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A Learning-to-learn Program in a First-year Chemistry Class

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ABSTRACT *This article describes a national teaching project which set out to address the problem of high student attrition and failure in a first-year introductory chemistry topic, through the introduction of a student-focused learning-to-learn program presented in context and which uses authentic course materials. The program focused on developing students' understanding of the learning process and of their own learning, both in general and in chemistry in particular. As part of the project the student approach to learning was evaluated and monitored by use of the Biggs study process questionnaire (SPQ). Results indicate that students who participated in the program were less inclined to engage only in surface learning activities, achieved better assessment outcomes and persisted with their studies. The 1997 class as a whole showed an overall increase in pass rate and a decline in attrition rate compared to the 1996 cohort. SPQ scale scores were generally not powerful predictors of academic success but positive correlation was observed with the deep approach and achieving approach scales for the third SPQ trial period.*

Introduction

The push to make higher education more universal has led to a 60% increase in the participation rate in the Australian higher education sector over the last decade (Karmel, 1999). Gone are the days when university classes contained only highly selected students, with present day classes now containing students with a more diverse range of academic skills, past teaching and learning experiences, prior knowledge, approaches to learning and expectations of the tertiary experience. Increased participation has unfortunately also seen an increase in student failure rates and student attrition. Recent Australia-wide figures (Illing, 1998) show a mean annual student failure rate at university of 11% (12% for science, 21% for mathematics) which represents a $360 million per annum financial drain on the tertiary system. Many of the problems faced by tertiary students arise during their commencing year in the tertiary sector. The report on the first year experience in Australian universities by McInnis, James and McNaught (1995) found that 30% of the first-year students surveyed had seriously considered terminating their studies

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during first semester. Studies on student difficulties in Australia (Zeegers, 1994) and in the USA (Seymour & Hewitt, 1994), found that the most frequently encountered difficulties which lead to students discontinuing their studies include: curriculum overload, perception of poor teaching, loss of interest in area of study and inadequate advice on academic problems. A conclusion drawn from these studies is that commencing students are in general poorly prepared for the tertiary experience and may not be willing to persist when they encounter difficulties. In an environment where students are required to be more independent learners it is necessary that they know how to carry out this activity. In order to make progress with these learners it may be necessary to inform students of their own approach to learning, to direct them on how to reflect on their learning and to develop in them the necessary skills to be become confident self-directed learners. This may have a flow-on effect in helping institutions reduce student attrition rates, particularly in science and mathematics based courses.

Considerable evidence exists (see examples in Biggs, 1999; Clark, 1995; Gibbs, 1994; Nightingale & O'Neil, 1994; Prosser & Trigwell, 1999; Ramsden, 1992) to support the view that the quality of learning outcomes is dependent on many factors, which may be contextual; such as the teaching/learning environment, course design and assessment procedures, or personological; such as prior knowledge and experiences. It has also been suggested that interactive intervention through learning-to-learn programs early in a tertiary course can have a lasting positive impact on learning approaches and in turn on self-directed learning and self-confidence (Biggs, 1984; Hattie, Biggs & Purdie, 1996). Ramsden, Beswick and Bowden (1986) presented a study-skills course to commencing tertiary students and found that intervention through a generalist program was of limited value. Instead of helping students adopt a deep approach to learning, the students focused a great deal on content retention and adopted more of a surface approach. The teaching of skills-based learning strategies and metacognitive awareness is best done when they are domain specific and seen as an integral part of the language and scholarship of the discipline content (Clanchy & Ballard, 1995; Vermunt, 1994, 1995).

Process-Oriented Instruction

Vermunt (1994, 1995) developed a "learning-to-learn" program for an introductory psychology class, which the author defined as: "instruction aimed at the development of meaning-directed and application-directed learning styles and discouraging undirected and reproduction-directed learning styles". The learning-to-learn program was founded on the 16 design principles of process-oriented instruction (see Vermunt, 1994 for details) and was presented in three phases. The first phase is diagnostic in which students' approaches to learning were evaluated using the Vermunt (1992) Inventory of Learning Styles (ILS). In the second phase, students were presented instructional materials in the form of a 55 page Learning Guide booklet. This guide contained the items of the ILS and their interpretation, as well as the instructional principles of the learning-to-learn program. The third phase consisted of two learning-to-learn tutorials which focused on students' approaches

to learning in general and their approach to learning psychology in particular. No course content was discussed in these tutorials. The success of the program was based on participants reporting greater insight into their own learning and scoring better in examinations, both in multiple-choice and open-ended questions.

An alternative to the Vermunt program, which is run in parallel to content delivery, is the *student-directed learning* (SDL) program developed by Katz (1996) for an organic chemistry class. This program required a complete restructuring of the course including course content, classroom teaching and assessment procedures. The SDL program focuses on improving student confidence, accountability and student control. The program replaces the didactic approach to teaching with learning modules presented through an interactive learning environment. Integral to this environment were interactive "reverse Socratic" lectures, small group sessions, regular quizzes, peer teaching and mastery learning. As a result of the SDL program Katz reported improved student examination results and a reduction of student failure, to a failure rate of zero 4 years after the introduction of the program.

The Study Process Questionnaire (SPQ)

The Study Process Questionnaire (SPQ) developed by Biggs (1987) is a 42-item self-report inventory designed to evaluate students' approaches to learning in higher education. The SPQ conceptualises the SAL in terms of three broad learning scales (deep, surface and achieving) each of which is a composite of a motivation and strategy sub-scale. Implicit in this theory is that a student's approach to learning is amenable to change in response to student perceptions of the context and that students can be taught to adopt those approaches that are thought to lead to success, that is a deep approach and deep-achieving approach. The SPQ was chosen as the instrument of choice for the present study as it was developed using Australian tertiary students, scoring is available commercially through the Australian Council for Educational Research and many recent examples of its use attest to its reliability (Biggs, 1992; Jones & Jones, 1996; McKay & Kember, 1997; Murray-Harvey, 1994; Wilson, Smart & Watson, 1996; Volet, Renshaw & Tietzel, 1994).

Student perception of a study task, how it will be accomplished and the associated assessment methods greatly influence learning outcomes. It is also generally believed that a deep approach/meaning orientation to learning will contribute positively to learning outcomes. Watkins and Hattie (1981) using the Biggs Study Behaviour Questionnaire (SBQ) found consistent positive correlation between GPA and Internalising (Deep) and Achievement scales and negative correlation with the Utilitarian (Surface) scales. However, a study by Provost and Bond (1997) using a shortened version of the Approaches to Study Inventory (ASI) (Entwistle & Ramsden, 1983) found the instrument scales not to be a good predictor of academic performance for second year psychology students. In a similar study in Hong Kong, Jones and Jones (1996) found no significant association between student performance and scores from the SPQ scales. In a study with physiotherapy students, Tang (1998) found that students who formed collaborative learning groups and who exhibited characteristics of a deep approach to learning, showed no significant improvement on

assignment scores when compared to self-study students who exhibited characteristics of a surface approach to learning.

The Present Study

The overall approach of our national teaching grant was to introduce a learning-to-learn program as part of a first-year chemistry course. We define learning-to-learn here as the enhancement of students' knowledge of the learning process in general and of their own approaches to learning in particular, broadening the range of learning strategies available to students to tackle different types of learning tasks effectively and enhancing students' metacognitive awareness. These aims were to be achieved within the domain-specific structure of a science discipline course. The premise behind the project was that if students are more knowledgeable about how they learn, more cognisant of alternate learning strategies and the means to evaluate and monitor their learning, they should be better equipped to become confident self-regulated learners in the tertiary environment. An integral part of the study design was to monitor the students' approaches to learning (using SPQ scales) and to investigate the relationship between the approach scales and student sex, age and student academic achievement as measured by semester scores for chemistry and grade point average (GPA). There are two key limitations in the study which need to be borne in mind. The major problem was in obtaining complete data sets for all the variables under investigation. This was due mainly to the voluntary nature of the program components, to some students choosing not to complete the SPQ trials, to student withdrawal from the topic or from study altogether and to incomplete student personal or assessment details. The reduced data sets over time may lead to sample bias and reduced statistical power. The second limitation which needs to be borne in mind is that we had very limited control over the chemistry course content, the teaching of that content and the assessment procedures, such that the learning-to-learn program needed to be tailored around a pre-existing course.

Methods

The learning-to-learn program designed for the present study was based on aspects of the Vermunt *process-oriented instruction* model and the Katz *self-directed learning* model, both of which were modified for use with a class of students studying Introduction to Chemistry in 1997. We adopted the basic three phase structure of the Vermunt model and the aspect of running sessions in parallel to the Chemistry content course, while using the Katz concept of SDL interactive small group teaching and peer teaching. The materials used came directly from the subject matter (i.e. course books, tutorial problems, set assignments and past examination papers) or were specially prepared for the program. Measurement of students' approaches to learning (SAL), using the SPQ, was repeated on three occasions during the academic year. The impact of the program was evaluated in three ways. The program as a whole was evaluated by comparing the attrition rate of all students enrolled in the chemistry topic in 1997 and those in the previous academic year. We

compared the assessment results for the two semester courses of chemistry, the attrition rate, annual GPA and the SPQ scores of students who attended the SDL tutorial program and those who did not attend. We also sought student comments, anecdotally during the program, and through semi-structured interviews of 20 students at the completion of the program. Students for interview were selected so that we had equal representation by student sex and age.

The Students and the Topic

The participants were students enrolled in semester 1 ($N = 278$) and/or the semester 2 ($N = 276$) course for the first year topic *Introduction to Chemistry* at Flinders University. Of the total enrolment of $N = 328$ students there were 165 males and 163 females, the mean age was 23.0 years (SD = 7.4, range 17–55 years). The chemistry topic is a two-semester service course with no assumptions of prior study in chemistry and which attracts a heterogeneous variety of students from across the sciences. Many of these students are non-traditional students of science (i.e. with no appropriate prior studies) or students who entered university through special entry schemes. The majority of students study this topic as a pre-requisite for further study in the biological sciences or health sciences. The topic is designed to give students an understanding of the underlying principles of chemistry as applied to their daily lives. The topic is delivered by means of twice-weekly lectures, a weekly tutorial and regular laboratory classes. The assessment consists of end of semester examinations, weekly tests and laboratory grades. The nature of the end of semester examination changes from one with a multiple-choice component in semester 1, to one that is problem based in semester 2. The topic is largely content driven and the volume of material and rate of presentation progressively accelerates during the course, together with the change in emphasis from largely descriptive material in semester 1 to calculation based material in semester 2. Student comments and past examination results suggest that students find semester 2 to be the more difficult of the two semesters. Most students find the topic very demanding and conceptually difficult, which can cause students to lose confidence and this in turn leads to high attrition and failure rates. In most previous years 30–35% of the students initially enrolled either fail some part of the topic or completely withdraw from it. Each of these scenarios requires students to repeat part of or the whole topic in order to continue with their chosen course of study.

The Learning-to-Learn Program

Phase 1: SPQ Evaluations and Maths Pre-test

The SPQ evaluation was administered during the normal laboratory sessions. The first SPQ evaluation, trial 1, was completed by 278 students in week 2 of semester 1. Of those completing the questionnaire, 237 students commenced their tertiary studies in 1997. SPQ trial 2 was conducted at the commencement of the second half of semester 1, after 8 weeks ($N = 183$) and trial 3 was conducted towards the end

of semester 2, after 30 weeks ($N = 159$). After the scores for trial 1 were available, students had an opportunity to discuss the findings of their SPQ evaluation and their individual approach to learning. The overall nature of the program and its various stages were explained to the students who were asked to participate over the duration of their enrolment.

At the commencement of the program students were informed that the study of chemistry requires confidence with basic mathematical skills (e.g. simple algebra, logs, exponents, graphical interpretation) and that most of these skills would be assumed knowledge. Students who felt that their mathematical skills may not be sufficient were encouraged to undertake a maths pre-test. The test was a take-home exercise with a score of 40, from a maximum score of 60, considered as the minimum score required to enable students to understand the mathematical concepts as applied to the study of chemistry. Extra assistance with mathematical skills was available to students elsewhere in the university and was thus not considered to be part of the current program.

Phase 2: The Process of Learning

Students were introduced to aspects of successful tertiary study through the normal lecture course for the topic in the second week of semester 1. Aspects covered included: Bloom's taxonomy of learning, the cycle of learning and factors contributing to success, approach to learning scales (Biggs SPQ), planning for study, critical analysis of content, reading for a purpose, problem solving strategies, strategies to overcome study blocks and creating learning aids. The material presented was designed to enhance students' understanding of the process of learning in general and of their own learning, by emphasising independent learning in terms of student ownership, student control and accountability.

Phase 3: Interactive SDL Tutorials

Phase three consisted of weekly interactive self-directed learning (SDL) tutorials that ran in parallel to the content tutorials. These skills-based sessions centered on the elaboration of the ideas presented in the earlier lectures through the use of learning activities fundamental to the process of (chemistry) knowledge assimilation, understanding and application. The activities were centred on small group dynamics and included strategies for planning to learn, monitoring and evaluation of personal progress, peer tutoring through students presenting content summaries and answers to problems and the deconstruction of tutorial problems and past examination papers. The activities were seen as integral to confidence building in an effective learning environment. Students were encouraged to attend as many SDL tutorials as they felt necessary but were at all times free to choose to attend as they wished. The learning strategies for each SDL group were modified according to the nature of the student groups meeting on a weekly basis and the course content. The groupings were to a large extent based on timetable restraints and as a consequence cohorts of students studying similar topics were often in the same tutorials. Each group worked

at a self-paced mode on learning activities designed by the tutor for each group but based on the problem areas identified by the students. The role of the tutor was crucial in developing a climate in which the initial teacher-directed learning would rapidly be transferred to a student-directed learning environment that would promote self-confidence and stimulate the use of deep processing strategies and reinforce self-directed learning.

Data analysis

Student attendance in the SDL tutorials was recorded weekly. Repeated measures analysis of variance (ANOVA) was used to analyze the SPQ changes between trial 1 and trail 3. One-way ANOVA was used to compare the SPQ scores and assessment results for the SDL attendees and the non-attendees and differences based on student age groupings and student sex. Pearson correlation coefficient was used to correlate predictor variables and assessment outcomes.

Results

Attendance in the SDL Tutorials

During the course of the year, 93 students attended one or more of the SDL tutorials. In semester 1, 60 students (21.7%) attended a mean of 3.0 tutorials (range 1–6 tutorials). This group comprised 43 females (72%) and 17 males (28%). The mean age of this group was 26.9 years (SD = 9.2, range 18–53 years). In semester 2, 84 students (37%) attended a mean of 5.5 tutorials (range 1–19), which comprised 51 females (61%) and 33 males (39%). The mean age was 25.4 years (SD = 8.7, range 17–53 years). Within this group, there were 5 students who regularly attended more than one SDL tutorial session per week for the semester.

Evaluation of SPQ Scores

The mean scores for each of the three SPQ studies for all students are shown in Table 1. The reliability of the scales in trial 1, using Cronbach alpha, ranged from 0.50 for surface motivation to 0.77 for deep approach and are consistent with the values of previous studies (Biggs 1992; Murray-Harvey 1994; Wilson, Smart & Watson, 1996). Mean SPQ scores were used to compare students based on sex, age, change over time and SDL tutorial attendance.

(i) Student sex

The mean SPQ scores for females were higher for the deep approach and the achieving approach and lower for the surface approach compared to the males for trial 1 and trail 3, but none of the differences were statistically significant. This concurs with the lack of a statistical difference between the sexes found by Richardson (1993) using the ASI and by Wilson, Smart and Watson (1996) using the SPQ.

TABLE 1. Mean SPQ scores (SD in parentheses) for all students who completed the SPQ evaluations and a comparison (ANOVA) between the SPQ scores for students who attended any of the SDL tutorials and those who did not

	Achieving approach	Deep approach	Surface approach
Trial 1 (T = zero)			
All students ($N = 237$)	47.5 (8.2)	45.7 (7.8)	46.5 (6.9)
SDL Attendees ($N = 75$)	48.0 (7.1)	46.2 (7.8)	46.5 (7.2)
SDL Non-attendees ($N = 162$)	47.2 (8.6)	45.6 (7.0)	47.0 (6.7)
Trial 2 ($T = 8$ weeks)			
All students ($N = 183$)	45.2 (7.5)	44.6 (7.4)	48.1 (7.0)
SDL Attendees ($N = 69$)	45.8 (6.8)	44.5 (7.4)	48.3 (6.8)
SDL Non-attendees ($N = 114$)	44.8 (7.0)	44.7 (7.4)	48.0 (7.2)
Trial 3 ($T = 30$ weeks)			
All students ($N = 159$)	45.4 (7.5)	45.5 (7.3)	46.5 (7.2)
SDL Attendees ($N = 67$)	47.1 (7.3)	47.2 (7.4)	43.9 (7.3)
SDL Non -Attendees ($N = 92$)	44.2 (7.5)*	44.2 (7.3)**	48.5 (6.4)***

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

(ii) Student age

Student age had a significant impact on the SPQ scores. In general terms, older students had a higher mean score for the deep and achieving approach scales and a lower mean score for surface approach. These results are consistent with those of other studies (Biggs, 1987; Richardson, 1994; Sadler-Smith, 1996). For one-way ANOVA comparisons by student age, students were allocated to one of three age groups: those less than 20 years old, those between 20 and 25 and those over 25 years. The oldest group of students started with the highest mean score for the achieving approach at trial 1, the difference was significant at trial 2 ($F = 4.8$, $p = 0.009$, df = 2,180) and trial 3 ($F = 3.5$, $p = 0.03$, df = 2,156). The oldest group reported a significantly higher score for the deep approach for all three trials (e.g. for trial 1: $F = 15.5$, $p < 0.001$, df = 2,233). These students also consistently had the lowest mean score for surface approach with the difference being greatest at trial 1 ($F = 7.7$, $p = 0.001$, df = 2,233) but was still significant at trial 3 ($F = 4.5$, $p = 0.01$, df = 2,156).

(iii) Change in approaches with time: repeated measures ANOVA

A repeated-measures analysis of variance was conducted for each of the three approaches to learning scales. The within-subject factor was time with three levels, one for each of the trials. The time effect was decomposed into linear and quadratic components to establish the overall shape of the time effect. The time effect was statistically significant for the achieving approach ($F = 12.7$, $p < 0.001$, df = 2,103) with the a linear model giving the best shape of the response. The deep approach also showed a significant time response ($F = 3.3$, $p = 0.04$, df = 2,103) and in this

instance the response was curvilinear. No statistically significant response was seen for the surface approach with time. Paired-samples *t*-test showed that the change in achieving approach between trial 1 and trial 3 was the largest change observed for any of the 3 approach scales ($t = 3.8$, $p < 0.001$, df = 128). Comparison of the two sub-scales of achieving strategy and motivation showed it was the strategy sub-scale which was the major contributor to this observed change in approach ($t = 5.5$, $p < 0.001$, df = 128).

(iv) SDL tutorial attendees

The mean SPQ scores for the SDL tutorial attendees and non-attendees is also shown in Table 1. A one-way ANOVA showed that only for trial 3 was there a statistically significant difference between the SDL tutorial attendees and the non-attendees for the achieving approach scale ($F = 5.7$, $p = 0.02$, df = 1,157), the deep approach scale (F = 6.8, p = 0.01, df = 1,157) and the surface approach scale (F = 17.9, $p < 0.001$, df = 1,157). For the SDL tutorial attendees the mean scores for deep and achieving approach scales both recovered to commencing levels after an initial decline, but for the non-attendees the score for both approach scales continued to decline. For the surface approach the opposite trend was observed in that the for the SDL attendees, after an initial rise there is a fall to below the starting value where there is no such recovery for the non-attendees. For all students it was the achieving strategy that showed the greatest change over time. At trial one the mean score for achieving strategy for the students who attended any of the SDL tutorials ($M = 25.2$, SD = 4.5) was higher than for the non-attendees ($M = 23.6$, SD = 5.6) but the difference was not statistically significant. By trial 2 the difference between the SDL attendees ($M = 23.7$, SD = 4.5) and the non-attendees ($M = 21.6$, SD = 4.8) was significantly different ($F = 4.4$, $p = 0.04$, df = 1,183). This difference was accentuated by trail 3 when the attendees ($M = 23.9$, SD = 4.6) again showed a significant difference ($F = 7.5$, $p = 0.007$, $df = 1,159$) to the non-attendees ($M = 21.4$, $SD = 5.4$).

Maths Pre-Test Scores

Students who completed the maths pre-test ($N = 128$) had a mean test score of 43.9 out of 60 ($SD = 8.3$, range 16–60). Forty-five students (34%) had a score of less than 40. These students had significantly lower assessment outcomes compared to those who scored 40 or more, for semester 1 chemistry ($F = 24.6$, $p < 0.001$, df = 1,116), semester 2 chemistry ($F = 8.0$, $p = 0.006$, df = 1,104) and overall GPA ($F = 6.6$, $p = 0.01$, df = 1,113).

Evaluation of Assessment Outcomes

One of the ways the program was evaluated was the assessment outcomes for all the students. Table 2 shows the results for Introduction to Chemistry for semesters 1 and 2 as well as the overall grade point average (GPA) for all students enrolled in

TABLE 2. Comparison of mean assessment outcomes, pass rate and attrition rate for 1996 and 1997 students

	Semester 1 (mean %)	Semester 2 (mean %)	GPA
Mean topic score			
1997	59.0 (SD = 23.8)	51.2 (SD = 23.6)	3.2 (SD = 2.0)
1996	55.5 (SD = 20.9)	42.7 (SD = 21.7)	3.0 (SD = 2.0)
Pass rate			
1997	77.5	60.1	
1996	66.0	55.1	
Student attrition			
1997	8.9	20.0	
1996	23.0	28.0	

the topic in 1996 and 1997. We expected to find some overall positive impact for the 1997 students as a result of the learning-to-learn lectures presented early in the year as these were not presented in 1996. Though we are hesitant to directly compare the results of one year with those of another year, the overall pass rate, mean topic scores and final GPA for 1997 all compare favourably to those for 1996. Of the peak enrolment for semester 1, a total of 27 students (8.9%) withdrew from the course during the semester and did not receive a grade. For the SDL students this attrition was only 3.3% compared to 10.3% for the SDL non-attendees. For semester 2 the withdrawal rate for the SDL attendees was 18.6% which was slightly lower than for the non-attendees which was 22%. The comparative withdrawal rate figures for semester 1 and semester 2 of 1996 are respectively 23% and 28%. These figures on face value show that there has been a substantial decline in semester 1 withdrawal rate in 1997 and a small decline in withdrawal for semester 2 when the nature of the chemistry becomes more problem-based and intellectually challenging.

(i) Student age

For comparison purposes student age was categorised into three groups as previously. One-way ANOVA showed no difference between the groups in semester 1 but that older students have a better semester 2 result ($F = 5.0$, $p = 0.008$, df = 2,219) and higher GPA ($F = 5.6$, $p = 0.01$, df = 2,284). When student age was correlated with the assessment outcomes the respective correlation coefficients were $r = 0.20$ ($p = 0.003$) for the semester 2 result and $r = 0.17$ ($p = 0.004$) for the 1997 GPA.

(ii) Student sex

Females had higher mean scores for each of the three assessment outcomes compared to their male colleagues but the differences were small and none were significantly different using a one-way ANOVA.

TABLE 3. Mean Assessment outcomes for all students who had recorded results and a comparison (ANOVA) between the assessment outcomes for SDL tutorial attendees and non-attendees

	Semester 1 (final %)	Semester 2 (final %)	Final GPA
All students	59.0 (23.8) ($N = 274$)	51.2 (23.6) ($N = 222$)	3.2 (2.0) ($N = 287$)
SDL attendees	68.7 (17.8) ($N = 58$)	62.9 (16.5) ($N = 65$)	4.0 (1.8) ($N = 81$)
SDL non-attendees	56.2 (24.5)*** ($N = 216$)	45.9 (24.2)*** ($N = 157$)	2.9 (2.0)*** ($N = 206$)

*** $p < 0.001$

(iii) SDL tutorial attendance

A comparison of the assessment outcomes for the SDL tutorial attendees and non-attendees is shown in Table 3. The students who attended the SDL tutorials obtained better mean assessment outcomes compared to the SDL non-attendees for the semester 1 result ($F = 12.6$, $p < 0.001$, df = 1,272) semester 2 result ($F = 18.5$, $p < 0.001$, df = 1,220) and 1997 GPA ($F = 17.2$, $p < 0.001$, df = 1,285). When the SDL tutorial attendance for all students, including a zero attendance, was correlated to the assessment outcomes a positive correlation was found for semester 1 result ($r = 0.23$, $p = 0.02$), semester 2 result ($r = 0.29$, $p = 0.04$) and 1997 GPA ($r = 0.33$, $p < 0.001$). The SDL tutorial attendees had a pass rate of 93.1% compared to 73.4% for non-attendees in semester 1 and 81.5% compared to 53.6% for semester 2.

(iv) Predictive variables and assessment outcomes

One of the aims of this project was to investigate the relationship between students' approaches to learning and assessment outcomes. Table 4 shows the Pearson correlation coefficients between a number of possible predictor variables and the three relevant assessment outcomes for the year. Student age had a positive correlation to all assessment outcomes which was statistically significant for the semester 2 result ($r = 0.20$, $p < 0.01$) and the final GPA ($r = 0.17$, $p < 0.01$). For the approaches to learning scores, no significant correlation was observed for the trial 1 SPQ scores and any of the assessment outcomes, which is in agreement with findings of Provost and Bond (1997). There was however a significant positive correlation between the SPQ trial 3 achieving approach and semester 2 results and between the deep approach and achieving approach and final GPA. SDL tutorial attendance in semester 1, but particularly in semester 2, showed a statistically significant correlation with all assessment outcomes. The maths pre-test showed significant positive correlation to all assessment outcomes. It was particularly strong for semester 1 results ($r = 0.48$, $p < 0.01$) despite the fact that the chemistry content

TABLE 4. Correlation (Pearson *r*) between student assessment outcomes for Chemistry in semester 1 and semester 2 and cumulative GPA, with some possible predictor variables. (SA is Surface Approach, DA is Deep Approach, AA is Achieving Approach, S1 is semester 1, S2 is semester 2)

Predictive variable		Semester 1 Chemistry result ($N = 276$)	Semester 2 Chemistry result ($N = 222$)	Cumulative GPA ($N = 287$)
Student age		0.05 ($N = 274$)	0.20** ($N = 220$)	0.17** ($N = 285$)
Maths pre-test score		0.48** ($N = 118$)	0.35** ($N = 106$)	0.31** ($N = 115$)
SPQ SA	Trial 1	−0.07 ($N = 206$)		−0.08 ($N = 203$)
	Trial 3		0.04 ($N = 150$)	−0.02 ($N = 151$)
SPQ DA	Trial 1	−0.02 ($N = 206$)		0.001 ($N = 203$)
	Trial 3		0.12 ($N = 150$)	0.20* ($N = 151$)
SPQ AA	Trial 1	0.005 ($N = 206$)		0.01 ($N = 203$)
	Trial 3		0.21** ($N = 150$)	0.25** ($N = 151$)
Number of SDL tutorials (S1)		0.23** ($N = 276$)	0.26** ($N = 222$)	0.27*** ($N = 287$)
Number of SDL tutorials (S2)			0.29*** ($N = 222$)	0.31*** ($N = 287$)
Total number of SDL tutorials				0.33*** ($N = 287$)
Chemistry result (S1)			0.80*** ($N = 203$)	0.83*** ($N = 267$)
Chemistry result (S2)				0.86*** ($N = 218$)

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

in that semester was largely descriptive in nature. Both semester results for the chemistry assessments correlated very strongly with final GPA.

(v) What factors identify the SDL attendees?

The students who attended the SDL tutorials also tended to participate in the SPQ evaluations and had consistently higher semester results and better GPAs. Are these students simply more academically able or more motivated individuals? Based on the motivational scales of the SPQ evaluations, no difference could be found between scores for the tutorial attendees and the non-attendees, for any of the three trial periods. The factors which distinguished the attendees from the non-attendees were that the former were generally older, there was greater representation by females and they had a consistently higher mean score for achieving approach and deep approach and a lower mean score for the surface approach to learning. In semester 1 the ratio of female to male attendees was 2.5:1 and the mean age was 26.9 years (the overall class sex ratio was 1:1 and the mean age was 23.0). In semester 2, more younger students attended the tutorials, but the female to male ratio was still 1.6:1 and the mean age was 25.4 years. The mean score for the achieving strategy for the SDL students was marginally higher at the commencement of the academic year compared to the non-attendees but by the end of the year the gap between the two means had become substantial ($F = 7.5$, $p = 0.007$, $df = 1,157$). Differences between SDL students based on sex and age showed some variations with the class as a whole. As far as age is concerned, the mean SPQ scores and assessment outcomes were as previously described. There were some important

variations based on student sex. Firstly, males had higher mean scores for all but one of the approach scales in trial 1 and trial 3, the exception being the deep approach in trial 1. The males also showed the largest mean increase in deep approach from trial 1 to trial 3. Secondly, the males had higher mean scores for each of the assessment outcomes, in direct contrast to the class as a whole. However, none of the SPQ or assessment differences based on age or sex was statistically significant.

Student Comments

Formative evaluation in the form of student feedback was welcomed and encouraged for the duration of the program as it was important that the students feel that the tutors were responding to their needs. At the conclusion of the program, 20 students were selected, based on equal representation by student age and sex, for a semi-structured interview in which their views of the program were sought. Students commented that they valued the program highly, despite some early reticence. In particular, the students valued the opportunity to discuss aspects of learning in a non-threatening atmosphere. Comments indicated that many of the students felt they had a distinct "advantage" over their peers in having a greater insight into how tertiary science teaching and learning works and that being aware of their own learning was beneficial to them in terms of having greater control. Students' views of the program are perhaps best summarised by the following comments:

> *Teaching someone else is a great way to ensure full understanding of the topic, I mean you know it sort of has to make sense to you to be able to help someone else in the group* (19 year old male)

> *Why wasn't it taught like this last year, then I wouldn't have failed* (28 year old female repeating the topic)

> *I really enjoyed Chemistry this year, you know I never thought I'd say that* (43 year old female, coming back to study after 15 years)

> *For me the tutorials were invaluable. I'm really interested in the subject material but coming from an Arts background I found the whole way of learning totally new. My confidence had been eroded by failure last year, but er … yeah I thought the whole idea was great, thanks* (25 year old female medical student, with a BA)

Discussion

The findings from this project support Vermunt's view (1995) that making students more aware of the process of learning and of their own learning, through a learning-to-learn program presented in context, has a positive influence on students' approaches to learning and on assessment outcomes. Vermunt also argued that it is not enough to modify the instructional design to adapt to domain-specific

knowledge, but that teaching students about thinking strategies and self-regulatory knowledge is essential to bring about high quality learning behaviours. With this in mind, the SDL tutorials focused on the development of learning strategies and metacognitive awareness so that the students have a broader range of skills at their disposal that may lead to confident self-directed learning. The key role in this process is played by the tutor. Tutors must be a supportive and a motivating influence in the development of the students' learning, be aware of the individual learning approaches and be prepared to help with individual student's management of his/her learning. This will enable the learner to accept control from the tutor who gradually becomes a resource person and a facilitator who guides the learning process according to the needs of the learner. One of the other major aspects of the SDL tutorials was cooperative small group learning in which students share their conceptual and procedural knowledge as they solve problems together. Mutual critique would clarify student's thinking about chemistry concepts and principles and how these should be applied to particular problems. Furthermore, each member can observe others perform the varied thinking strategies required to solve a problem.

Integral to our design of the learning-to-learn program was evaluation of the students' approaches to learning over time. Previous studies have shown that approaches to learning are sensitive to student perceptions of study tasks, the teaching and learning environment and assessment methods. For example, Volet *et al.* (1994), using the SPQ over a 12 week period, found that students adopted less of a deep and achieving approach in order to "keep up" with their studies. We expected to find similar trends. What we found was that the achieving approach showed a steady decline over the study period, the deep approach showed a decline followed by a rebound to the initial level, while the trend for the surface approach showed an initial increase then a return to trial 1 values. The observed changes were independent of student sex or age. Small changes were observed in the motivation scales but more substantial changes occurred in the strategies the students reported using, with students opting to adopt those strategies which they believed were what was required to keep up. Students reported that factors such as the volume of the course content, the rate of content delivery, demands on time to meet deadlines for assignments and the lack of time to reflect on what is learned all impact on the learning strategies which they adopted. Further, students' perception that course requirements do not need more elaborate cognitive skills leads them to adopt those strategies which they believe will be successful.

When comparing the SPQ scales and assessment details for the students who attended the SDL tutorials and those who did not, there are certain provisos that need to be taken into account. The SDL attendees were predominantly female and the mean age was older than that of the non-attendees. These students also had a greater participation rate in the three SPQ trials. Watkins and Hattie (1985) have previously commented that students who participate in questionnaire trials were in some way fundamentally different in their approach to learning than those students who chose not to participate. With these provisos, the SDL attendees showed some general differences in their learning approaches. Looking at the change over time

between trial 1 and trial 3, the SDL students showed a decline in surface approach and an increase in deep approach and achieving approach. The SDL non-attendees showed a decline in deep and achieving approaches and an increase in the surface approach. The most striking difference in terms of the SPQ scores was the mean scores for achieving strategy, which remained largely unchanged for the SDL students during the course of the study. In a review of mature students in higher education, Richardson (1994) argued that mature students are better equipped in terms of life experiences, are more motivated towards success in their studies and are willing to devote more of their energies to study. This pattern seems to describe in general terms the SDL attendees. In terms of the bias towards higher female participation, it may be that male students, in particular younger males, are less inclined to identify themselves with programs incorporating aspects of group work and prefer to work individually.

Finally, we wanted to explore the impact on academic outcomes of the learning-to-learn program as well as the relationship between some other variables and academic outcomes as measured by semester results for the topic and annual GPA. We found that older students generally outperformed their younger colleagues with a positive correlation between semester 2 and GPA with age. These finding concur with several previous studies (see Richardson, 1994; Sadler-Smith, 1996). SPQ scores for trial 1 in general correlated poorly with all assessment outcomes, but the SPQ scores for trail 3 (30 weeks later) showed significant positive correlation with semester 2 results and GPA. The nature of the chemistry examination changes from one with a multiple-choice component in semester 1 to a mainly problem based format in semester 2. The greater correlation between the deep approach and in particular the achieving approach and outcomes in semester 2 compared to semester 1, could imply that the nature of the assessment procedure in semester 2 (i.e. more problem based) rewards those students with more favourable approaches to learning. However, if students perceived that the semester 1 examination, with its multiple-choice questions, would favour an approach to learning more reliant on surface strategies, then a positive correlation between the surface approach scale and the semester results might be expected. This was not observed to be the case. Sample bias here however has the potential to skew the findings, as the number of student participants in SPQ trial 3 had decreased by about 25% from trial 1. One possible explanation for our correlation findings and previously alluded to by Watkins and Hattie (1985), is that the students who chose not to continue to participate in the SPQ trials and/or those who chose to withdraw rather than persist with their studies, are perhaps also those who are less likely to utilise favourable approaches to learning and thus achieve inconsistent assessment outcomes.

The students who attended any of the SDL tutorials had consistently better assessment outcomes. The total number of SDL tutorials attended during the year, including a zero attendance, was correlated to outcomes and found to give consistently positive correlation. In principle it may be that the SDL students were more academically able and more motivated individuals or that there may be some other factors which identify these individuals. We could not distinguish between the SDL attendees and non-attendees using the SPQ motivational scales, but as alluded to

earlier, they differed significantly by their strategy use. This could be interpreted as the SDL students being more acutely aware of what is required to succeed at a tertiary level in terms of extra reading, more commitment time wise, seeking help when needed as well as having a broader range of learning strategies and meta-cognitive skills on which to draw and a higher degree of cue consciousness with regards to assessment procedures.

When SPQ scale scores and assessment outcomes were compared by student sex, females overall had consistently lower mean scores for surface approach and higher mean scores for deep and achieving approach, but none of these differences was statistically significant. SDL tutorial attendance, particularly for semester 2, correlated significantly with deep approach ($r = 0.29$, $p < 0.001$) and achieving approach ($r = 0.31$, $p < 0.001$) when each of these two scales also correlated significantly with the semester 2 result and GPA. For the SDL attendees the increase in deep approach between trial 1 and trial 3 (particularly for males) and the concurrent decrease in surface approach (more so for females), is opposite to the trend for the SDL non-attendees and may be a significant contributing factor to the academic success of these students. Females in general showed consistently better assessment outcomes, but for the SDL attendees it was the males who had better assessment scores. It could be interpreted that there is a positive influences on all SDL tutorial attendees, in terms of favourable approaches to learning and enhanced assessment outcomes, but that this impact is greater for males than for females.

A consistent positive correlation with assessment outcomes was seen for the score in the maths pre-test. The students who identified themselves as possibly in need of maths assistance and who completed the maths pre-test, are a subgroup of the total class so it is difficult to know how to interpret the result. The highest correlation found was for the semester 1 chemistry which when compared to the semester 2 content is less reliant on mathematical skills. Though the maths pre-test was primarily designed to measure basic mathematical skills, it was also considered to be a crude measure of students' problem solving and analytical thinking skills. Perhaps it is this latter aspect which we are seeing here, and that further development of the test is warranted to make it a useful predictive indicator for success in basic science courses.

Conclusions

This study has shown that a learning-to-learn program can have a positive impact on student learning and on assessment outcomes. Not all students are initially amenable to, nor may they initially benefit from, this more demanding type of learning environment, as it requires students to develop what may be for them a new self-regulatory approach to learning. We would argue that the long term benefits are significant and that this type of program should be integrated into current discipline teaching rather the being seen as an "add on" to the domain specific and content driven syllabus. We are also aware that with increasing workload on teaching staff, decreased funding and greater student diversity, that there is increasing pressure on institutions to explore more effective and efficient modes of teaching. Programs such

as that presented here bear an additional cost to the department or faculty, but this may in time be rewarded by lower student attrition and students who are better prepared for their continuing tertiary studies.

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