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## ABSTRACT

There is evidence to suggest that first-year chemistry learning experiences may discourage students from studying further chemistry courses. This paper reports on an investigation on the influence of first year learning experiences in two first year chemistry courses on students' chemistry enrollment choices. Students enrolled in first year chemistry in a New Zealand university were surveyed using the learning experiences scale of the Chemistry Attitudes and Experiences Questionnaire (CAEQ) at two times throughout the academic year. Nineteen students enrolled in a first year chemistry course also were interviewed at the beginning of their tertiary education career and again at the end of their first and second semester chemistry courses. The students dislike lecturing styles where the entire set of notes was handed out before the lecture. They enjoy tutorials, but were less positive about practical learning experiences because of the large emphasis on volumetric analysis. Their learning experiences influenced their attitude-toward-enrolling in subsequent chemistry papers, with most of the students' attitudes becoming less positive. The results suggest that tertiary chemistry academics need to modify teaching practice if they wish to encourage students to continue with tertiary level chemistry study. (Author)

**Students' Perceptions and Learning Experiences of Tertiary Level Chemistry**

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**Students' Perceptions and Learning Experiences of Tertiary Level Chemistry**

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There is evidence to suggest that first-year chemistry learning experiences may discourage students from studying further chemistry courses. Here we report on an investigation on the influence of first year learning experiences in two first year chemistry courses on students' chemistry enrolment choices. Students enrolled in first year chemistry in a New Zealand university were surveyed using the learning experiences scale of the *Chemistry Attitudes and Experiences Questionnaire (CAEQ)* at two times throughout the academic year. Nineteen students enrolled in a first year chemistry course also were interviewed at the beginning of their tertiary education career and again at the end of their first and second semester chemistry courses. The students' dislike lecturing styles where the entire set of notes was handed out before the lecture. They enjoy tutorials, and but were less positive about practical learning experiences because of the large emphasis on volumetric analysis. Their learning experiences influenced their attitude-towards-enrolling in subsequent chemistry papers, with most of the students attitude becoming less positive. The results suggest that tertiary chemistry academics need to modify teaching practice if they wish to encourage students to continue with tertiary level chemistry study.

## Introduction

Science subjects are often seen as being unpopular amongst students, with negative attitudes developing as early as primary school level (Greenfield, 1996). Consequently, researchers in the field of science education have often sort to improve the experiences of students in science classes (Aldridge, Fraser, Fisher & Wood, 2002; O'Brien & Treagust, 2001). The aim of such research is to make science more attractive and interesting to students. More recently research in this area has moved beyond the compulsory schooling classroom, with studies been carried out in higher education institutions – especially amongst students who are non-science majors, such as pre-service teachers (e.g. Moscovici, 2002) and liberal arts majors (e.g., Gogolin & Swartz, 1992). Much research reported in the literature focuses on students that do not enjoy science, or who are study such subjects because of course requirements. In contrast there is little work reported on the experiences students who enjoy science and of science majors. These students are the academics of tomorrow, and the experiences they have in their university education may impact upon the way they teach the students of tomorrow. It is therefore important that the teaching practices that students find to be undesirable are identified so that pedagogical changes can be implemented.

The purpose of this study was to investigate first year chemistry students' perceptions of a year of tertiary level chemistry. The inquiry aimed to understand the first year chemistry learning experiences of undergraduate science and technology students.

## Tertiary Chemistry Pedagogies and Student Perceptions of Pedagogies

Examination of the science education literature suggests that the content, structure and teaching style for first-year or introductory tertiary chemistry courses are similar across the world (Fensham, 1992; Zoller, 1990). In introductory courses students are typically introduced to the fundamentals of chemistry including basic organic and physical chemistry, atomic theory, solution chemistry, concepts such as the mole, equilibria, solubility, acid-base and so forth. The usual means of delivery of these concepts are lectures, laboratory classes, and tutorials, although the emphasis placed of these modes of delivery varies from institution to institution.

### Lectures

For large classes, which are common at the first-year level, particularly for course containing an element of 'service teaching', lectures are the principal source of delivery of content. They are typically about one hour duration, and provide little opportunity for students to ask questions (Fensham, 1992). Common teaching methods include the provision of extensive written material presented on black- or whiteboards, overhead projectors, along with extensive verbal instruction. These methods mean students must concentrate on copying written material (even if written notes are provided, this is usually after the lecture, or at the end of the lecture course) rather than 'processing' or attempting to understand content (Laws, 1996). *Non-English Speaking Background* (NESB) students in particular find such a teaching style problematic and as a consequence rely heavily on prescribed textbooks (Mulligan & Kirkpatrick, 2000).

At the secondary and tertiary levels, science students' perceptions of their lessons are linked to their perceptions of teaching staff (e.g., Aldridge, Fraser, Murray et al., 2002). Research suggests that students who are positive about their teaching are usually positive about their classes (Ebenezer & Zoller, 1993; Waldrip & Fisher, 2001; Young, Fraser & Woolnough, 1997). However, other studies suggest that students' and instructors' views about what makes a 'good' science teacher are different (Robertson & Bond, 2001, Yäger & Penick, 1986). For example, instructors at the tertiary level value research ability, and see competence in research as an important factor in the ability to teach science effectively (Robertson & Bond, 2001). Surprisingly, there is little research on students' perceptions of a good lecturer at tertiary level, although there is a plethora of research on effective teaching in lectures (see, e.g., Donald, 1993). At the secondary school level content knowledge of their teachers is rated highly by students (Wareing, 1990) and this is also reflected at the tertiary level, with the exception of postgraduate students who do not rate research competence when choosing a PhD supervisor, rather they presume academics are expert in their fields (Neale, 2000).

The literature suggests that at the primary or elementary school level students prefer methods other than the traditional 'chalk and talk' approach for the teaching of science. For example, students prefer the 'social' aspects of science such as discussion of content, 'creative' science, and an entertainment component within the context of the lecture topic (George & Kaplan, 1988; Pibum, 1993; Sullins, Hernandez, Fuller & Tashiro, 1995). A number of reasons for have been posited to explain why student preferences for teaching style have not been taken on board; for example, teachers and academics are constrained by

course prescriptions, government prescribed curricula, or departmental policy and, especially in developing countries, financial constraints (Giddings, 1993; Sullins, Hernandez, Fuller & Tashiro, 1995; Swain, Monk & Johnson, 1999).

### *Laboratory Classes*

Laboratory classes are more popular than lectures with students because such lessons involve students in more exciting physical activities such as making observations and using new apparatus or scientific equipment (Bennett, Rollnick, Green & White, 2001; Pibum, 1993). However, while laboratory classes may be more enjoyable for students, they are not necessarily more effective sources of learning. For instance, teaching experiments are often designed with unrealistic or highly predictable outcomes, that neither challenge students nor engage students cognitively (Meester & Maskill, 1995). Furthermore, students are introduced to many new practical techniques without sufficient time in the laboratory to effectively master new skills (Meester & Maskill, 1995). This is particularly true in large first-year tertiary laboratory classes which may rely on bench demonstrations and typically have a higher student to staff ratio (Fensham, 1992). Students' perceptions of their laboratory classes are related to their perceptions of the teachers and graduate assistants. Students value the opportunity to ask questions of teaching staff (Bennett, Rollnick, Green & White, 2001), but tend to have negative perceptions of their laboratory classes if they find staff unapproachable or perceive them as lacking in confidence due to, for example, lack of experience (Fensham, 1992; Van Keulen, Mulder, Goedhart & Verdonk, 1995). Students also find it difficult to link ideas presented in lecture and laboratory environments (Laws, 1996; Van Keulen et al., 1995).

### *Tutorials*

There is much less research on students' perceptions of their tutorial classes. What research there is, suggests that the smaller class sizes provide an opportunity for tutors to answer questions (Laws, 1996; White et al., 1995). Mature and NESB students in particular value tutorials due to the small class sizes and what they perceive to be generally more enthusiastic and approachable tutors (Bennett, Rollnick, Green & White, 2001; Mulligan & Kirkpatrick, 2000).

### *Perceptions of First-Year Chemistry and Science*

For first-year students beginning their tertiary studies, all three learning environments (i.e., lectures, tutorials and laboratory classes) are somewhat alien as they represent significantly different experiences to those encountered at secondary school. At the secondary level, the focus is commonly on content knowledge for end-of-year external examinations (White et al., 1995). Beginning tertiary education is a particularly difficult experience for mature students who have typically been absent from formal education for long periods of time (Fensham, 1992). Likewise, NESB students find beginning tertiary studies difficult, since they also have to cope with learning new content in a second language (Mulligan & Kirkpatrick, 2000). Consequently, there is often a high attrition rate at the first-year level, particularly in the sciences (Wilson, Ackerman & Malave, 2000). The introduction of academic orientation or bridging programmes at the tertiary wide level has been effective in reducing the attrition rate, by, for example, offering university orientation courses that include an introduction to the physical environment and academic study, as well as, changing enrolment information structures to ensure

students are better informed about the courses they are enrolling in (Pitkethly & Prosser, 2000).

It appears from the literature that students' general perceptions of first-year science, and in particular, their chemistry classes, are not particularly positive. In addition, there is a large body of literature on alternative conceptions of first-year chemistry students, in most content areas (Boo, 1998; Hesse & Anderson, 1992). This is particularly so in the case of topics such as equilibria (Huddle & Pillay, 1996; Quíñez-Pardo & Solaz-Portolés, 1995), and such findings suggest that current teaching practices are not as effective as might be hoped (Bonner & Holiday, 2001). This has resulted in recent debate on the appropriateness on the traditional first-year chemistry course content and teaching style (see, e.g., Kettle, 2001). Principal stakeholders in science education including academics (Razali & Yäger, 1994; Shumba & Glass, 1994), prospective employers (Reid, 2000) and science funding bodies (Kyle, 1997) have suggested that traditional chemistry courses over-emphasise content at the expense of higher cognitive skills such as problem-solving, communication, and the nature of the research process (Coles, 1998). There is also debate in the literature regarding the importance of teaching chemistry concepts as opposed to teaching the use of problem-solving algorithms and related techniques (Chang & Bell, 2002; Jackman, Moellenberg & Brabson, 1990). Interestingly, assessment of chemistry courses is typically based on algorithmic type problems rather than conceptual understanding. It seems this occurs because examiners assume that students will be unable to solve algorithmic problems without the related conceptual understanding (Hobden, 2001). In other words, it is assumed that if students can solve algorithmic type

problems, they must understand the underlying concepts. However, research suggests that while students with greater conceptual understanding are better at solving algorithmic problems – suggesting a casual link (Mason, Shell & Crawley, 1997; Voska & Heikkinen, 2000), they fail to link the use of algorithms with the underlying chemistry/science concepts (Bunce, Gabel & Samuel, 1991). It is interesting to note that students that focus on the learning of concepts are more successful in their further chemistry studies – studies that build on concepts presented in introductory courses (Mason, Shell & Crawley, 1997). Additionally, there is some evidence to suggest that the examination-driven nature of courses can influence students' perceptions of the course. For example, some studies suggest that teachers believe some students do not embrace new learning environments and techniques due to concerns about examinations (Aldridge, Fraser, Murray et al., 2002).

#### *Learner Centred Models of Classroom Practice*

It has been suggested that tertiary teachers should modify their classroom practices to produce a more learner-centred environment. Such a notion has arisen, in part, from the constructivist view of learning that has been so influential in curriculum development for compulsory schooling world-wide (Russell, 1993; Shaw & Etchberger, 1993). Research on the validity of this claim and students' perceptions of a more learner-focused approach to science teaching has been carried out in both secondary and tertiary level classrooms (e.g., Von Sencker & Lissitz, 1999). However, it has been suggested that for learner-centred science instruction to be effective, students require a high level of scientific vocabulary and content knowledge, commonly achieved by teacher-centred

methods (Von Sencker & Lissitz, 1999). Some students respond well to learner-centred teaching finding it more mentally and emotionally engaging particularly in laboratories (Waldrip & Fisher, 2001; Young, Fraser & Woolnough, 1997), but others dislike such an approach and prefer a teacher-dominated style of teaching (Coll, Taylor & Fisher, 2002; Lucas & Roth, 1996). It has been suggested one reason students prefer teacher-centred instruction is their desire to establish exactly what teachers think it is important for them to know, particularly when assessment is largely dependent on summative external examinations (Mulligan & Kirkpatrick, 2000).

First-year chemistry classes have undergone some investigation through research into traditional methods of teaching in lecture, laboratory and to a lesser extent tutorial classes. This research examined students dislike of traditional teaching methods, the use of new methods in teaching – such as learner-centred classrooms, as well as examining students' experiences at university more generally. A significant amount of research has been carried out on elements of the content of typical first-year chemistry courses. However, there is a clear gap in the research, with few studies linking students' perceptions of all three tertiary learning environments and of first-year chemistry courses as a whole.

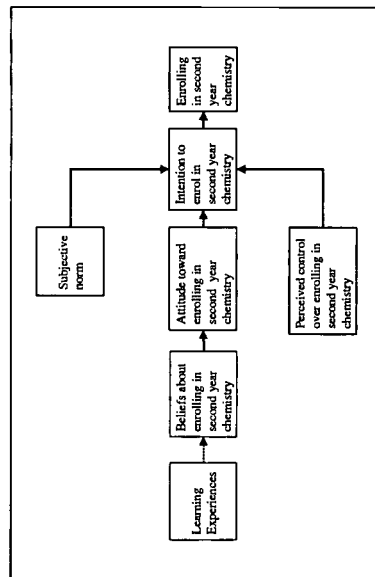
#### **Theoretical Framework**

The key research objective for this inquiry is to understand what influence first-year learning experiences in chemistry has on students' attitude-towards-enrolling in second-year chemistry. To examine this we extended and adapted the *Theory of Planned*

*Behaviour* (TPB), which maintains behaviour is determined by an individual's attitude toward the behaviour, their associates (e.g., peers, family and mentors) attitude toward the behaviour, and the individual's perceived control over the behaviour (Ajzen, 1989), to take into account the antecedents of attitude - incorporating chemistry learning experiences (Figure 1).

We have described the MTPB in greater detail elsewhere (see, Dalgety, Coll & Jones, in press) and in this paper we focus on the relationship between learning experiences and enrolment actions as mediated through beliefs and attitude toward enrolling in second year chemistry and intention to enrol in second year chemistry (centre part of Figure 1). Learning experiences directly affect attitude-towards-enrolling in second-year chemistry

**Figure 1**  
Theoretical framework used in the study of students' perceptions and learning experiences of tertiary level chemistry. Adapted from the *Theory of Planned Behaviour* (TPB) (Ajzen, 1989).



by generating new salient beliefs about enrolling in second-year chemistry. Consider a student, who enjoyed his/her first-year chemistry course. Such student would likely think that taking second-year chemistry would be enjoyable based on that experience. Students' learning experiences also influence the evaluation components of subjective norm and perceived behavioural control. As the relationship between learning experiences and all these components is tentative, it is therefore represented by dotted lines in Figure 1.

As a first step we sought to define chemistry and learning experiences. Chemistry is defined as the learned patterns for thinking, feeling, and acting that are transmitted via the acquisition of chemistry theory, skills and values. Learning experiences are considered to be any experience resulting in a belief formation about chemistry as defined above (where that belief is attitudinal, knowledge, or skill based).

### Methodology

This study involved monitoring an intact class of students across both semesters of first year chemistry; both quantitative and qualitative methods were used.

### Survey Administration

The quantitative component involved two administrations of the lecture, practical and tutorial subscales of the learning experiences scale of a previously validated survey instrument, the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) (Coll, Dalgety, & Salter, 2002; Dalgety, Coll & Jones, in press). Data was also collected on

student's gender, ethnicity, and reason for enrolling in first year chemistry. Both administrations were conducted during scheduled laboratory classes. The first administration occurred at the end of a first semester chemistry course (n=102). This response rate at 57% is a little lower than anticipated and was attributed to pressures on students in their laboratory classes at the end of the semester. Furthermore, there was a high non-response rate for the demographics questions for this administrations (on average 31%), however, of those who did respond 51% were male, 78% of New Zealand European descent, 13% Maori (indigenous New Zealanders)/Pacific Islanders and 7% Asian/Indian. The administration of the instrument was moved to earlier on in the semester, towards the second at the end of the second semester course in order to improve the response rate (n=84). This represented a response rate of 75%, of whom 52% were male, 75% of New Zealand European descent, 14% Maori (indigenous New Zealanders)/Pacific Islanders and 9% Asian/Indian.

#### *Interview Protocol*

In addition to the quantitative data collected as described above, 19 students were identified at the beginning of the academic year participated in interviews in order to ascertain what components of first year chemistry they were anticipating enjoying and not enjoying (Table 1, *Start of Year*). Of these, 14 were re-interviewed at the end of the first semester and nine at the end of the second semester to ascertain the experiences each had in both first year chemistry courses (Table 1, *End of First Semester* and *End of Second Semester*).

**Table 1**  
**Interview Protocol**

#### **Start of the Year**

1. What parts of the first year chemistry course do you think you are going to enjoy?
2. What parts of the first year chemistry course do you think you are not going to enjoy?

#### **End of First semester**

1. Can you tell me what you thought about the 101 lecture course?
2. Can you tell me what you thought about the 101 practical course?
3. Can you tell me what you thought about the 101 tutorials?

#### **End of Second semester**

1. Can you tell me what you thought about the 102 lecture course?
2. Can you tell me what you thought about the 102 practical course?
3. Can you tell me what you thought about the 102 tutorials?
4. Of the different lectures you've had throughout this year, which lecturing style do you like the most?
5. Of the different lectures you've had throughout this year, which lecturing style do you like the least?
6. Of the lab experiments you've done this year which would you say like the most?
7. Of the lab experiments you've done this year which would you say like the least?
8. Do you have any suggestions about ways the lectures could be improved?
9. Do you have any suggestions about ways the practical classes could be improved?
10. Do you have any suggestions about ways the tutorials could be improved?

#### *Data Validation*

Checking of respondents' data was carried out in two ways. First, the quantitative data was examined by a series of statistical methods to see if students responded to similar questions in the same way. In the first instance, data was subjected to principal component factor analysis, with Varimax rotation. Examination of the factor analysis (Table 2) suggests that the data from the study loaded on similar factors as indicated by the instrument development, with some items removed (Coll, Dalgety & Salter, 2002).

Analysis of the Cronbach  $\alpha$  reliability data shows that adequate reliability was observed for all subscales in both administrations. That is, for the lecture learning experiences subscales  $\alpha$  reliabilities of 0.80 and 0.84 were achieved, 0.82 and 0.68 for the tutorial learning experiences subscales, and 0.81 and 0.83 for the practical learning experiences



**Table 2**

Final factor analysis for the validation of the *learning experiences* scale of the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) from the end of first semester and end of second semester administrations of this instrument.<sup>1</sup>

Item	Subscale	End of First semester KMO= 0.751, Non-redundant residuals=34% (n=102)	End of Second semester KMO=0.702, Non-redundant residuals=44% (n=84)
1	L	0.44	0.39
2	L	0.49	0.72
4	L	0.50	0.73
5	L	0.83	0.71
6	L	0.47	0.59
8	L	0.45	0.63
9	L	0.49	0.64
10	T	0.55	0.85
11	T	0.77	0.73
13	T	0.57	0.37
14	T	0.68	0.46
15	T	0.67	0.61
16	T	0.33	0.60
18	T	0.65	0.48
19	P		0.52
21	P	0.47	0.40
22	P	0.79	0.55
23	P	0.48	0.62
24	P	0.60	0.60
26	P	0.39	0.65
27	P	0.71	0.73

Key: L= Lecture Learning Experiences, T= Tutorial Learning Experiences, P= Practical Learning Experiences

<sup>1</sup> Solution was rotated by Varimax rotation. Correlation's less than 0.3 are omitted

subscale. Similarly statistical discriminant validity showed adequate discrimination between the subscales, with values of 0.41 and 0.44 for the lecture learning experiences scale, 0.39 and 0.43 for the tutorial learning experiences scale and 0.44 and 0.45 for the practical learning experiences scale.

The qualitative data also were examined and compared with quantitative findings for two reasons. First, was as a means of triangulation of the quantitative data, and second, to investigate underlying reasons for quantitative research findings. The interview

participants' completed questionnaires were identified and their responses compared with interview responses. To illustrate, Alan's response about the environmental awareness of chemists, suggested that he held a positive attitude, which when compared with his interview data was found to be consistent with statements he made at the start of the year: "Chemists couldn't be that naïve not to be aware about what's going on [environmentally]." Similarly Alan was positive in both interviews and relevant CAEQ questions about whether or not 'chemistry advances society' in the attitude-towards-chemistry scale. In addition, all interview transcripts were returned to the interview participants to allow them to examine and verify the data to ensure it accurately represented their viewpoints.

*Data Analysis*

The respondents were asked to provide a response to each item in the 'learning experiences' scale of the CAEQ using a 5-point Likert scale from strongly agree to strongly disagree (5 and 1 respectively). From this response, a value for each subscale - termed the subscale response - was calculated from the mean response to the relevant items. Summary statistical data were then calculated resulting in an estimated mean. The term 'estimated mean' is used here in order to show the researchers' understanding that these data are ordinal level and not ratio/interval level. The quantitative data were analysed in a number of ways, drawing upon recommendations by authors such as Rennie (1998) and Carver (1978) about the role of statistical significance in educational research. Data were examined by ANOVA and results that were statistically significant at the p<0.05 level were further examined. Subsequently, statistically significant results were

analysed by Scheffe's post-hoc method to determine where the statistically significant differences occurred. Furthermore, in order to be deemed educationally significant, the statistically significant findings had to have an effect size value ( $\eta^2$ ) needed to be above 0.10 (Dalgaty, Coll & Jones, in press).

The qualitative data was analysed in two different ways. First the participants' responses were coded to identify the relevant component of a given research question, for example, chemistry learning experiences. Next, the responses in each coded section were grouped with similar responses and the major trends established. Any responses that did not fit in with this approach were examined to give the conclusions extra depth. The data were also analysed as a whole with each participant's responses summarised. The summaries were subsequently examined for similarities and differences, and any conclusions drawn compared with the conclusions from the previous data analysis method outlined above.

### Results from Survey Administrations

The respondents were overall 'positive' about their first semester learning experiences. The estimated means for the learning experiences sub-scales at the start of the year were: 3.4 for lectures, 3.8 for tutorials and 3.5 for laboratory classes (Table 3). The estimated mean responses were tested by ANOVA analysis and the differences are statistically significant ( $p < 0.01$ , Table 3). Post-hoc analysis of the ANOVA results using the Scheffe method found that the estimated mean response for the *tutorial learning experiences*

<sup>1</sup> For a 5-point Likert scale, a response of greater than 3.0 is deemed to be positive

**Table 3**

Differences in the estimated mean responses for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) *learning experiences* subscales for the administration at the end of the first semester ( $n=109$ ).

	Mean	Std.Dev	F	p	$\eta^2$
Lecture Learning Experiences	3.4	0.6	9.77	0.00	0.06
Tutorial Learning Experiences	3.8	0.6			
Laboratory Learning Experiences	3.5	0.6			

subscale was statistically significantly different to both the *laboratory* and *lecture learning experiences* subscales estimated mean response (Table 4). However, size effect analysis ( $\eta^2$  of 0.06) suggests that the observed effect is likely to be small. The first semester learning experiences data were further analysed using ANOVA to investigate what influence, if any, gender, ethnicity, and reasons for enrolment exerted on students' learning experiences. The results of the statistical analyses show no statistically significant differences for any of these demographic groups.

**Table 4**

Post-hoc Scheffe analysis of the ANOVA data of the differences in *learning experiences* subscales for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) from the administration at the end of the first semester ( $n=109$ ).

	Subsets are statistically significantly different at $p < 0.05$	
	1	2
Tutorial Learning Experiences	3.8	
Practical Learning Experiences		3.5
Lecture Learning Experiences		3.4
p. (within subset)	1.00	0.46

The respondents were still overall positive about their learning experiences at the end of the second semester (Table 5). Estimated mean responses were 3.6 for *lecture learning experiences*, and 3.8 and 3.6 for tutorial and *practical learning experiences* subscales respectively. These data show an interesting trend, with the estimated means greater than 3.5, and a higher proportion of responses greater than 4.5 than at the beginning of the semester, for all three subscales. ANOVA analysis of the three learning experiences subscales for the second semester shows statistically significant differences ( $p < 0.05$ , Table 5). However, post-hoc Scheffe analysis suggests that when comparing differences individually, there are no statistically significant differences (Table 6). Furthermore,

**Table 5**

Differences in the estimated mean responses to the *learning experiences* subscales for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) from the administration at the end of the second semester ( $n=84$ ).

	Mean	Std.Dev	F	p	$\eta^2$
Lecture Learning Experiences	3.6	0.5	3.18	0.04	0.03
Tutorial Learning Experiences	3.8	0.7			
Practical Learning Experiences	3.6	0.6			

**Table 6**

Post-Hoc Scheffe analysis of the ANOVA analysis of the differences in the *learning experiences* subscales from the end of the second semester administration for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) ( $n=84$ ).

Tutorial Learning Experiences	3.8
Practical Learning Experiences	3.6
Lecture Learning Experiences	3.6
p. (within subset)	0.09

Subsets are statistically significantly different at  $p < 0.05$

effect size analysis ( $\eta^2 = 0.03$ ), suggests that the statistically significant differences identified by ANOVA analysis are likely due to statistical variation.

Further examination of the end of second semester learning experiences data suggests that although there are no significant differences based on gender, and ethnicity, there are differences in the estimated mean responses for the *practical learning experiences* subscales, between groups of students based on enrolment reasons (Table 7). Post-hoc Scheffe analysis suggests that students who enrolled in the second semester course as a science support or interest course had less positive experiences than those for whom the

**Table 7**

Differences in the estimated mean responses to the *learning experiences* subscales for the *Chemistry Attitudes and Experiences Questionnaire* (CAEQ) for respondents of different gender, ethnicity, decile rating of contributing school and enrolment reason from the administration at the end of the second semester ( $n=84$ ).

	N	Lecture Learning Experiences			Tutorial Learning Experiences			Practical Learning Experiences				
		Mean	Std Dev.	p	Mean	Std Dev.	p	Mean	Std Dev.	p		
<b>Gender</b>				1.06	0.31		0.00	0.98			0.65	0.42
Male	40	3.7	0.4		3.8	0.5		3.7	0.6			
Female	37	3.6	0.6		3.8	0.8		3.5	0.5			
<b>Ethnicity</b>				0.01	0.93		3.69	0.06			0.66	0.42
New Zealand	58	3.6	0.5		3.7	0.7		3.6	0.5			
European	18	3.6	0.4		4.0	0.5		3.7	0.7			
<b>Enrolment reason</b>				0.68	0.51		2.67	0.07			6.54	0.00*
Chemistry Major	18	3.7	0.4		4.0	0.5		3.8	0.3			
Science Support	26	3.6	0.5		3.6	0.9		3.3	0.5			
Subject and Interest	29	3.5	0.6		3.9	0.6		3.8	0.5			
Compulsory Course												

\* statistically significant at  $p < 0.01$

second semester course was a compulsory course - as part of a chemistry or another science major (Table 8). Furthermore, effect size analyses ( $\eta^2$  of 0.18) suggests that this result is likely a real reflection of student viewpoints rather than due solely to statistical variation.

ANOVA analysis comparing the first semester and second semester *learning experiences* subscales shows no significant difference for any of the three learning environments. This suggests that the students were no more positive about their learning experiences in either course.

**Table 8**

Post-Hoc Scheffe analysis and  $\eta^2$  of the ANOVA analysis of the differences between the *practical learning experiences* subscales for respondents who enrolled in the second semester course from the end of the first semester administration for the *Chemistry Attitudes and Experiences Questionnaire (CAEQ)* ( $n=109$ ).

	Subjects are statistically significantly different at $p < 0.05$		$\eta^2$
	1	2	
Science Support Subject and Interest	3.3		0.18
Chemistry Major		3.8	
Compulsory Course		3.8	
P. (within subset)	1.00	1.00	

### Results from Interviews

At the start of the year many of the participants were apprehensive about tertiary learning. The participants were particularly concerned about lectures and, for example,

were concerned that it would be difficult to ask lecturers questions in large lecture classes. The reason for this concern stemmed from a perception of differences between mass lectures they expected to encounter, based on previous experiences in interactive small classes in high school. Similarly, a belief that they were expected to be more independent in the tertiary setting, apprehension for some participants. For example, Leanne, believed tertiary chemistry study would require her to “spend a lot of time on my own trying to study and get my head around things as well as adjusting to the fact you can’t ask someone right then and there. If you have a problem, you have to wait till maybe tutorial time or when you can speak to a lecturer.”

Other students were more concerned about the study skills required of them, including memorisation and learning approaches. Alan, a mature student returning to study after five years in the work force, specified memorisation of content as a particular concern:

The whole memorising thing has got me a bit scared at the moment. I will have to remember all these things. I think that might be a bit challenging. Trying to sit down and study, and trying to remember it all might be a bit of a culture shock.

A few of the students coming from a schooling system heavily reliant on final summative examinations were worried about the assessment at university. In particular they were worried about appropriate ways to present assignments and how they would cope with “passing tests.” This was of less concern for the more academically able students like

Robert who was looking forward to the opportunity to “learn more chemistry, and new chemistry.”

At the end of the first semester many of the students initial concerns had dissipated, as they became more familiar with the tertiary learning environment. At the end of the first semester, only two of the interview participants mentioned study skills as a problem - both in reference to aspects of their second semester course. Kerrie said she would not like “the work because I don’t like organic [chemistry].” Interestingly, one of the interview participants who did the second-year analytical chemistry course (which is entirely internally assessed) was unhappy that there were no final examination: “I just like exams, that is all. I usually do way better in exams than tests I like sitting there, trying to figure out things.” By the end of the second semester none of the participants had concerns about the study skills required for second-year chemistry courses.

#### *Lecture Learning Experiences*

At the beginning of the year, the interview participants voiced very little opinion about the lecture structure of the course beyond the concerns identified previously. Many of the participants identified organic chemistry as a course component that they expected to enjoy - although few were able to articulate what exactly they would enjoy about organic chemistry, beyond references to previous learning experiences: “I liked it at school,” and “I find it interesting.” Some of the participants thought that they would not like the inorganic component of the course - many associating this with memorisation of large amounts of content. Patrick, for example, said he would not like “inorganic I will

struggle a bit with [inorganic]. I do have a bit of problem with the recollection of chemical names.” Other interview participants suggested that the basic concepts and the aqueous chemistry component were less appealing because of the mathematical component. For example, Neil, an engineering student, after just one week of tertiary chemistry was particular unhappy: “The mathematics part, that just bugs me out. You go to chemistry to learn about chemicals, and you have to learn a whole bunch of maths to go with it, and it’s like, man, I go to maths to learn about maths.”

Although some of the interview participants thought they would not like the basic concepts and aqueous chemistry part of the first semester course: “Aqueous [chemistry], I don’t really like that,” others thought they would like it because the content was similar to their secondary school studies: “I like what are we doing at the moment, I think it’s pretty much an overview of [Year-13] with a bit more added to it.” Interestingly, none of the interview participants expressed concern about the physical chemistry part of the course, despite its high mathematical component.

At the end of the first semester and at end of the second semester the participants were focussed mainly on the structure of the two courses, rather than the content. Of the participants that mentioned course content during interviews, a number talked generally. For example, Samantha, an academically-able chemistry major, found the course “good, there was quite a bit of new material from like [Year-13], but it wasn’t hard to understand.” At the end of the second semester a number of participants identified organic chemistry as the part they found most interesting (for both first-year courses) -

even those interview participants who did not think they would like organic chemistry at the start of the year. Patrick comments: "I said in one of the other interviews that I thought I would hate [organic chemistry], really loath it. But it's not too bad. It actually turned out to be really good." In contrast, other participants were particularly negative about physical chemistry commenting: "A lot of mathematics," "it was more physics and maths orientated," seeing physical chemistry to be "a bit more sort of textbook, like you don't encounter it as much," and saying "it was a bit alien, I couldn't relate to it really." Some of the interview participants found parts of the first semester course "hard to follow," and requiring a lot of work outside formal classes. Alan said "I didn't find the lectures as beneficial as the tutorials and the laboratories. They sort of give you a bit of understanding, they sort of talk about the topic, but I found I had to do a lot of work outside to understand it."

The interview participants felt that the course notes influenced their ability to understand the course, with most preferring to write some notes, rather than relying solely on a study guide that contained all the notes. For example, Patrick commented:

When you are just sitting there and you've got all the notes in front of you and he's just talking away you just go off on tangents. With the study guide I am going to have to do a lot of revision to remember what happened, what he was talking about.

However, the alternative of writing down full notes was not considered desirable either. For example, Alan said "I don't have a problem sitting in a lecture writing notes, but [that

lecturing style] was just unreal, [the lecturer] just writes so fast and expects us to write so fast." The majority of the participants preferred a lecturing style that used skeleton notes, which the students filled in during lectures. For example, Robert noted:

If I'm going to it [i.e., the lecture] I don't mind a little bit of writing. I suppose because my writing isn't so neat, so I like printing better. But then if you do write it, you have the added benefit of already kind of studied it a bit. So I like a little bit of both, as long as everything is kept in the same book.

The interview participants felt inhibited about approaching lecturing staff: "It is off-putting to go and ask them for help if you are having difficulties with it." But one lecturer in particular was seen as highly approachable with a good relationship with students. Tabitha commented: "[the lecturer] is, a lot more personal and interacts a lot more with the students."

Some of the interview participants enjoyed the use of visual aids, with Celia commenting that she preferred lectures when the lecturer "brings in props and blows up balloons and makes it more real life, because you can relate to it." One student, Karen, liked it when the course material was contextualised to familiar examples: "He related everything to what we do. He put it in terms of alcohol, and going out, and it's like I know that, and then it's like, that's right." Other popular contexts, particularly for engineering students, were applied chemistry examples. For example, Jack said he liked lectures that discussed

“finding out about petrochemicals, finding out where petrol comes from, how it’s made in New Zealand, all the different things in nature that you find out using chemistry.”

#### *Laboratory Class Learning Experiences*

At the beginning of the year the interview participants were looking forward to their laboratory classes, in particular the opportunity to “see it for yourself,” and “do it all yourself.” The interview participants believed they would enjoy the “hands on” nature of laboratory classes. For example, Kevin, a chemistry major, said “I just like doing hands on stuff, being able to mix chemicals.”

Although many interview participants identified the laboratory classes as the most enjoyable part of the course, at the end of both semesters, they were much less positive about some specific experiments. In particular, the amount of time spent doing titrations in the first semester course was unpopular with an overwhelming number of participants. The accuracy and precision deemed necessary by the laboratory supervisors was seen as the major factor contributing to lack of enjoyment. Kevin an intending chemistry major, dropped out of his second semester chemistry course as a direct result of his experiences in the laboratory classes in the first semester course. He comments:

I’m not sure what I thought we would be doing, but it is just titrations. Fun, fun! It is standardisation of things, it’s having to do it so accurately that if you get it not within 0.04 of a mL you have to get three like that. I just don’t like having to be so accurate. I mean I usually get it, but I don’t like the repetitiveness.

The interview participants were more positive about the organic chemistry experiments enjoying the opportunity to use equipment not available at school, as seen in Jack’s comment: “You get to use equipment that you don’t really use back in high school. We used burettes and pipettes [i.e., at school], but with the organic you get to use different equipment, reflux condensers, separating funnels, etc.” The interview participants were less positive about the physical chemistry laboratory experiments due to the amount of time spent measuring and waiting. For example, Kerrie said she did not like “the kinetics one from physical chemistry. Measuring the temperature was pretty boring, and you had to sit and do the temperature for a minute, for 45 minutes.” Interestingly, despite the participants dislike for physical chemistry and titration experiments the most popular experiment from the two courses was an experiment in which they used an ion exchange column to measure the concentration of copper sulfate, an experiment in the physical chemistry laboratory classes involving titrations. The interview participants found this particular experiment easy and reiterated that they got to use equipment they had not used before. Robert noted that he liked using “new equipment [i.e., the ion-exchange column]. It was a little bit time consuming, but it was easy work. Like you set up two at a time and the titration was nice and easy.” It is worthwhile to note that this experiment was carried out at end of the second semester, by which time the students were more proficient in the conduct of titrations. In addition, the supervisory staff involved were less concerned with precision in titration results in this experiment compared to previous experiments involving titrations.

Approachability of the staff also influenced the interview participants' perceptions of their laboratory classes. Some of the interview participants found the staff difficult to get along with, and one student, Tabitha, changing her laboratory class. She "enjoyed the labs quite well [after changing]. I've enjoyed them a lot more than my last semester labs, probably because my new lab demonstrator this semester was a lot more relaxed." Other interview participants commented on a shortage of supervisory staff, with, for example, Kerrie saying: "We only had two demonstrators and I thought we could have done with a bit more because everyone needed help and it was a bit hard getting around everyone in the class."

The interview participants generally found the laboratory classes confusing and believed that the classes could be improved by having introductory talks at the beginning of each class. For example, Patrick said:

Perhaps a bit of a talk at the start with a bit of background theory. Like in a couple of the laboratories the supervisor showed us how to do some of the techniques that we used and some of the reactions that occurred and that was really good. The others when that didn't really occur, it was sort of mix this with this and stuff like that and I'll chuck five mLs of that in and hopefully I will get the right conclusion. Just a bit of talk at the start to get the basic theory, just about 10 minutes at the start. That would help me.

Similarly, the interview participants felt that the laboratory classes could be improved by some instruction on what was required for the experimental write-up, as well as help with post-class questions. One student, Jack, suggested this could be accomplished in tutorial classes by "allowing a little bit of tutorial time for lab write up and help." Others thought the laboratory classes in the first semester course could be improved by reducing the length of the experiments, and noted that the second semester course was better in that the shorter duration of experiments enabled the students to leave the classes early: "I enjoyed the practicals quite a bit. But three hours of chemistry practicals sometimes gets to be a bit too much."

#### *Tutorial Class Learning Experiences*

As mentioned above, tutorial classes are voluntary at the institution involved in this study. Participants that attended tutorials found them for the most part beneficial. The interview participants felt the problem sheets provided helped them prepare for tests and examinations. For example, Jack noted that the tutorials "were really helpful, the problems sets they gave me something to do, to work through and make sure I knew everything, and the tutorials just helped reinforce that." In fact, the problem sheets often contributed to the participants' attendance at the tutorials, as answer sheets were handed out at the tutorials. Some interview participants found that the tutorials were not relevant. For example, they felt the physical chemistry problems were not relevant to the material presented in lectures. To illustrate, Patrick stated: "Some of the questions are sort of just completely abstract from the lectures." In addition, the participants felt if they did not get a chance to do the problem sheets, then the tutorials were not as useful and thus they often did not attend tutorials. Felix comments:



I went to some of them [i.e., tutorial classes]. I actually stopped going to them. I was finding that I wasn't getting the tutorial questions done by going to the tutorials. I was going and getting the answer sheet and going through it. But I wasn't finding time to go through the questions otherwise. I think the tutorials would probably be more beneficial if I was able to get through the questions first.

The participants overall thought the tutorials reinforced the lecture material, and helped explain some of the concepts that they found confusing in the lectures, as seen in Alan's comment:

They were really helpful because we discuss the theory in the lectures and they provide us with examples of questions that we have to answer ourselves. Going away and having to answer them is quite difficult just from the lecture material, and in the tutorials we can go through and discuss them it makes things a bit clearer. Most of the tutorials I don't bother going to for most of my subjects, but chemistry I make a real effort to go.

Like their learning experiences in the laboratory classes and lectures, the teaching staff influenced the participants' learning experiences in their tutorial classes. Interview participants who had the same person as both lecturer and tutors, found some of the same negative experiences in the lectures present in the tutorial classes as well. Tabitha found the tutorials "were quite good to help you understand, but my tutor was the lecturer. So I found it a little hard." One participant did not enjoy his tutorial classes as he thought the

tutor "seemed to always pick on me, even if I didn't know the answer, which I didn't like. So I haven't been going for a while." Other participants had a better relationship with their tutor than the lecturers, and felt the tutor explained these concepts better. Patrick stated that the tutor "knows what he/she is talking about and if we have any questions he/she's able to answer them without any problem."

#### *Direct Entry Students*

The two direct entry students had very different learning experiences to students who completed the first semester first-year course. At the start of the year Robert stated: "I've really gone into second-year to learn something different. That's what I intend to get out of it." But both of these students found the lecture course boring seeing it as "different to the kind of chemistry we normally did when we were at school. It was more machines and how they worked." In addition, they were ambivalent about their laboratory classes stating that they preferred the second semester course "because your doing your own chemistry, sometimes with the [second-year laboratory class] you can just roll along with it and not take much notice. Someone's usually doing stuff for you and then you get printouts at the end of the lab."<sup>2</sup> However, Kirsten acknowledged that, "from school I had a perception of what chemistry would be, like experiments and stuff, and that was what the second-year course was." These students enjoyed their tutorial classes since they provided an opportunity to ask the tutor about other second-year chemistry courses and keeping them up to date with what their peers were doing in the first-year class.

Robert comments:

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<sup>2</sup> As these classes involve expensive equipment, students typically observe technicians operating the instrumentation rather than carrying out this manipulation themselves

They were all right. It was more keeping up to date with what the first-year students were doing, and it gave us a bit more advances to see what we are going to be taught in the future and if we had any problems with anything else he would go over it.

The direct entry students enjoyed the second semester course seeing it as an opportunity to return to studying more “normal” chemistry.

#### *Understanding of Different Teaching Methods*

It seems that the interview participants believe that tertiary chemistry learning experiences are determined by the academic staff and their preferred teaching style. For example Patrick noted that “each lecturer has their own style and you can’t expect each lecturer to give up their style.” So whilst some of the interview participants were positive about their learning experiences, finding, for example, that the course was well structured, they seldom expressed an opinion about affective aspects of learning such as enjoyment and interest. For example, Samantha said the first semester lectures were “good, it was all really relevant to the tests, it taught you everything you need to know and relevant to the labs as well,” and saw laboratory classes as “good, the lab manual was clear and it set out how to do everything.”

#### *The Influence of Chemistry Learning Experiences on Attitude-Towards-Enrolling in Chemistry*

Some of the interview participants said that they enjoyed chemistry at secondary school and enrolled in chemistry at first-year because, as Eleanor put it, she “enjoyed it at school and so I thought I’d carry it on.” Although the participants seldom identified specific first-year chemistry learning experiences as reasons for studying chemistry in the second semester or at second-year level, two of the interview participants who dropped out of chemistry said that their first-semester experiences influenced their decisions. Kevin, an intending chemistry major commented at the start of the year:

I just don’t like the lab work. I enjoy the lectures. I like all the material in them, but I don’t like the actually having to do three hours lab each week. Maybe because I’m slower and I have to work a lot harder, but I just don’t like that part of the course.

Lawrence, was planning to supplement his *Resource and Environmental Planning (REP)* specified programme with additional chemistry, instead he dropped chemistry at the end of the first semester: “I’ve kind of gone off [chemistry] a bit I suppose. It’s just that we haven’t done anything new. We have just done the same things for the last few years and it’s kind of got a bit boring.”

## Discussion

The structure of the first-year chemistry courses at the tertiary institution involved in this study is similar to that in other universities world-wide (Fensham 1992; Zoller, 1990). Students are taught chemistry theory in lectures, with lecture material complemented by laboratory classes intended to provide students with an opportunity to gain 'hands on' experience in laboratory chemistry. Regular tutorial classes are provided and these are intended to allow students clarify lecture material and to provide a mechanism for self-evaluation by the use of problem sheets that mimic topic tests and examinations. The research findings reported here suggest that the participants see the three learning experiences to be very different in nature, and that they serve different purposes to high school learning experiences.

The lecture classroom environment was of concern for many of the students. In particular, the students were worried that they might not possess the requisite study skills anticipated difficulty in completing assignments, and in mathematical manipulation. This result is consistent with other research - particularly for other countries for which university entry is based on external summative examinations (White et al. 1995). Mature students were apprehensive about their tertiary studies: previous research involving mature students, suggests that this is likely to lead to a high attrition rate for first-year science courses (Fensham, 1992; Wilson, Ackerman & Malave, 2000). This latter fear was borne out in the present work with a significant number of first-year students (both mature and new entrants) dropping out after the first semester.

Interestingly, despite some initial concerns, the students reported positive first-year learning experiences - in contrast with other research (e.g., Boo, 1998; Hesse & Anderson, 1992). The quantitative data suggests that the students had no particular preference for a given course. However, the qualitative data identified some topics within these courses that were popular with the students and others were that were unpopular. As it turns out, the most popular topic (organic chemistry) and the least popular topic (physical chemistry) both are presented in the second semester course. Furthermore, the students' views about inorganic chemistry and aqueous chemistry (taught in the first semester course) varied with some liking aqueous chemistry because it was familiar, and others disliking the heavy mathematical component of these topics. It is somewhat surprising that some of the students liked aqueous chemistry given that equilibria (part of the aqueous chemistry component of the course) has been reported to be very unpopular in other studies (e.g., Huddle & Pillay, 1996; Quilez-Pardo & Solaz-Portoles, 1995). Another interesting finding was that some of the direct entry students did not enjoy the lecture content for the second-year course - mostly because it was so different to their secondary school chemistry study. This is an important finding for the institution involved in this study since direct entry into the second-year is seen as a useful recruitment tool intended to encourage more academically able students to pursue a major in chemistry.

The students made a number of useful suggestions of ways in which they believed their chemistry courses could be improved. First, they did not like lecturers to provide them with full, detailed, lecture notes: this, they reported, inhibited them from engaging with

the subject and made the lectures seem rather dry and pointless. The students did not like taking extensive lecture notes either; for example, copying notes verbatim from the blackboard or from overhead transparencies (Laws, 1996; Mulligan & Kirkpatrick, 2000). The best form of lecture notes, according to the students, consists of 'skeleton notes' containing the main points, that require the students to add additional material based on the lecture presentation and in-class discussions. The students also liked lecture material to be contextualised, using relevant real-world examples that were familiar to them. This latter finding is consistent with the findings of Ebenezer and Zoller (1993) and Manzana, Barreiro and Jiménez (1999) who found relevant contextual examples to be effective in enhancing student interest in chemistry. Other suggestions about the lecture component of the course included increased use of visual aids: a finding reported to be effective at other tertiary institutions (Deschri, Jones & Heikkinen, 1997).

At the start of the year the students were looking forward to their laboratory classes. Although they still enjoyed the classes, the students were less positive in attitude towards the laboratory component of their courses after their experiences in the first and second semester courses. This result is somewhat concerning and contradicts other research, which found that students reported the laboratory classes to be the most enjoyable aspects of their chemistry study (Bennett, Rollnick, Green & White, 2001; Piburn, 1993). The qualitative data in the present work was useful in identifying reasons for this apparent anomaly. In general the students did not like the high emphasis placed on titrations - particularly what they saw as an overemphasis on accuracy and precision. The students enjoyed experiments that allowed them to use new equipment. It seems this

latter aspect is particularly influential in that the most popular experiment involved titrations, but also allowed students to use new equipment and the staff running this experiment placed less emphasis on accuracy and precision. An interesting finding was the two direct entry students were less than positive about their laboratory classes. It seems these classes, which are often demonstrator-led rather than student-led, were not popular with the students, due to the reduction of 'hands on' experience for the students. Thus, when students have less 'contact' with experiments they tend to enjoy the classes less (as found in previous studies, see, e.g., Fensham, 1992).

The students made few suggestions for the improvement of the laboratory classes. The main suggestions were that the laboratory manual needed a better introduction to the experiment and that introductory laboratory talks would be beneficial as would time set aside for laboratory questions in tutorials. Although laboratory talks do occur in these classes, they are typically informal as the students turn up, and have no set structure. It appears that students would prefer a more formal approach to these talks. Students also wanted more guidance on how to present their data in the write-up of their laboratory classes. These findings are similar to those of other studies that found students engage better in laboratory classes when they are better prepared (Rollnick et al., 2001).

The students were most positive about their learning experiences in their tutorial classes as reported elsewhere (Bennet et al., 2001; Mulligan & Kirkpatrick, 2000). Interestingly, this positive feeling only occurred for the first semester tutorial classes. Interview data suggests that this probably occurred because the students stopped attending tutorial

classes in the second semester, when they found that they could cope with lecture material without help. Tutorial learning experiences were seen in a positive light because the students found them useful in preparation for topic tests and examinations. However, as reported previously, tutorial sheets that contain mainly algorithmic problems are seen as being less useful because students cannot see what relevance such problems have to lecture material (Mason, Shell & Crawley, 1997; Voska & Heikkinen, 2000). It appears the majority of students see the tutorials as a positive learning experience, not because of the opportunity to ask questions, but because of their relationship of the material presented in tutorials to examination and test questions (Hobden, 2001; Jackman, Mollenberg & Brabson, 1990).

Lecturing style, staff-to-student ratios in the laboratories, and in some cases staff attitude-towards-students, were identified as important factors in all three learning environments: indeed negative learning experiences were commonly attributed to such issues. Some lecturers were deemed unapproachable, and in some cases students felt that there were too few laboratory demonstrators. Other interpersonal issues reported included a perception that some tutors 'picked on' target students in tutorials (see, Tobin & Gallagher, 1987). This is of concern, given that interpersonal relationships between students and teachers have been found to be highly influential in formation of student attitude-towards-science for both practical and theory (Ebenezzer & Zoller, 1993; Van Keulen, Mulder, Goedhar & Verdonk, 1995).

It was interesting to note that the students felt academics and course tutors could not be expected to modify teaching styles to suit student needs. Although the students made some suggestions that a more learner-centred method of instruction would be better, for the most part any discussion on teaching style was within a context of a teacher-centred method of instruction. It is unclear, whether this is because, as reported previously, that tertiary students are content with teacher-centred methods of instruction (Coll, Taylor & Fisher 2002; Mulligan & Kirkpatrick, 2000), or if students do not consider different methods of teaching possible in the tertiary environment.

### Conclusions

If one seeks to effect changes to pedagogy, the beliefs of the people involved in the educational context must be taken into account. Many of the findings of this research suggest that, as reported elsewhere, a transmissive style of teaching generates some negative feelings about learning undergraduate chemistry. However, it seems unlikely that the research in presented here is sufficient to effect a complete change in ideology for the science academic staff that seemingly hold more positivistic beliefs. Rather, these teachers and scientists would likely rebel against, rather than conform to, a new way of thinking. With this in mind, we have produced a series of recommendations from this research that involve modifying codes of practice, that does not require changes to tertiary chemistry teachers' metaphysical beliefs

It appears from this study that some of the learning experiences in first-year chemistry are not particularly encouraging for students, especially for students from atypical chemistry

backgrounds (e.g. computer science majors). Enrolment retention could be improved by examining teaching practices for all components first-year chemistry. The study shows that lecture classes would benefit from the use of 'skeleton' notes, rather than a complete set of notes or large amounts of photocopied material. This appears to appeal to both academically able and less able students because it allows them to listen to the lecturer, without feeling that they can 'tune out' because it all they need is already provided for them. Lecture material could be made more interesting by the use of relevant examples and better use of visual aids. Such activities would introduce more variety into lectures and would be particularly useful for less popular components of the course, as in, for example, basic physical chemistry that academics see as useful and necessary, and students do not.

Laboratory classes should be designed so that the students focus on the concepts behind their laboratory work rather than trying to achieve unrealistic 'high' standards of accuracy and precision, especially for experiments involving titrations. Such experiments need not be discarded, but they can be readily improved and made more appealing by making the experiment itself more relevant and interesting, and by allowing students to use new or novel equipment. This study showed, for example, that experiments that included the use of ion exchange chromatography were popular, and such tools should be exploited and be used in conjunction with less popular techniques such as titrations. Laboratory classes would also be more enjoyable for students if they are provided with a clear introduction to the class before beginning work and by a quick sum up or conclusion talk at the end of the class.

The students in this study reported that the tutorials were the most valuable of the three learning environments they experienced, and these classes should be targeted in action seeking to improve student retention. Tutorials would benefit from dedicated discussion of laboratory and lecture classes. Ideally the same tutors should be used throughout the academic year, so that students develop an enduring relationship with at least one staff member of the chemistry department. Tutors could also be present in student's laboratory classes, as this will enable students to have a communality of experience with at least one member of staff and can provide a chemistry 'mentor' for the student. This deeper personal relationship with their tutor, would likely improve attendance of the students at tutorials - which in turn should result in an increased academic performance.

Like many traditional science classes at tertiary level (Laws, 1996) assessment in the courses studied in this research is based mostly on algorithmic type questions. The literature suggests that academics often erroneously assume that if students can answer such questions, then they understand the underlying fundamental concepts (Hobden, 2001).

Coll, Taylor and Fisher (2002) found that tertiary students expect to encounter similar learning experiences at university to what they experienced at high school. Such an observation was also borne out in the present study. The chemistry lecturers of the future will be drawn from a pool of students like those that participated in this study. As pointed out at the beginning of this section, it is likely to be problematic to change the metaphysics and pedagogies of current tertiary chemistry teachers, however, if we expose

current students to some different teaching approaches - however modest - this would at least expose the teachers of tomorrow's chemistry students to greater diversity in teaching style.

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