

# *Non-major Chemistry Students' Learning Strategies: Explaining Their Choice and Examining the Implications for Teaching and Learning*

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**ABSTRACT** *This paper examines the learning strategies of first-year non-major chemistry students who commonly have limited chemical and mathematical backgrounds that influence their attitude, motivation and approach to learning chemistry. Nearly all students identified multiple learning strategies. Most commonly reported were traditional strategies such as practicing problems, studying worked solutions, highlighting notes, re-writing notes, memorizing notes and working with other students. By probing students' opinions about the learning strategies they use and the factors that influence their choice, the data indicated that teaching and assessment strategies direct students' choice of learning strategies. The study provided evidence that many students are interested in their own learning and have a high level of metacognitive awareness that could be further utilised. An awareness of this appreciation could be used to more effectively teach this particular group of undergraduate chemistry learners.*

**KEY WORDS:** *Learning strategies, chemistry, metacognition.*

## **Introduction**

The unique needs of non-major first year university chemistry students usually influence their choice of learning strategies and ways of learning. While we would like all learning to be conceptually meaningful, in reality there are situations where rote learning may be more appropriate and beneficial to the student (Battino, 1992). The pressures of money, time and not passing a course, in addition to the desire to learn are the realistic motivators to learning. This paper examined students' perceptions of their own learning strategies and the factors that have influenced their choice of learning strategy.

## *Background Information*

Learning is often described in terms such as shallow learning (Atherton, 2001), rote learning (Battino, 1992), meaningful learning (Ausubel, 1968), conceptual change (Posner, Strike, Hewson, & Gertzog, 1982), and intentional learning (Bereiter & Scardamalia, 1989). While these descriptions refer to the level of understanding of content and concepts that is achieved as a result of the *process of*

*learning*, they tell us very little about how students learn.

The question – How do students learn? – has continued to interest educational researchers and is indeed difficult to answer. Nevertheless, this question is most important, as Hewson, Beeth and Thorley (1998) explain “for teaching to be effective, it needs to be rooted in an understanding of how students learn” (p. 199). The temptation to teach the content that students are required to understand can sometimes override the need to teach students how to learn the content themselves (Spencer, 1999). The belief that teachers can transfer their knowledge transmissively to their students by explaining and demonstrating their understanding is common (Skemp, 1976). However, the question of what to teach students is less important than why and how concepts are taught, emphasising the *process of learning*.

Pintrich (2000) recognises the learners’ “motivational beliefs about the self and learning” (p. 33) to be pivotal for learning to occur. Students’ personal motivation or “goal orientations” (Pintrich, 1999, p. 35) can influence the way their learning is approached, which in turn can influence the depth of understanding achieved. If students are not motivated, interested or confident of success, then there is little chance of students reaching the stage where mental processing of information occurs. Consequently, no conceptual change or meaningful learning can occur.

#### *Non-Major Science Students*

Chemistry is not the major area of study for non-major science students and they commonly have limited background knowledge in mathematics and chemistry. Consequently, Rowe (1983) has recommended that learning chemistry in context is especially important for non-major students.

#### *The Importance of Metacognition*

Metacognition is the process of learners consciously using strategies to enhance learning. It is of relevance to this study that students’ metacognitive ability has been shown to improve with maturity and knowledge (Bransford, Brown, & Cocking, 2000). Through learning metacognitive strategies, the learner is learning how to learn. Davidowitz and Rollnick (2001) present data to support the assertion that there is a link between cognitive actions and metacognitive knowledge and experiences. They claim that “metacognition is a necessary pre-requisite for deep [learning] approaches” (Davidowitz & Rollnick, 2001, p. 17). This position is supported by Hewson (1996) who claims that “teaching for conceptual change is explicitly metacognitive” (p. 136). On the other hand, Sinatra and Pintrich (2003) claim that conceptual change can occur without the learners’ intentions – inferring that deep learning can occur with and without metacognition.

Familiar teaching resources that are used in a metacognitive manner are evaluative and reflective questions, concept mapping, and Venn diagrams. These teaching resources are designed “to generate information that will help people to be knowledgeable about, aware of, and in control of what they are doing” (Baird & White, 1996, p. 191), thereby acting on interpretations and increasing reflection. Many valuable pedagogical resources can be used in a metacognitive manner, when they are used in a purposeful inquiry that involves action and reflection, resulting in increased knowledge, awareness, and control.

Baird and White (1996) in a *Project for Enhancing Effective Learning* (PEEL) observed the need for metacognitive development in teachers before metacognitive development in students. They identified four conditions necessary for the personal development of both teachers and students – time, opportunity, guidance, and support. Davidowitz and Rollnick (2001) designed the *Competency Tripod*, a device to help students describe their thought processes consisting of three legs – “declarative knowledge, communicative competence, and procedural understanding [held together] by the link made by the students to achieve coherence of the three concepts” (pp. 3-4). These projects illustrate an improvement to learning through the use of resources and strategies that engage students in metacognitive tasks.

The process of learning requires learners to think about an idea, generate a personal mental model and evaluate it. Pintrich (1999) proposes that students’ self-efficacy, referring to their “confidence in their own thinking and learning strategies” (p. 42), and their “ability to do a particular task” (p. 42) should facilitate learning. Consequently, the process of learning is closely associated with the process of metacognition (Garnett, Garnett, & Hackling, 1995; Hennessey, 2003; Hewson, 1996; Rickey & Stacy, 2000). From this position, we can conclude that developing students’ awareness of their learning and developing their metacognitive skills may enhance their level of conceptual understanding.

Metacognitive tasks that engage the learner are inherent in the descriptions of both the intentional conceptual change learner and the intentional learner (Bereiter & Scardamalia, 1989). Sinatra and Pintrich (2003) define intentional conceptual change “as the goal-directed and conscious initiation and regulation of cognitive, and motivational processes to bring about a change in knowledge” (p. 6). Bereiter and Scardamalia (1989) describe the intentional learning “as having learning as a goal, rather than an incidental outcome” (p. 363). According to Pintrich (1999), the intentional learner has some control over his/her learning; is goal-directed with a focus on learning, understanding and mastering the task; can monitor and regulate his/her learning in a metacognitive manner; adopts a constructivist perspective; values the course material; and is developing higher levels of self-efficacy, i.e., building confidence, and is adopting a belief in personal control of learning. Obviously, the motivation and intention of the learner influence the process of learning.

These descriptions of the learning process include ideal metacognitive skills, such as being aware of their own knowledge; being aware of their learning goals; being responsible for their own learning; being able to identify data that conflicts with their existing conception leading to dissatisfaction; being able to use knowledge to achieve their learning goals, and being able to evaluate the plausibility, fruitfulness, and intelligibility of the new conception. In reality, students are at various stages of developing these skills. Some may be completing metacognitive tasks, learning content and skills without being aware of their own learning process, while others may be purposively completing the metacognitive task being assured that the task will help them to achieve the learning they desire. This study reports on students’ awareness of their own learning and on tasks that are designed to promote this development.



These descriptions of the learning process also assume that students value learning, want to fully understand the concepts and master tasks, are highly motivated to learn, and are interested in the way they learn (Pintrich, 1999). While there is a positive correlation between the students' intrinsic goals for learning and their deeper processing and understanding (Pintrich, 1999), without the intrinsic goals there will be no deeper learning. Unfortunately for various reasons, not all students are highly motivated to learn and, consequently, their opportunity for meaningful learning is reduced. Thus, this study examined students' motivation for learning with a focus on the effects of motivation on their learning.

### *The Importance of Assessment*

The role of assessment does influence students' learning approaches (Bell, 2000). In a previous study (Chittleborough, Treagust, & Mocerino, 2002), students' approach to learning was consistent with the type of assessment, e.g., algorithmic style questions promoted rote learning, while problem-solving questions promoted a more conceptual level of learning (Bodner & Herron, 2002). Formative assessment is consistent with a metacognitive approach to learning, because it utilises feedback and requires reflection and self assessment. Formative assessment is identified as being advantageous for low achievers more than other students. Black and William (1998) elaborate on the nature of formative assessment. "When anyone is trying to learn, feedback about the effort has three elements: recognition of the desired goal, evidence about present position, and some understanding of a way to close the gap between the two. All three must be understood to some degree by anyone before he or she can take action to improve learning" (p. 144). A formative style of assessment is adopted in this study and its effect on the way students learn is examined.

The purpose of the study was to examine the learning strategies that non-major chemistry students use in learning chemistry. Aspects, including motivation, formative assessment, and course organisation, are considered in answering the three research questions: a) What learning strategies do non-major chemistry students use in learning chemistry? b) What are the influences on the students' choice of learning strategies? and c) How does students' metacognitive awareness influence their learning of chemistry?

### **Method**

This paper reports on a study conducted over two consecutive years with first-year non-major chemistry students undertaking compulsory introductory chemistry courses (called Chemistry 117 and Chemistry 118). The students were enrolled in degree courses for Environmental Biology, Health Sciences, Human Biology, and Environmental Health. Chemistry 117 is designed for students with no previous chemistry knowledge and is a prerequisite for Chemistry 118. Students in these courses generally do not continue with chemistry after first year, and chemistry is not their major area of study.

### *Student Sample*

The students in this sample were taking a first-year university chemistry course that assumes no previous knowledge of chemistry. The students are described as "non-major" chemistry students, because they were not intending on continuing in chemistry after their first year of university studies. This is compared to "major" chemistry students who have completed chemistry to a high level at high school



and continue studying chemistry courses at university for a period of at least three years. The non-major students typically have a limited background in chemistry and mathematics, a lack of motivation to understand chemistry at a deeper level, and some have had negative experiences in chemical education (Chittleborough et al., 2002) (see Table 1)

*Table 1  
Breakdown of Students in Year 1 and 2 of the Study by Age and Gender*

Year of Study		Category	Male	Female	Age Profiles*			
Study	N		%	%	1	2	3	4
1	160	Whole class	35	65	-	-	-	-
1	19	Volunteers**	47	53	53	5	26	16
2	115	Whole class	46	54	-	-	-	-
2	19	Volunteers**	32	68	42	10	21	27

Age Profiles\* (1-attended high school last year, 2- within 2 years of leaving school, 3- between 2- 5 years of leaving school, 4- more than 5 years since leaving school, \*\* Not all volunteers completed all volunteer tasks as availability varied).

- = Data not available.

*Chemistry Course Design*

Both chemistry courses 117 and 118 use the Personalised Student Instruction (PSI) learning program (Curtin University of Technology, 2003). The tuition consists of a one-hour lecture and a three-hour laboratory session per week. The courses are self-paced, mastery-learning programs designed to provide flexibility and cater for students with a wide range of backgrounds and destined for a variety of professions. Both courses have a formative assessment style of continuous assessment throughout the semester requiring students to gain a mark of at least 80% to pass each topic test. This formative assessment style provides students with feedback from a tutor on their test results, and they may re-sit the test any number of times. The tests require students to complete mainly algorithmic type problems. The style of questions in each test is similar; however, the number values and unknowns can vary, so students are not re-sitting exactly the same test.

*Data Sources and Collection Procedures*

In both years of the study, students were observed, surveyed, and interviewed about their personal learning styles. The first author was a participant researcher in the laboratory working as a demonstrator with students. Group data in the form of surveys provided an overview, while data from individual students primarily from interviews and observations provided more specific data. The data collection is outlined in Table 2.

*Table 2  
Data Sources and Collection Procedures*

Year	Data	Details
1	2 <sup>nd</sup> Interview	Learning strategies
2	Online Survey	Online Survey containing 19 Likert-type Items and 8 open-ended Items
1 & 2	Observations	Participant-researcher working in the laboratory observing students and managing the website questions.

In the second year of the study, a website was created for the course providing students with e-mail communication, a discussion page, access typical test solutions, suggested internet links, access to check their marks, as well as pre-laboratory exercises. The compulsory pre-laboratory exercises were introduced to better prepare students for the laboratory work by asking questions about the objectives of the experimental procedure, equipment, and calculations (White, 1996). The pre-laboratory exercises were marked electronically and students received immediate feedback on their responses. Students had the opportunity to repeat twice the exercises in light of the feedback. In this way, the exercise was encouraging students to reflect on their responses in light of the feedback and reattempt the exercise.

In the first year of the study, student volunteers were interviewed about their learning strategies. In the second year of the study, the students completed the Online Survey that gathered information about their opinions of the online pre-laboratory exercises as well as their learning strategies and aspects that were perceived to influence their learning. The Online Survey was administered through the WebCT site to students. It contained Likert-style items, requiring a response on a five-point scale to items such as "I understood the experiments, having done the pre-laboratory exercises" (Item 14, Table 4), as well as Items requiring written responses such as "What aspects of the pre-laboratory exercises are helpful to your learning of chemistry?", and "List any strategies you make use of in learning chemistry." The inconsistent numbering of the Online Survey shown in Table 4 is a result of combining the survey administered in Year 1 (numbered items) with additional items in Year 2 (letters). Where the items were identical the same item numbers have been used in both surveys.

The transcripts of interviews and written responses in the survey were transcribed and coded in terms of relevant aspects of students' understanding and activity (Silverman, 2000). As categories were created and coding continued, the robustness of each category was assessed, resulting in continual adjustment and refinement of the categories. This process continued throughout the coding process. After the coding of all documents was complete for a particular question or concept, the coded data for each category was inspected, and the frequency and accuracy of the coding assessed. The software package N-Vivo was utilised in the coding process. A colleague acted as an independent researcher (Merriam, 1998) by crosschecking the coded categories and the coded text to verify the accuracy of the coding practice. Pseudonyms are used for students' names throughout this paper.

Data collected in the first year of the study was analysed and explored further in the second year to provide corroborating or refuting evidence. For example, ideas that were identified in the first year of the study through interviews were developed and tested on larger samples in Online Survey in the second year, confirming the validity of the results. The data from Year 1 of the study was consistent with the data from the Year 2; and the various sources of data both qualitative and quantitative provided comparable results confirming the reliability of the data. The introduction of the web-site and pre-laboratory exercises at the beginning of the second year were made in response to identifying a need for further avenues of communication for students and a lack of preparedness of students for the weekly laboratory experiments.

## Results and Discussion

With a holistic approach the data from Years 1 and 2 of the study were used to address each of the three research questions, and the implications for learning are discussed. The students were enthusiastic to have feedback on their learning experience in the hope of improving their learning situation. They were also thoughtful in their responses – they were serious and earnest in their criticisms. The nature of university education, with the student choosing to undertake the education, incurring the cost for the tuition, the university maintaining the academic standards, and providing an independent learning situation without the individual instruction of a school classroom, generated a more disciplined attitude in the university students than in a school situation.

### *Common Learning Strategies*

The non-major first-year chemistry university students were directed to using learning strategies that promoted a rote-learning approach in response to the assessment demands of the course. The learning strategies chosen were influenced by the individuals' prior knowledge, motivation, personal learning styles, in addition to the course structure, and assessment requirements. Data from both years of the study were used to address the first research question – What learning strategies do students use in learning chemistry? From the interview data in Year 1 of the study, the well-known, traditional and proven learning strategies, such as underlining, highlighting, memorising, reading, copying out notes, studying worked solutions, practising problems, and getting help with mistakes after doing topic tests, proved to be the most commonly learning strategies that students mentioned.

In the second year of the study, students were asked, in the Online Survey, to write about any learning strategies they make use of in learning chemistry. The students' written responses to the question were coded and ten categories were distinguished. The results presented in Table 3 confirm that students used multiple learning strategies. The traditional learning strategies identified at the end of the second year with a large anonymous group (n=115) are similar to those identified in the first year of the study with a small volunteer group (n=19) of students.

Table 3  
*Frequency of Learning Strategies as Reported in the Online Survey  
by First Year Chemistry Students (n=115) the Ten Categories*

Category	Frequency
Working out problems, practising problems, using solutions	67
Underlining, highlighting copying notes, rewriting notes	49
Working with other students, tutors	48
Memorising and reading	45
Researching texts, course study notes, websites	35
Drawing concept maps, diagrams	25
Lectures	4
Laboratory work	3
Sequential learning	2
Contextual learning	1

The strategy with the highest frequency was *Working out problems, practising problems, using solutions*. This strategy was used by students to promote meaningful learning and understanding of the concepts being studied, and suggests that stu-



dents are studying worked solutions and practising problems to identify trends and patterns in problem-solving tasks. The strategies *underlining*, *highlighting* *copying notes*, *rewriting notes* and *memorising and reading*, with the second and fourth highest frequency, respectively, are both strongly associated with rote learning techniques. These rote-learning strategies are valuable and an essential part of learning chemistry. Rote-learned information forms the basis on which further knowledge can be constructed and is often the most appropriate learning style in introductory chemistry (Battino, 1992). Responses to the Online Survey question, requesting students to list any strategies they make use of in learning chemistry, illustrate the focus on rote-learning techniques.

*Re-writing the work covered in the lectures in my own words, as if I were explaining it to someone else.*

*I divide the topic into sections, using different colours to separate out different aspects of the topic. This reduces the (given) notes into manageable units, and makes it easier for me to handle. Talking it through, even just talking aloud to myself, often clarifies things. Telling myself it's just another foreign language; I enjoy learning languages, and do so easily.*

*I'm always taking notes.... and sometimes these notes are repeating themselves...but I always have them with me for reference... and I write little notes all over the place...usually in pencil so I can erase them when I have to hand something in.... I personally find it easier to work on my own and going to find help when I need it.... I also have a small chemistry pocket book that has basic chemistry facts that's useful for definitions and helps put things into different words when sometimes I do not understand something.*

The third most frequent learning strategy was *Working with other students, tutors*. This learning strategy includes activities, such as working collaboratively with other students, the discussion of ideas, listening to others, and negotiation of meanings that require the learner to have a positive attitude to learning. The fifth most popular learning strategy was *Researching texts, course study notes, websites*. The majority of students only claimed to make use of the course study notes, which has detailed chemical content corresponding to the lectures, with examples of worked problems with answers, and trial test questions. The course study notebook is printed in an economical format of black and white print with very few diagrams. However, the recommended textbook is not purchased by many students, because, firstly, the course is closely aligned to the PSI course study notes, and students can pass the course using only those course study notes; secondly, the book is expensive; and, thirdly, students cannot see the value in purchasing a textbook in a subject in which they are not going to continue after first year. The sixth most popular strategy was *Drawing concept maps, diagrams* with some students recognising the importance of understanding chemical representations in learning and understanding the abstract ideas in chemistry.

#### *Factors Influencing Students Choice of Learning Strategies*

In addressing research question 2 – What are the influences on the students' choice of learning strategies? – students' interview comments and survey data indicated that a number of factors were influential. These included the assessment structure and opportunity to obtain feedback provided by the organisation of the course, and the individual students' motivation and self-efficacy, time management, and prior knowledge.

### Assessment Structure

The course had a formative assessment style of continuous assessment throughout the semester comprising 11 weekly laboratory tasks (10%), 11 compulsory mastery tests (45%), three optional topic tests, and an optional final review examination. The questions in the 11 topic tests were mainly of an algorithmic style and did not require conceptual understanding. The assessment structure of algorithmic questions encouraged students to adopt learning strategies that reinforced the memorisation of facts and algorithmic understanding (Nakhleh, Lowrey, & Mitchell, 1996). Consequently, the strategies of *working out problems, practising problems, using solutions, underlining, highlighting, copying notes, rewriting notes, and memorising and reading* were prominent. However, considering the students' backgrounds, the volume of chemical content and the speed at which students must digest it, this assessment scheme may be the most appropriate to achieve the course objectives for these non-major students.

In his interview, Stuart described his learning strategies as follows.

*Stuart: Prior knowledge helped me - I had good background knowledge. Did the tests, most were OK, when I failed one I went home, learnt it all from the yellow book [course notebook] and practised the problems, worked them backwards to understand what they were trying to do; it is just hard work. I learned the stuff from each unit - crammed for each unit, memorised it, passed the test and then, that's it, I don't always remember it.*

All students interviewed described rote-learning to be the primary method of preparation for tests. This is exemplified in the following excerpt from the second interview with Simon:

*Simon: I think I pretty much rote learned a lot of it. I don't think I'd be able to get 80% in my tests now, but I think I'd pass.*

Rote learning can have a valuable role in chemistry (Battino, 1992); however, the process of learning should not be marginalised by the need for assessment. The assessment format of testing and examination appears to promote an individualistic even isolationist approach to study. Students, such as Margaret, who had to engage a tutor for extra assistance in her learning chemistry suggested that optional tutorial groups would help students who feel isolated and thereby help overcome the workload.

In line with being a personal instruction scheme, the assessment structure allowed students to elect what grade they were aiming for, by the number of tests they completed by the end of the semester. Students completing just the compulsory tests would achieve a passing grade, whereas students completing all the compulsory topic tests and the optional topic tests were able to take the optional examination to be eligible for a higher grade.

*Int.: How did you go with the tests?*

*Simon: Yeah good I got them all done, so I didn't do the exam, so I was just basically going to be a pass, so as soon as I got them done, I knew I passed, so I just concentrated on my other courses, which I don't know is a good thing or a bad thing.*

Simon was being pragmatic and decided that his time was better spent on another course. The grades do not therefore necessarily reflect students' ability, but may reflect their effort. The fact that chemistry is not their major field of study becomes a determining factor in their attitude and learning approach. This beha-

viour and decision-making is consistent with an intentional learner and demonstrates a maturity that is not always observed in younger students.

#### *Opportunity to Receive Feedback*

The PSI testing system and the pre-laboratory exercises provided opportunities for students to obtain feedback and reflect on their understanding. The learning opportunities provided by the PSI testing scheme was exercised by many students:

*Steven: Sometimes, if I don't know how I'm going, so I book in [to do the test] and try the test and get feedback.*

*Int.: That is a strategy you have worked out to help you succeed. Have you failed any tests?*

*Steven: Yeah, I failed two organic ones.*

*Int.: What did you do to get around that?*

*Steven: I went home and stayed up all night studying.*

*Int.: OK, How did you learn it when you were studying? Did you memorise it?*

*Steven: Yeah, basically I got the book out and went over it and I did a topic test, and if I failed it, I went back and went over it.*

Similarly, the following excerpt describes Leanne's and Simon's learning strategies that are also aligned with the philosophy of the PSI approach.

*Int.: How did you go about learning the section/topic? What strategies did you use?*

*Leanne: I booked [in to do] the test, and then I had to go [attend], even if I didn't pass – I learnt from it, got help and then could try again.*

*Simon: I went in [to the PSI testing room] when there was no one else in there and I just sat down with the tutor before I did the test and went through everything, so yeah that was helpful.*

They both recognised that receiving feedback was an important part of learning. A similar opinion was expressed about the feedback from the pre-laboratory exercises that were designed to provide students with feedback on chemical skills, such as laboratory techniques, and basic chemical concepts such as neutralisation, related to the weekly experiment. The Online Survey results (see Table 4) showed 83% of students agreed that "getting immediate feedback on the online pre-laboratory exercises was valuable" (Item 8), and 90% of students agreed that "being able to try an exercise more than once helped me learn from my mistakes" (Item 10). The value of feedback and the renewed opportunity appeared to be appreciated by students. Similar results for Items 6, 12, 13, and 14 confirm this conclusion (see Table 4). The pre-laboratory exercises show that many students took the opportunity to retake the exercises to improve their mark. The mean percentage score for the pre-laboratory exercises at the end of the study was 87.7 %, and the average number of attempts was 1.9. This very high score is in line with the objective of the exercises to give the students confidence and to help them learn from their mistakes. The fact that many students recognised the value of obtaining feedback to their learning and organised their learning around it demonstrated a metacognitive awareness.

#### *Motivation and Self-Efficacy*

Motivation and self-efficacy can influence the students' choice of learning strategies. From the interviews and the Online Survey responses, it was apparent that for many students the motivation was to learn in order to pass the tests and



Table 4  
 Percentage Responses to Online Survey — in Study 4 - Semester 2 (n=115)

Item	Mean (1-5)	SD	SD <sup>1</sup>	% Frequency				
				D	N	A	SA	
A	My computer skills are good enough to use the Web CT program effectively	4.5	0.8	2	2	6	23	67
B	Without good computer skills I could not use the pre-lab exercises effectively	2.6	0.9	7	47	32	13	2
2	I had difficulty accessing the website from home	2.1	1.1	33	40	14	10	3
3	I had difficulty keeping the website up and running.	2.0	0.9	32	47	11	9	1
4	I had difficulty navigating the website for the course.	1.9	0.8	34	53	8	4	1
5	The online pre-laboratory exercises allowed me greater flexibility with my time	3.8	1.2	6	10	12	39	33
6	The online pre-laboratory exercises provided feedback on my understanding.	3.7	1.1	6	9	16	52	17
7	The online pre-laboratory exercises helped me to learn and understand the concepts in the experiment.	3.7	0.9	3	8	1956	14	
8	Getting immediate feedback on the online pre-laboratory was valuable	4.2	0.8	0	4	13	46	37
10	Being able to try an exercise more than once helped me learn from my mistakes	4.4	0.8	1	3	6	36	54
11	I had to read the laboratory notes in order to do the online pre-laboratory exercises	3.6	0.9	2	9	30	44	15
14	I understood the experiments better having done the online pre-laboratory exercises	3.8	0.8	0	8	23	52	17
15	The pictures and diagrams in the online pre-laboratory exercises were valuable	3.8	0.8	0	7	23	53	17
17	I use the solutions to the typical tests on the website regularly	3.5	1.2	7	17	19	37	21
C	I monitor the discussion page on the website regularly	2.7	1.2	21	29	23	20	7
D	I find the e-mail facility useful	2.9	1.0	10	18	53	11	9
E	I usually completed the pre-lab exercises before the laboratory session	3.3	1.2	9	17	22	36	16
F	I find the calendar useful	2.7	0.9	10	23	53	12	2
G	The website has directed me to relevant Internet sites.	2.6	0.8	10	33	49	7	1

<sup>1</sup>The instrument required students to indicate the extent of their agreement with the statements on a 5-point scale where 1= Strongly Disagree, 2=Disagree, 3=Neutral 4 = Agree and 5= Strongly Agree. The values have been rounded off to whole numbers

hence the course, rather than to learn for understanding. While this is understandable, remembering that chemistry is not their major field of study, it certainly is not desirable.

The value of the chemistry content to the degree course was questioned by some students who did not appreciate its relevance. For example, Sharon, who was interviewed in Year 1, struggled to learn organic chemistry and did not see the relevance of it to her career.

Sharon: There were these things you had to know things you had to know in and out and if you didn't know it in and out then you couldn't do the test well enough to pass.

Int.: OK, Do you think it was valuable learning it? Was it worthwhile?

Sharon: Not for our course.

Sharon could not see the relevance of some of the course content. Her discontent with the chemistry course may influence her attitude to chemistry.

### *Time Management*

Time management was a factor that influenced the students' choice of learning strategies. Without any formal time restrictions, many students fell behind schedule with the PSI tests, resulting in a student possibly losing the opportunity to re-sit tests as often as was needed to pass, or learning masses of content at the end of the semester in order to pass all the required tests in the required time. This problem identified a common student characteristic of underestimating the time needed to learn, and a general lack of organisation and allocation of that time. The ultimate deadline at the end of the semester resulted in many students queuing to take the PSI tests, the system was overloaded, and the philosophy of feedback and reflective learning lost to the pressures of time, thus jeopardising the philosophy behind the self-paced learning program. The guideline specifically guards against the time management dilemma:

*Strict quality guidelines in the Course Outlines ensure that students meet their obligations within sensible time frameworks (Curtin University of Technology, 2003).*

Despite these warnings the problem still remained, and its repercussions were contrary to the philosophy behind the PSI testing scheme. It may be unreasonable to expect all these non-major students to have a passion for chemistry, but it is desirable that they gained an appreciation of the chemistry from their learning experiences. The pressures of time, the amount of content that had to be covered, and the rigour of the assessment regime directed even interested and earnest students to those learning strategies that prepared them for tests.

### *Prior Knowledge*

Students' prior knowledge did influence their approach, attitude, and perception of chemistry. As might be anticipated, inexperienced students had no concept of the sub-microscopic nature of matter on which chemistry is based and were inexperienced in using calculators and scientific notation. These students struggled to complete laboratory reports, and had difficulty with the algorithmic questions in the topic tests. Obviously, the students' with no previous chemical knowledge and with weak mathematical knowledge had to undertake a steep learning curve and commonly adopted a rote-learning regime to cope with the demands of the course.

### Students' Metacognitive Awareness

In responding to the third research question – How does students' metacognitive awareness influence their learning of chemistry? – it is perhaps obvious that students' who have an understanding of the process of learning are more likely to achieve the chemistry learning. At the university level, (the age of the students undertaking this course ranges from a minimum of 17 years and upwards) most students had some metacognitive awareness, if not specifically in chemistry, and were able to apply generic learning skills to learning the new content area of chemistry. Since metacognitive skills appear to improve with maturity and knowledge, this cohort of students have potential for development in this area (Bransford et al., 2000).

The responses to Items in the Online Survey (Table 4) suggest that students did appreciate the value of various learning tasks and did have an understanding of how they learn. Many students (70%) agreed that the pre-laboratory exercises helped them to learn and understand the concepts in the experiment (Item 7); and 69% thought they understood the experiments better (Item 14) having done the online pre-laboratory exercises. These results draw attention to the students' awareness of their own learning and the impact of specific learning strategies on their understanding.

Representative students' written responses to the open-ended questions in the Online Survey demonstrated their reflectivity about their learning experience.

*Doing the pre-labs made me gain a better understanding of the experiments in general, but also allowed me to think about what I learned from them and apply them to the practical aspect, while I'm actually doing the experiment. The questions and answers are direct so there's little confusion, which I also think, is important.*

*It has provided me with quite adequate information about the coming lab exercises, but it would be much better if we could add an aim to the above, namely, help students get an understanding of how the experiment works and what logical reasoning is behind the chemistry of the experiment itself. Most of the time, students can do the experiment well enough to get good marks, but they don't understand how the actual experiment proves the theory behind it, or describe the logic in obtaining the steps to calculate results for an experiment, such as the iodine or saponification value. If Web CT were to be able to help develop students' understanding about the logic of calculation and provide feedback of certain cases (i.e., adding excess acid), it would certainly help them, especially to those who have little understanding of chemistry.*

It is important for the university that it helps to make students understand the concepts of the lab rather just give practicals without enough information. This way, we can understand what exactly we are doing in the lab and know what our numbers mean, how we get them, and the logical thinking in getting them.

The metacognitive awareness expressed by many students demonstrated an appreciation of their responsibility for learning and their value of the learning resources. The excerpts provide evidence that these students had an appreciation of their changing position in the learning process. Further to this, students' remarks provided critical awareness about the way they wanted to learn.

*An observation I have made is that the lectures are orientated around passing the course tests rather than 'understanding' what is happening with the chemistry. This is probably a result of the breadth of information we are encompassing this year. While this allows for students to pass the course components fairly easily (and get good marks), it doesn't necessarily equate with an understanding of chemistry, but rather an ability to remember how to do set problems.*



*The typical test solutions showing the workings has been extremely helpful in LEARNING, not only getting the answers, as each problem has been set out step by step. [student's emphasis] Because of the structure of Chem 118, I have understood and enjoyed chemistry more. Being able to set my own pace with only my own pressure has meant learning it more thoroughly and more effectively. I have felt more satisfied with myself. I feel this way of learning helps you to retain what you have learnt rather than just cram and forget - This is especially true as a pre-requisite subject. Although there will only be biochemistry in my course after this year, 117 and 118 has laid a good foundation*

*The lectures seem only aimed at passing the assessments, not actually learning any theory. But, I can see the reason for this. Generally, I am very happy with the course.*

With some students expressing an interest in learning as well as those expressing a desire to learn just enough to pass, the alternative motivations of the student population are revealed. Catering for these different needs is a challenge that chemical educators face.

### **Implications for Learning**

The type of learning that will be achieved is influenced by the profile of the students. Rote-learning is a most valuable and important process especially for those students with little or no chemical background, or for those students who are motivated only to pass. All learners begin with rote-learning strategies, because they are familiar with how to learn this way. Rote-learning provides a necessary fallback position from which more conceptually demanding levels of learning can occur. With a solid foundation, students can extend to higher orders of learning.

The instructors and organisers of the course have a responsibility to provide appropriate learning opportunities – time, opportunity, guidance, and support (Black & William, 1998). The students have chosen to undertake the course and they want to pass it. Nevertheless, the data have shown that most students are discerning and critical learners who value feedback and direction for their learning. Considering the profile of the students and their career needs, the chemistry content of the course could be more contextual and relevant to the students' future careers (Wildy & Wallace, 1995).

Assessment structure plays a significant role in learning in terms of motivation, expectations, and direction of type of learning. The educators have a responsibility to select the most appropriate assessment techniques to achieve the desired objectives. It is up to the educators to establish the rules, so that the students can attain a high academic standard in both content and process of learning.

Because university students have the responsibility for their own learning, their motivation, time management and organisational skills are part of the process of learning. In this study, the data provided rich examples of students' opinions and understanding of their own personal learning processes indicating that they have taken responsibility for their own learning. The data suggests that many students are intentional learners, actively undertaking tasks to meet the requirements to pass the course.

The continual feedback provided through the topic tests and the pre-laboratory exercises that comprise the formative assessment scheme appeared to be critical to students' learning. The feedback helped students to recognise what they needed to know, appreciate what they already knew and understand, what they needed to do in order to learn, and what they didn't know (Black & William, 1998). The

importance of self assessment and reflection was evident in that these metacognitive processes are closely associated with and should facilitate meaningful learning (Pintrich, 1999).

The attribute of metacognitive awareness can be used to promote learning and is one that can be fostered at all levels of education. Bereiter and Scardamalia (1989) describe the intentional learner to be self-disciplined, well-organised, and motivated. The responses from the university students indicated that many adopted these characteristics in order to pass the course. Although the content of any particular course is important, it is equally important for students to gain an understanding and appreciation of the process of learning. The data from this study showed students learning content but also showed many students appreciating the learning process.

### **Conclusion**

Understanding the learning process and knowing how to learn requires generic metacognitive skills, whereas learning chemistry and knowing how to learn chemical concepts requires foundation knowledge in chemistry that allows for the building, evaluation, and accommodation of ideas. Pintrich (2000) suggests that students' self-efficacy and confidence in their own thinking and learning skills is most important for learning. The confident learner will learn irrespective of the content.

This study has gathered valuable data on students' perceptions and understanding of their personal learning strategies, and the factors that influence their choice. The results revealed that many students had a deeper level of understanding of the process of learning than had been expected. The results of this study show that many university students are interested in their own learning, displaying qualities such as being discerning, pragmatic, critical and analytical in their attitude towards their learning. By confusing the students' ability of learning with the students' limited chemistry ability, the students' self efficacy can be flattened. There is potential to make greater use of the students' ability to learn to assist in their learning of chemistry.

Nearly all students identified the multiple learning strategies they used. The traditional and reliable strategies, such as practicing problems, rewriting notes and memorizing, were most commonly reported. While students used new technologies to access information, the learning strategies remain the same regardless of the learning medium. Most important is that all learning strategies require mental effort by the learner.

The most important influence on the students' choice of learning strategies is the students' agenda (Wildy & Wallace, 1995). Because chemistry is not their major area of study, students' motivation and self-efficacy, time management, and prior knowledge are frequently adversely affected. The organisational factors, such as the assessment structure and opportunity to obtain feedback, also influenced the students' learning strategies. Identifying the factors that influence students' choice of learning strategies provides opportunities to improve or modify these factors to improve the students' learning.

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