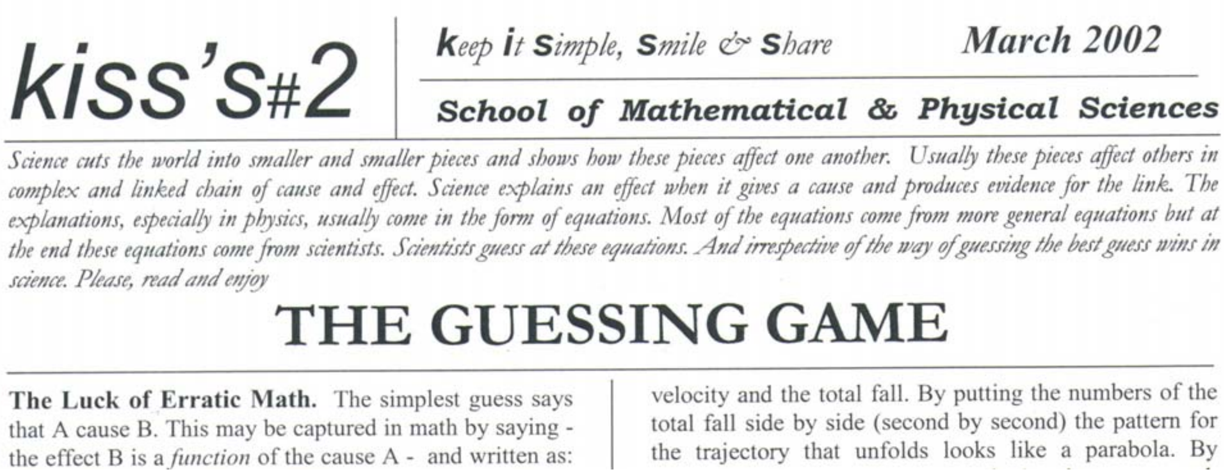
(1) Have you read (heard) about the bulletin?; (2) How many issues of the bulletin have you read?; (3) Would you recommend the bulletin to other science or engineering students?; (4) The bulletin stimulates my interest in science; (5) Would you like to comment on 'outside-course' activities in the Physics Department?

Questions (1), (3) and (4) had very high ranking in both groups of the first-year students: 90% read the bulletin, more than 80% would recommend the bulletin to fellow students, and only 8% disagreed with statement (4). This shows that the students found the bulletin to be an accessible, readable and valuable outside class learning experience. Written comments (question 4) were equally encouraging and included 'I am a big fan of the bulletin'; 'write more and often'; 'would like to read more about…'. The survey also showed (question 2) the 2001/2002 first-year students' preferences: the Advanced Physics course students ranked the texts: 'The Midas Formula', 'Nanoscience…Nonsense' and 'The Mystery of Ettore Majorana', significantly higher than the Introductory Physics class (in this group the 'The Hollywood Physics' and 'The Good, The Bad…' had the highest rank). In both groups the texts: 'The Law of the Farm…' and 'The Legacy of Cargo People', had the lowest ranking.

The evaluation questionnaire for the group of former first year students contained questions (1), (3) and (4). The survey was conducted on a very small group of students and showed that only 2 students (out of 16 responded) did not read the 2002 bulletin (issued in the first semester 2002); 12 students would recommend the 2002 bulletin to fellow students; and 10 students agreed with (5).

Conclusions

In summary, the project to design an outside-class science learning environment was generally effective in delivering most of the anticipated benefits A survey of students clearly indicates the great potential that exists for this type of outside-class-learning-environment design to bring in substantial teaching/learning advances. The evaluated design represents a valuable potential for integration between course units, different courses, as well as linking a course content with contemporary, cutting-edge science. The discussed design can also result in increased depth of learning, student teacher interaction, and development of critical thinking and communication skills. The identified main challenges to the presented design are: (a) available time for writing and editing the bulletin, and (b), lack of students (and other academic/teaching staff members) engagement in preparing and editing the bulletin.



kiss's#2

keep it Simple, Smile & Share

March 2002

School of Mathematical & Physical Sciences

Science cuts the world into smaller and smaller pieces and shows how these pieces affect one another. Usually these pieces affect others in complex and linked chain of cause and effect. Science explains an effect when it gives a cause and produces evidence for the link. The explanations, especially in physics, usually come in the form of equations. Most of the equations come from more general equations but at the end these equations come from scientists. Scientists guess at these equations. And irrespective of the way of guessing the best guess wins in science. Please, read and enjoy

THE GUESSING GAME

The Luck of Erratic Math. The simplest guess says that A cause B. This may be captured in math by saying - the effect B is a *function* of the cause A - and written as:

velocity and the total fall. By putting the numbers of the total fall side by side (second by second) the pattern for the trajectory that unfolds looks like a parabola. By

Figure 1. The graphical design for the PHYS100 and Beyond and KISS's bulletins distributed in 2001, and 2002, respectively

Students' perceptions of their understanding in *Chemistry 1* for Veterinary Science

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Introduction

The aim of this study was to investigate the relationship between students' perceptions of their understanding of chemistry, and their performance as measured by the end of semester examinations. Prior to commencing the study, it was hypothesised that there should be some correlation between students' perceived understanding and exam performance. Furthermore, experience suggested that high achieving students are generally better able to identify their strengths and weaknesses than are weaker students. It seemed logical, therefore, that the strength of any correlation should vary with exam performance. This study was designed to test this hypothesis, and this paper is the first refereed report of results from this on-going investigation.

A search of the literature found no previous studies of direct relevance to this work. However, the literature does offer some background. A number of studies have examined students' perception of their exam performance after completing an exam (e.g., Beyer, Riesselmann and Warren 2002), and students' overall expectations of academic performance has also been examined (e.g., de Campos, Grinberg, Garcia, Parise, da Silveira and Dumont 1998). Both are poor predictors of academic performance. Student self-marking has been shown to correlate well with the marks given by their professors for lower-order cognitive skills questions, but not for questions requiring high-order cognitive skills (Zoller, Fastow, Lubezsky and Tsaparlis 1999). Academic self-efficacy (confidence in one's ability to complete academic tasks) has been shown to be positively correlated with academic performance (Chemers, Hu, and Garcia 2001; Vrugt, Langereis and Hoogstraten 1997). However, the Chemers et al. (2001) study examined generic skills and overall performance in a degree program, and was not linked to a domain. The Vrugt et al. (1997) study examined psychology freshmen, and whilst subject matter understanding was included in their model, they found that 'self-efficacy and goals accounted for 5% of the variance in exam performance' (p. 67), and thus their model has a poor predicting power for student achievement. House (2000, 2003) examined self-beliefs (measuring agreement/disagreement with statements such as 'Science is boring', 'I enjoy learning Science' and 'Science is important to everyone's life') amongst 13-year-olds. These studies found a correlation between self-beliefs and science achievement test scores, but these beliefs were also found to be poor predictors of performance, explaining 6.29% of the variance in test scores in Hong Kong (House 2003, p. 201) and 6.8% in Ireland (House 2000, p. 110).

Method

CHEM1405 unit of study

The CHEM1405 (Chemistry 1 for Veterinary Science) unit of study is a compulsory, one-semester-long subject, taken in the first semester of the Bachelor of Veterinary Science degree program. It consists of 24 lectures of general/inorganic chemistry (equilibrium, thermodynamics, osmosis, acids and bases, redox/electrochemistry and kinetics, etc.) and 28 lectures of organic chemistry (simple organic transformations, spectroscopy, amino acids and proteins, carbohydrates and DNA). Students also undertake 27 hours of laboratory work during the semester. Some prior knowledge of chemistry is assumed (to around HSC level), and those students who have not previously studied chemistry are strongly encouraged to complete a bridging course prior to commencing the unit of study.

The unit of study is assessed primarily by a 3 hour long end-of-semester exam, which constitutes 75% of the assessment program. This exam is divided approximately equally between multiple choice and short answer questions, and between general/inorganic and organic questions. Analysis of the exam scripts for this study has involved both quantitative (statistical) and qualitative methods, with the qualitative analysis looking for evidence of misconceptions and examining commonalities in student approaches (both correct and incorrect). Some of the results from this analysis are summarised elsewhere in this volume (Read, George, King and Masters 2004b).

Participants

Students in the CHEM1405 unit of study were surveyed in the final teaching week of Semester 1, 2003. The survey instrument used asks students for some general background information (gender, age, prior study of chemistry), their student identification number (SID—provision of which was optional) and for their opinion of the most and least positive aspects of the unit of study. Respondents are then asked to rate how well they believe they understand, and can apply that understanding to answer questions about, 17 nominated areas of the unit of study on a 7 point Likert scale (1 = no understanding to 7 = excellent understanding).

The exam scripts for this unit of study were then analysed. For those students who provided an SID, exam performance was compared to their perceived understanding of the areas nominated in the survey instrument. The performance of the respondents was compared to the CHEM1405 cohort as a whole, to check that the respondents constituted a representative sample of the student population. As a preliminary exercise, an in depth interview was also conducted with one student, 'Karen', to provide some further insight into the students' perspective. It is intended that more interviews will be conducted with CHEM1405 students from 2004 during semester 2.

Results and Discussion

Participants and Response Rate

93 students completed CHEM1405 in Semester 1, 2003, of whom 52 participated in the study by returning the survey. A total of 36 respondents provided both an SID and sufficient information for the full analysis to be completed, and thus the overall response rate for full participants was 39 %.

Responses show that most of the respondents were recent school leavers (69% aged 17-19), and most had a good background knowledge of chemistry (78% had completed HSC chemistry or its equivalent). Only 5% had no prior knowledge of chemistry, and a further 5 % had the bridging course as their only prior study of chemistry.

Sample Representivity

Figure 1 shows the distribution of exam grades achieved by the full participants, and also the distribution for the whole student cohort. Exam results are unscaled, and it should be noted that these represent only the result from the end-of-semester exam, and so grades do not include other parts of the assessment program, such as tutorial quizzes and laboratory work. There is no statistically significant difference between the exam grade distributions of the respondents and non-respondents ($\chi^2 = 0.69$, df = 4, $p = 0.95$), nor is there any difference in distribution of background knowledge ($\chi^2 = 6.4$, df = 3, $p = 0.093$) nor gender ($\chi^2 = 0.20$, df = 1, $p = 0.65$).

Figure 2 shows the distribution of exam grades for different levels of background knowledge, for both full participants (Figure 2(a)) and the whole cohort (Figure 2(b)). In Figure 2, students have been categorised according to their level of prior study of chemistry. Students who had only completed a bridging course were classified as having a poor background; students who had studied chemistry to HSC level (or its equivalent) were classified as having a good background; and, students who had undertaken prior university level study of chemistry were classified as having an excellent background. There are no statistically significant differences between these distributions, and from this and the above statistical tests we can confidently conclude that the full participants are indeed a representative sample of the student cohort as a whole.

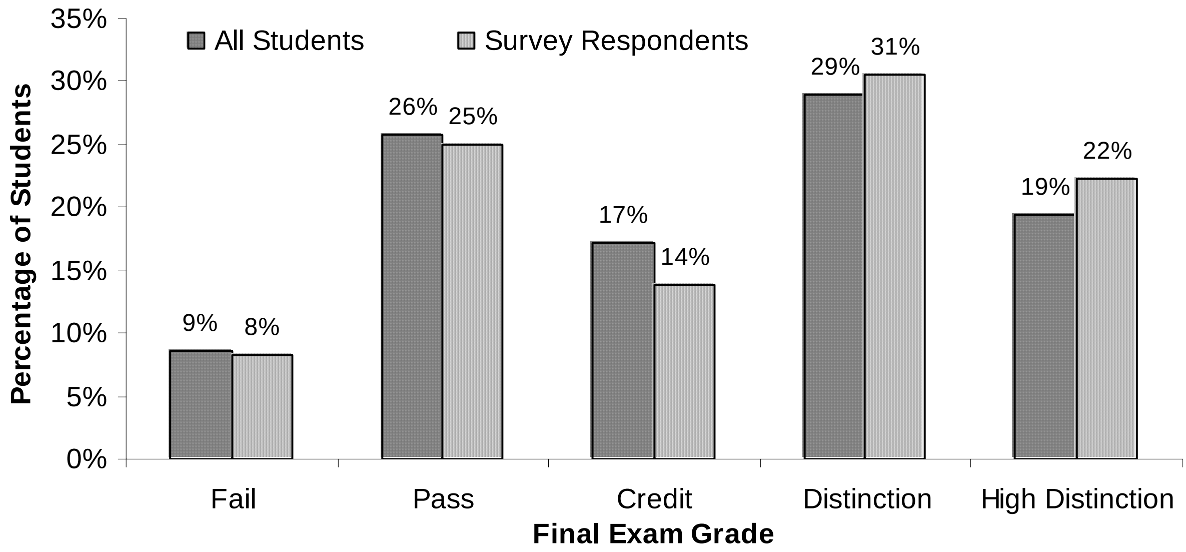


Figure 1. Distribution of exam grades for survey respondents and the whole CHEM1405 student cohort

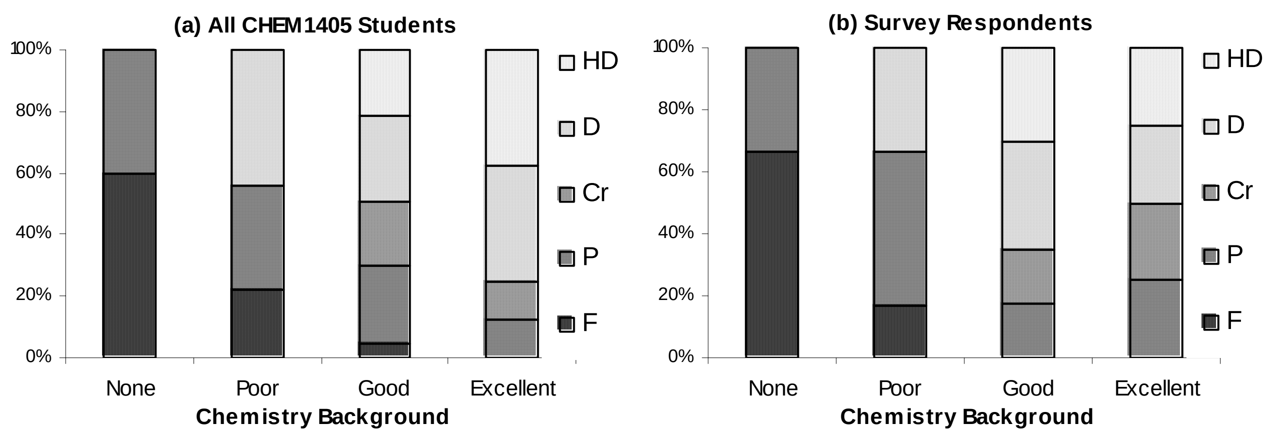


Figure 2. Distribution of exam grades for different levels of prior knowledge for (a) all CHEM1405 students and (b) the full participants in the survey

Figure 2 also shows that exam performance improves substantially with prior study – a finding that is not particularly surprising. However, the difference in performance between those students for whom a bridging course was their only prior study (poor background), when compared to those with no prior chemistry study, is surprisingly large. The bridging course that these students undertook comprised 13 hours of lectures, plus 26 hours of small group tutorials, spread over a 7 day period. The fact that such an intense but short period of study is associated with a reduction in exam failure rates by a factor of about 3, and seems to provide the basis for students to complete university level study at distinction standard, is a testament to its value, and is the subject of on-going investigation.

Individual Correlations

The first analysis performed on the data sets from the full participants was aimed at determining the strength of the correlation between each participant's perception of their understanding of nominated areas of chemistry, and their performance in those areas. Figure 3(a) shows the scatterplot for Karen, which is representative of most of the results obtained. Figure 3(b) shows the scatterplot for the student with the strongest correlation between perception and performance data.

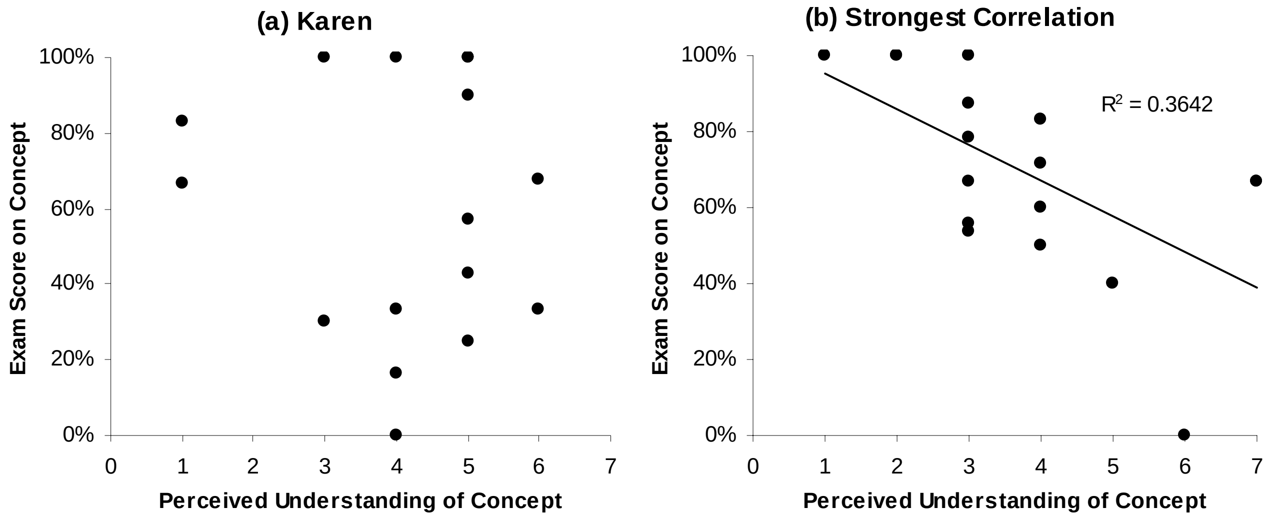


Figure 3. Scatterplots of perceived student understanding of nominated concepts against performance in exam questions on those concepts for (a) Karen, a typical CHEM1405 student, and (b) the participant with the strongest correlation

The results shown in Figure 3 were unexpected, especially given our starting hypothesis. In typical cases, there is no correlation between these factors (average $R^2 = 0.079$). In the case of the participant with the strongest correlation, whose R^2 is the largest by a considerable margin – the next largest was $R^2 = 0.255$ – although a weak correlation is present, it is a negative correlation. That is, it indicates that the student performed best in those areas where they believed they had the least understanding, and performance decreased as perceived understanding increased.

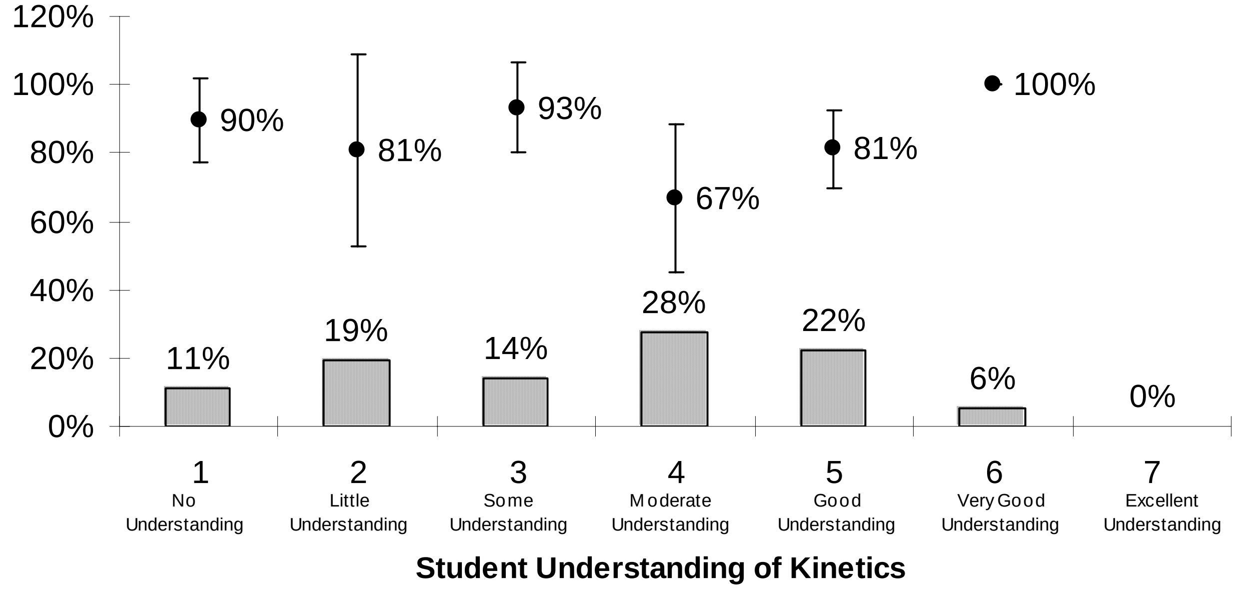


Figure 4. The distribution of reported student understanding of kinetics (bar graph, ▒) and 95% confidence intervals (●) of mean exam performance for each level of understanding

Since the analysis suggests that perceived student understanding and exam performance in individual areas are unrelated, it was decided to examine performance in a number of individual areas of the unit of study. One such area was kinetics, which the full participants rated one of the least understood concepts in CHEM1405. Figure 4 shows the distribution of reported levels of understanding of kinetics as a bar graph. For each of these levels of understanding, the 95% confidence interval for the mean exam performance has been constructed and plotted.

Figure 4 indicates that (for example) 11% of respondents reported that they had no understanding of kinetics. Despite this fact, the average exam score in the kinetics questions on the exam was 90 ± 12 % for these (perceived understanding = 1) students. Looking at the mean exam score over the range of reported levels of understanding, it is clear that exam performance on kinetics questions is independent of perceived understanding of kinetics. This was an unexpected result. Analysis of areas with higher reported perceived understanding also showed no substantial correlation between perceived understanding of a concept and exam performance on that concept.

Do we conclude from such results that students – at least, this group of students – are unable to identify what they do and do not understand? To address this question, we can look first to the interview with Karen. She was one student who rated her understanding of kinetics as ‘1’, but she performed well on the kinetics questions (scoring 83%). When asked to comment, she said:

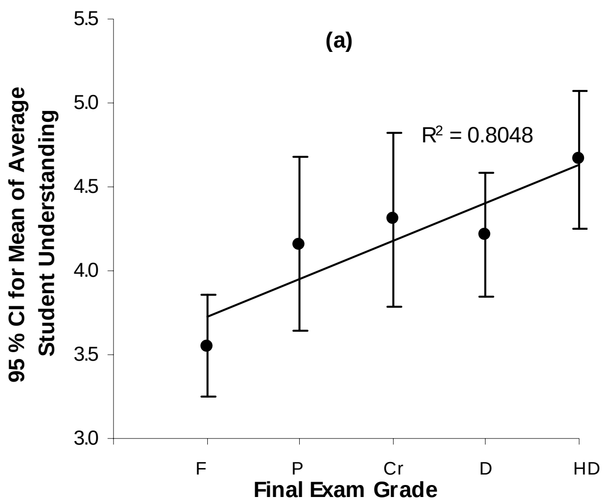
> That’s because they repeated the question, and I looked at the exam from the year before, and I practiced those questions … if they hadn’t of pretty much repeated the question, like, I would’ve been stuffed.

Karen went on to explain how she had now developed an understanding of kinetic phenomena, such as rate constants and half-lives, from second semester study. She gave a long example from a recent lecture concerning the use of thiopentone as an induction agent, discussing its biological half life in a number of different body tissues, and concluding:

> … and, I’ve now gone, oh my god, so this is just for this one drug that we’ve had a lecture on. And the *whole* mechanism by which it works, and its whole relevance to veterinary practice is based on its $t_{½}$. Like, because we know its $t_{½}$, we know how to use it.

It seems clear from these comments that Karen genuinely did not understand kinetics when she completed the first semester exam, relying instead on algorithmic and rote learning approaches to these exam questions. Qualitative data from exam script analysis suggests that such approaches were widely used by students in this unit of study (Read, George, King and Masters 2003; Read, George, Masters and King 2004a; Read et al. 2004b). There is ample evidence of algorithmic approaches and a lack of genuine understanding in the answers to questions in a number of areas of the exam. It seems likely, therefore, that the lack of correlation between student perception of understanding and exam performance in individual areas can, at least in part, be attributed to a failure of the exam to measure student understanding.

Group Correlations



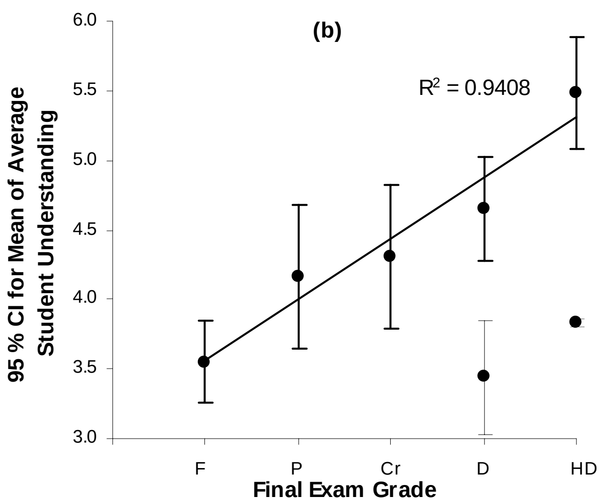


Figure 5. Correlation between average student understanding and exam grade grouped by grades for (a) all full participants and (b) with the perfectionist group separated

Since no correlation was found in individual areas of the unit of study, it was decided to check for any correlation between average understanding and overall exam performance. To do this, the reported levels of understanding for each of the nominated areas were averaged for each full participant. The data were then grouped by exam grades (rather than marks), and a 95 % confidence interval for the mean of average student understanding was constructed. When these confidence intervals were plotted against exam grades, a reasonably strong correlation emerged, Figure 5(a).

The correlation in Figure 5(a) is surprisingly strong, given the complete lack of correlation in individual areas of the unit of study, and especially since no correction has been made for exam weighting. That is, no correction has been made to compensate for the fact that the distribution of marks between the different nominated areas of the unit of study in the exam was not even.

When the data set within each exam grade is examined, it is apparent that the distributions are approximately normal for the lower grades, but bimodal for the upper grades. That is, there is a group of high achieving students, whom we term ‘perfectionists’, who report average levels of understanding much lower than would be expected given their overall performance. Figure 5(b) shows the correlation between average performance and understanding once this perfectionist group is separated. Performing this separation has two effects—it increases the gradient, so that average understanding is spread over a greater range, and it increases the strength of the correlation. (Investigations are continuing to try to identify the characteristics that make the perfectionist group different from other high achieving colleagues.)

The correlation seen in Figure 5(b) is remarkably strong, and further analysis was completed to check that this result is not an artefact created by the analysis. Since exam grade bands are not equally wide, the first check was to reconstruct Figure 5(b) using the same *y*-scale, but changing the *x*-scale to 95 % confidence intervals on the mean exam score for these groups, Figure 6.

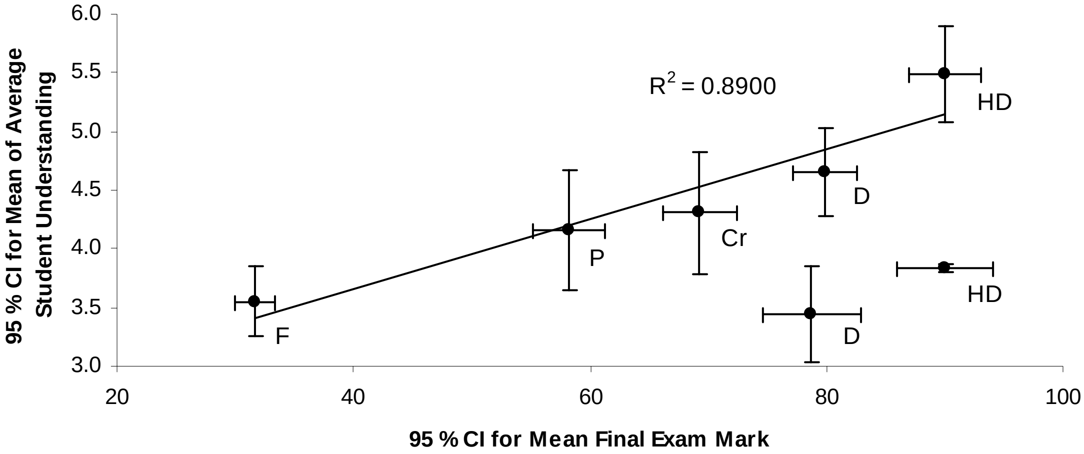


Figure 6. Correlation between average student understanding and average exam score

Figure 6 shows that the correlation between average perceived understanding and overall exam performance remains strong when marks are used. Results from other units of study (Read et al., 2003) show near identical results, with stronger correlations found in units of study with larger enrolments, where there were more full participants. It therefore seems unlikely that the observed correlation is merely a statistical artefact, although the reasons for its existence remain unclear. One possible explanation is that students who possess good exam technique, or higher self-efficacy, report generally higher levels of understanding—and further investigation is needed in this area.

Conclusion

The results from this study to this point show that there is no correlation between students' perceived understanding and their exam performance in individual areas of the CHEM1405 unit of study, a fact we believe can be attributed to the exam not measuring student understanding. The results also show that prior knowledge has a significant impact on exam performance. We have also shown that there is a strong correlation between average understanding and overall exam performance. However, the reason for the existence of this correlation, given our result that perception and performance in individual areas do not correlate, remains unclear.

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