Educational research

The strategies used by distance education students when learning basic chemistry; implications for electronic delivery

Robert Lyall

Monash University, School of Applied Sciences and Engineering
Gippsland Campus, Northways Road, Churchill, Victoria, Australia 3840
e-mail: Robert.Lyall@sci.monash.edu.au

Received 7 March 2005, accepted 2 June 2005

Abstract: The already developed learning profiles of distance education students could be a determining factor in whether or not electronic forms of instruction will be successful. Several groups of distance education chemistry students were interviewed to discover the strategies they use when studying from their present printed material. A number of strategies were identified and grouped into two major categories and several subcategories, depending on the content of the material being studied and time available for study. It was found that the students used a cognitive linear style of learning, using three distinct types of learning strategies revolving around the core strategy of taking, summarising and rewriting of notes. They then used a separate, but similar, set of strategies to validate their knowledge. A computer based learning program would have some advantages over print, but would need to support the present style of learning adopted by the students. Suggestions are made for an integrated program that may encourage students to adopt alternative strategies. [*Chem. Educ. Res. Pract.*, 2005, **6** (3), 150-165]

Keywords: distance learning; learning profiles; learning strategies; note taking; deep and surface learning; facts and concepts; computer based learning.

Introduction

In Australia, because of its large area and small population, the distance education students usually receive instruction on their own, and often at a remote site where they cannot physically meet with their fellow students. Printed study guides and textbooks are still the primary learning resources, and students have adopted their study methods around these. However, the rapid expansion of information technology combined with economic forces is forcing institutions to investigate more (supposedly) cost-effective methods to deliver their courses (Gladieux, 2000), and there is considerable pressure on educators to use modern technology to provide more flexible ways of delivering high quality educational programs (McNamara and Strain, 1997). This push to use technology has caused difficulties, not the least of which have been a failure to maintain a quality product (Vidovich and Porter, 1999), and the extra stress on the students brought about by a new and different form of communication (Hara, 2000). In his review of distance education, Dhanarajan (2001) pointed out the necessity to adapt the current teaching pedagogy to better exploit the technology.

Such a pedagogical change needs to be based on a learner-centred approach where the educational process is supported by the technology rather that being driven by it (Rumble, 2001; Petrides, 2002). Laurillard (2002) pointed out that it is a mistake to base the design of learning materials on the capabilities of the instructional media, and that good design must take into account the students' present state of understanding and the already established methods they use to acquire that understanding.

Students develop their own profiles of learning depending on their particular orientation, described as *"the predisposition of a learner to adopt a particular process"* (Biggs, 1993), which, in turn, depends on the students' approach, motivation, mental model and environment. It is suggested that this learning profile is relatively stable, but not unchangeable, and results in a set of strategies that the students use when confronted with a learning task (Vermunt, 1996).

Another barrier to electronic forms of delivery is that distance education students are reluctant to accept new ways of receiving instruction because their time is limited. They need to be convinced that there is some immediate benefit, measured by their learning outcomes, in adopting an alternative study method, and that they do not have to go through a period of re-learning how to study (Lyall and McNamara, 2000a).

In the first part of a study into the learning profiles of distance education chemistry students, their orientations to learning were explored (Lyall and McNamara, 2000b). This study found that these students are highly motivated and independent. They are pragmatic about their studies and tend to use a flexible 'strategic' or 'achieving' approach, which is concerned with the efficiency of learning and attainments by the use of planning, time management and the systematic use of study skills (Biggs, 1993; Richardson, 1994).

This paper continues the study of learning profiles by examining the learning strategies used by distance education chemistry students, where learning strategies are defined as the tactics or procedures students adopt for handling a learning task (Christensen et al., 1991). Recognition of these strategies is important in the first instance to assess, and possibly improve, the present method of instruction. A further aim was to use this information to assist the student in the transition to electronic delivery by suggesting a computer aided learning program (CAL) that would utilize the already existing learning strategies of the student and identifying those strategies that might be readily modified, and possibly enhanced, by the use of electronic media. The intention is that the data gained from this study will provide distance education chemistry educators with scientifically based tools to develop their teaching methods.

Methodology

The study was carried out on several groups of first year chemistry students at two Australian universities over a five-year period. The content and level of the units was similar, as was the form of instruction used by all groups. The universities supplied a printed unit book, and the students were expected to purchase a prescribed textbook. The unit books contained a series of study guides, the purpose of which was to guide the students' study within the particular areas of the unit by providing some information on specific concepts, referring students to areas in the prescribed textbook, and providing examples and self-assessment questions. Students in the latter years of the study did have access to electronic material, including interactive computer simulations, but it was left to the individual students to use as they saw fit. About half the students were compelled to attend a "laboratory" session of computer generated questions and answers.

A grounded theory approach was used. In this method, rather than start with a theory and try to prove (or disprove) it, the theory is *"discovered, developed and provisionally verified"* (Strauss and Corbin, 1990). This can be achieved by using ethnographic interviews, which are largely unstructured, with the interviewers adapting their questions during the course of the interview. The data from these interviews is then analysed according to a systematic set of procedures.

Conducting the interviews and analysis of the results was an ongoing process. The students were interviewed three times over the academic year. Most interviews were conducted in private with only the interviewer and interviewee present. For the first interview a battery of guiding questions was developed and tested in a pilot study. These questions were mainly open-ended and were modified as the interviews proceeded, depending on the participant's response (or lack of response). The interviews were recorded by audiotape and transcribed in full with the addition of any notes made by the interviewer. The data was then analysed and used as a basis for the second interviews. Similarly, results from the second interview were used for the third.

Analysis of the interviews was carried out using a three stage coding procedure outlined in Strauss and Corbin (1990). First, 'open' coding was used to identify and categorise phenomena relevant to the study. Phenomena are defined as being ideas, events, happenings or incidents. These were then given conceptual labels and classified into categories and sub-categories pertaining to a similar phenomenon. Properties (characteristics or attributes) and dimensions (some measure of the properties) of the phenomena were identified.

'Axial' coding procedures were then applied to the data to determine connections and links between the phenomena. The processes of open and axial coding were not performed in isolation of each other, nor in a strict sequence, but were often being conducted at the same time, it being found necessary to return often to the original transcripts and to modify the open coding categories during axial coding.

A final list of categories and sub-categories of phenomena relevant to the learning strategies of the students was prepared and presented to a panel of four experienced education researchers for their comments. They were amended in light of their recommendations. A 'selective' coding process was then carried out to integrate the categories to form the grounded theory and to identify the core category, which is the central category around which the others are integrated.

Students were also asked to submit (copies of) any written notes or other material they generated while studying, so that this could be examined in conjunction with the interviews.

Results

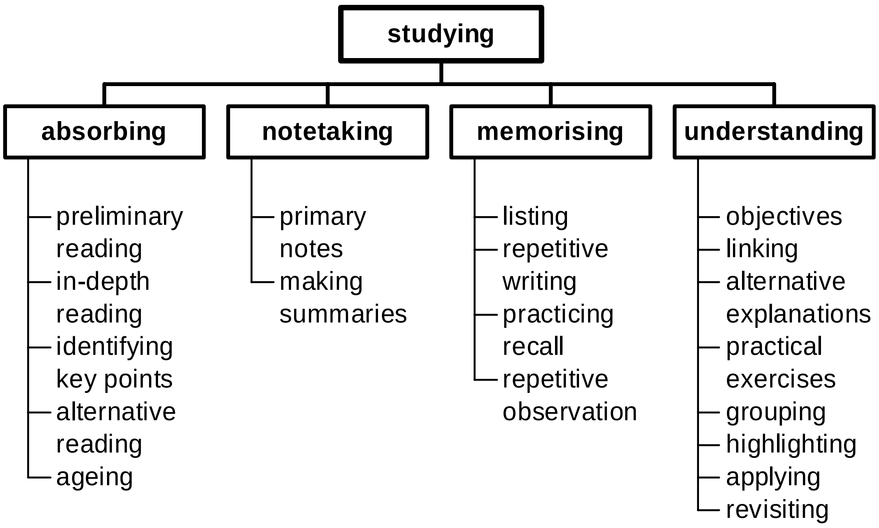
In all, fifty-nine students were interviewed from several different intakes of science students at two Australian universities. This represented about 22% of the students enrolled at the time.

Using the analysis procedure recommended by Strauss and Corbin (1990) the learning strategies used by the students were grouped into two major and intrinsically separate categories. These were called *studying* and *validating*. Studying could be identified as the actual mental and physical activities the student used to try and remember new material. Validating is a set of strategies used by the student to test and correct his or her newfound knowledge and understanding. These categories were then further divided into several sub-categories each with their own set of learning strategies. The results are presented as a general description of each learning strategy with specific findings and/or student comments in italics.

Studying

Studying was identified as being the 'core' category since this was where the students did most of their learning. All other categories and sub-categories related, in some way, to the studying category. Studying was divided into four sub-categories called absorbing, note taking, memorising and understanding. Note taking refers to the writing of notes by the learner and is the 'key' learning strategy. The other three are groups of learning strategies (see Figure 1).

Figure 1. Strategies associated with the ‘study’ category.



Absorbing

Absorbing involves the learner in ‘non-discriminating’ activities including reading and writing and is generally the first learning activity undertaken by the student. There are *five* learning strategies associated with absorbing: *preliminary reading*, *in-depth reading identifying the key points*, *alternative reading*, and *ageing*.

1) Preliminary reading through the study guide is a recommended study practice at both universities, but the majority did not do this for their chemistry units. Most claimed it was a waste of time since science in general, and chemistry in particular, was a hierarchical subject where new information was built on previous knowledge and therefore the study guides were designed to be read in sequence.

Peter claimed that he had very good recall, provided he “*got it right first time*”, so he didn’t need a preliminary read through, and Brian needed to take notes as a memory aid so a preliminary read was not helpful.

2) In-depth reading was where the ‘serious’ study began. All interviewees bar one worked through their study guides in a sequential manner, reading each topic in-depth one after another as they occurred in the study guide, for the same reasons as given above. Some worked through it slowly, doing examples and trying to master each concept thoroughly before going on to the next. Others would continually read the whole topic over and over again until, in the words of one, “*it clicked*”.

Lynne worked through each chapter three times whereas Margaret claimed she re-read the topics up to 15 times. Margaret’s continual re-reads were more than simple absorbing since she highlighted key and difficult points in the first reading and in her re-reading did all the examples and problems in the study guide. One interviewee claimed that he did not study sequentially but instead tried to structure the material at the beginning of the topic. His method was to divide a topic into two or three groups and then to divide that further into more groups, forming what he called a “pyramid tree”, which is a type of linking technique that will be discussed later.

3) Identifying the key points of the topic was an important strategy for most. This appeared to be an inductive process since they could not describe how it was done. Some key words were already highlighted in the study guide and textbook. Not surprisingly these key words were nearly always chemical or scientific terms such as ‘formula weight’ or ‘alkanes’ and sometimes headings to describe a chemical process such as ‘condensation reaction’. Often these key points were not identified until summaries of their notes had been made.

4) Alternative reading was a strategy used by nearly all the students. This refers to the use of textbooks other than the prescribed text. There were two main reasons for doing this. The first was to obtain different explanations for content that the student found difficult. The other was as an adjunct to the study guide in order to expand the material used for studying. Most students had obtained two or three alternative texts, some considerably more.

> Judith had about six other textbooks and said “*I usually use textbooks much more than I use the study guides – I read the study guide to find out what it is I’m supposed to know then I use textbooks to get to know it*.”

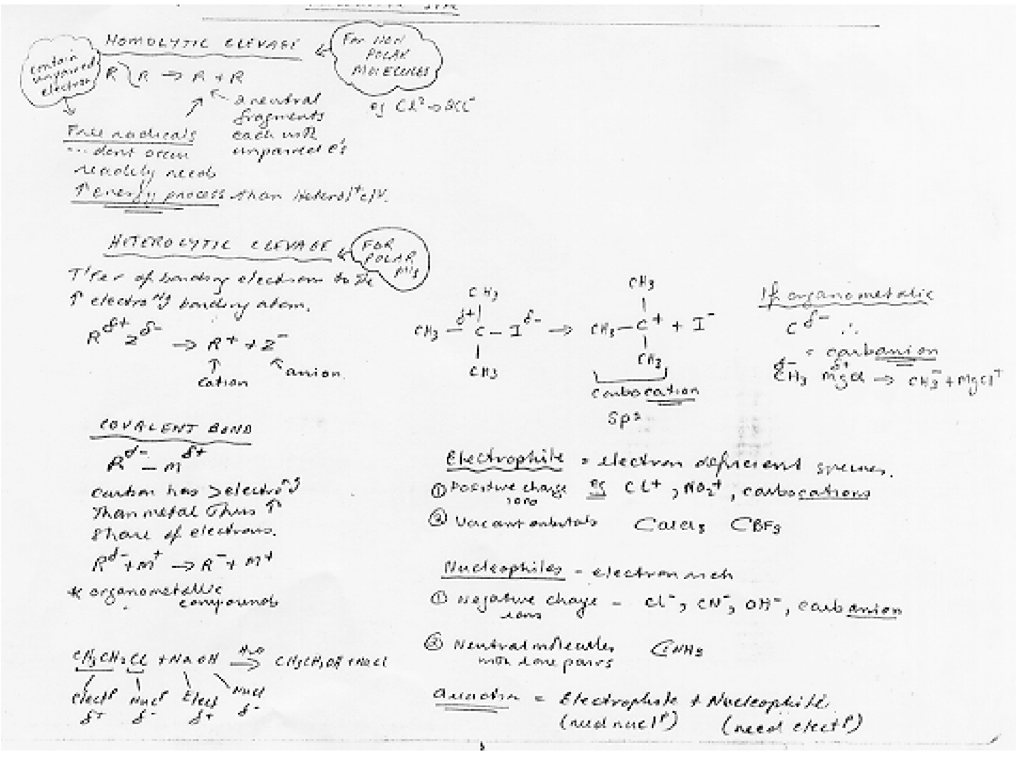
5) Ageing is a passive learning tool referring to the process of leaving content that is causing difficulty and coming back to it after a period of time. In some ways it is forced on the learner since the lecturer can seldom be contacted at the time needed, but several used it as a positive learning strategy.

> Joanne commented “*If I can’t work it out I’ll stop because I’m not getting anywhere, and then I’ll go away and either come back later that day or the next day and start from there again to try and work it out and I tend to find that if I do that I can usually work out most of my own problems*”.

Note taking

Possibly the most important strategy for most students was note taking. The content and detail varied considerably but their main function was to put descriptions and explanations ‘into their own words’. One example, shown in Figure 2, is typical of the less detailed style of note taking.

Figure 2: An example of ‘brief’ notes.



The primary level notes were generally summaries of the content in the study guide and/or textbook(s), taken directly from the study material and written down in the students' own words. Some of the interviewees made summaries of their own notes from time to time during the course of their study. Some made summaries of their summaries, up to three times. Many more made summaries at the end of semester when studying for the examinations.

> Brent made summaries and noted better explanations in his notes on one side of a sheet of paper. He then made further notes, on the other side of the paper, when revising and a third set when studying for the examinations. Lynne also made three summaries, an overview on the preliminary read, a one-page summary of each chapter on working through and a summary of those pages for the examination. Maria and Steven made brief notes on cards, which they could carry around with them.

As can be seen from the above example the notes were mainly simple explanations of chemical terms used in the study guides and almost invariably made use of chemical equations in the explanations. The terms were usually highlighted and as such were used as the key points discussed previously.

Any content that the students could not understand or they had difficulty in understanding was included in their notes. Often the key points were modified, or even not identified, until the second or third reading.

> Steven said "*I think it is very important, the key parts, because the first time around I failed to... not being used to studying for a long period, I failed to see certain key suggestions*".

There were generally two reasons for making notes. First, several of the students thought that the mere act of translating and writing it down helped them in remembering the content. The other reason was to ensure that when the student revised the material, especially for examinations, he or she would have it in words that could be understood more easily. Most used the notes for further study and revision, particularly around examination time.

Memorising

Memorising has two dimensions. One is as a part of the preferred studying routine where the information is expected to be retained for a long period. The other is used as a short-term strategy to pass examinations, which is called swotting. Most of the interviewees admitted that they had made use of swotting at some time or another, but regarded it as undesirable and claimed that they used it as a last resort, usually because of a lack of time to 'study properly'. In general the techniques used for memorising and swotting were similar. Without exception all the interviewees used some form of memorising or rote learning techniques, but regarded it as somehow being inferior to understanding.

There were four major learning strategies associated with memorising: *listing, repetitive writing*, *practicing recall*, and *repetitive observation.*

1) Listing is a learning strategy for memorising and is often inter-related to the 'understanding' strategy of grouping, in which the learner groups together different topics that appear to have some common characteristics. Once grouping is used to gain an understanding of the underlying concepts, it often then becomes a list, which is more easily memorised. For instance, a list of the important organic functional groups can be memorised but it is first necessary to understand the concept of functional groups. A majority of the students made up their own lists or groups in addition to the lists and tables given to them in study guides and textbooks.

> Alice was typical of this group. She made up lists, such as the ending of chemical names and what they meant, and kept them as references with her study books. Greg would make lists, such as the names and formulas of polyatomic ions, and memorise the first entry. He claimed he could then more easily remember the rest.

2) Repetitive writing was regarded as an important strategy for learning, with about half claiming to use it regularly. Most students would try to use different words when rewriting, which introduced a further level of activity in that it required the student to think about alternative wording for the material.

> Greg would keep writing material down until he felt he had retained it and may need to do this up to 20 times.

3) Practicing recall is a well-known technique for memorising, but surprisingly, less than half the students acknowledged using it as a learning strategy. It was, however, commonly used for 'testing'.

4) Repetitive observation by putting up lists, such as the structures and names of organic functional groups and polyatomic ions, in a place where they would be constantly seen, was used by a few students, often for swotting just before the examinations.

Understanding

This was one of the more difficult sub-categories to assess since many of the phenomena associated with understanding are mental processes, and as such an in-depth explanation of them is outside the context of this study. What was important was to identify the strategies the students used to aid their understanding. Seven such strategies were used: *objectives, linking, finding alternative explanations, applying theory to the solving of practice exercises, grouping highlighting material,* and *revisiting study material.*

1) Objectives were regarded as a useful learning tool. Most of interviewees did not rely on the objectives given in their study guides but defined their own from assignments and past examination papers. The majority of students regarded these as a more reliable guide to what they were expected to know.

> Roger and Rhonda claimed they always defined objectives by looking through the assignments and in this way they could gauge the depth of knowledge the lecturer required. Phillip thought that assignments also helped in his understanding and when reviewing his notes, and Margot used past examination papers to set her objectives early in her studies, and thought that she probably based her notes on what was in the papers.

2) Linking was finding how the newly learned content fitted in and connected with already acquired knowledge. Most assumed that what they had been studying immediately prior would provide that starting point or base. This reinforced the view previously expressed that the students regarded chemistry as being highly hierarchical.

> As Rhonda said "*chemistry sort of builds up, as you go you've got to remember and have a comprehension of what went on before, you need to know about electrons before you know about bonds*". Richard related it to a snowball effect using a similar example of "*atoms then electrons*

> *then bonds then compounds then reactions*". Roger explained it as "*once your knowledge reaches a critical mass you just tack on ideas at the end*".

About half of the interviewees made some kind of effort to connect items of content together by making up diagrams and flowcharts to see the connections between topics.

> Steven claimed that he didn't deliberately try to build on material but was always looking to see where it actually 'fitted in'. He used the example of using covalent bonds in organic chemistry, which was studied in the ninth week of semester, but to understand this he had to refer back to week three when bonding was first introduced. Several others said they worked backwards and forwards through the study guides trying to make links.

3) Finding alternative explanations was an important strategy for understanding. As has been mentioned previously, most of the students obtained several different textbooks. One of the reasons for this was to find alternative explanations for concepts. The majority of the students consistently searched for definitions and explanations until they found one they could understand.

> Judith said "*If I couldn't understand the study guide I'd go to another textbook ... another, then section*." As Brent commented "*if I think there was something in the textbook that says it better then I'll note this down in my notes*". Greg liked different angles to "*illuminate something you haven't seen*".

4) Applying the theory to the solving of practice exercises was considered to be a very important learning technique for most interviewees and most used practice exercises of some kind to gain an understanding of concepts. Assignments and, less commonly, examination papers were also used as a source of practice exercises.

> Typical views were expressed by Margot who described doing exercises as "*pushing in*" the content and Mary who commented "*I use examples a lot and I find that by working through the examples and working through the problems I learn more than I do by reading the text*". Steven used worked examples in the text and made sure his notes contained the information to solve them.

This was particularly true for topics that the students found were conceptually difficult, especially those requiring mathematical solutions such as pH of acids, bases and buffers. Understanding of organic reactions was also achieved by doing multiple examples. In this case students were adamant that they wanted 'real' compounds, with 'real' names rather than generic examples. In particular, many students disliked the use of R to denote an undefined alkyl group. There was a slight preference for having examples throughout the text rather than at the end of topics.

5) Grouping (mentioned previously in memorising) is a learning strategy for concepts where related information is formed into small groups in order to learn it more efficiently. It is a strategy most of the students used, although many did not recognise it as such, as only a few deliberately went looking for patterns between content, most thinking that associations were obvious or would be referred to in the study material.

The act of summarising their notes, which was mentioned previously under note taking, was an example of grouping. This was not a passive activity, as the students needed to make decisions about what to include in their summary, that is, what keywords and concepts were important, and to make links between the topics.

Samantha and Simone thought that they could understand things better if they could put them into groups themselves. Brent liked to group content and look for patterns and both James and Steven made summaries and diagrams grouping items together.

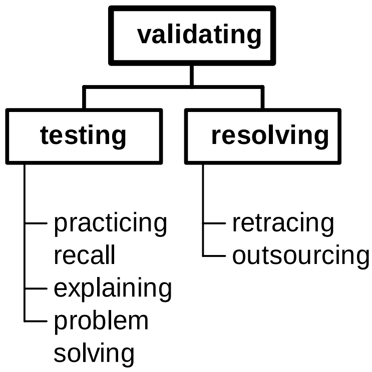
6) Highlighting material in their own notes, and less frequently in their study guides or textbooks, was used by most students to identify important passages or words that would act as a trigger for their memory. Generally, they wanted to be able to do this themselves as, when it was suggested that a list of key words at the beginning of each chapter would be useful, most felt that it would not really help them learn. As previously mentioned, chemical names, symbols and reaction equations were often highlighted.

7) Revisiting or looking back over study material had two dimensions. Most interviewees mentioned reviewing the material at regular intervals during the semester, and recognised that this was beneficial to their learning and should be done. Nearly all revised their material just before the exam.

Validating

Validating is the set of procedures that the learners use to determine how well they have retained their newfound knowledge. It is strongly related to studying, and many of the strategies involved are similar to, and practiced at the same time as, those in memorising and understanding. However, it is regarded as a different category, since validating occurs after the learning processes. Validating has two sub-categories referred to as *testing* and *resolving* (see Figure 3).

Figure 3: Strategies associated with the 'validating' category.



Testing

Most of the students interviewed agreed that they did test themselves in some way, and that it was an important strategy in their learning. Nearly all thought it was a good idea to test regularly through the semester, but the degree to which this was done varied considerably. There were three strategies identified with testing: *practicing recall*, *explaining*, and *problem solving.*

1) Practicing recall, as well as being used as an understanding tool, was considered as an important testing strategy.

2) Explaining was describing a concept to another person, often their partner. Students thought that if they were able to talk about a concept in a simple but clear way, so that non-chemists could understand it, then they had themselves understood it.

3) Problem solving was the most common form of testing, most often by answering the self assessment questions (SAQs) in the study guide and in the textbook, but also by attempting past examination papers. They were generally done as the students were going through the material, and were often attempted again before examinations.

One group had access to assessable online computer tests where they could get an immediate answer to a multiple choice or short answer question. Most considered it to be an excellent way of learning and testing. Although many did not like the pedantic nature of the computer, they also recognised that chemistry is often pedantic and that the difference of a single letter can be important, such as in the naming of organic compounds, pentene being a very different compound from pentane.

> Several students commented that, once they got over their initial disappointment when they gave a wrong answer in a test, they realised that they had learned a valuable lesson without being penalised greatly (there were 120 questions through the semester worth a total of 30% of the marks).

This view is not shared by on-campus students, which demonstrates the self-sufficiency of distance education students and their strong view that they are primarily responsible for their own learning. Similarly to recall, problem solving was used for more than one purpose. Apart from testing, it was also used when studying in order to understand the material, as discussed in applying theory, so it was difficult to separate these two outcomes.

Resolving

Resolving was the set of strategies the students used to solve any problems or shortfalls in memory retention following testing. Many of the strategies used in resolving are similar to those used in studying, but are different in that resolving is a short term strategy used, in the words of two students, "*to add pockets of information*" and "*to top up the larger pool of knowledge*" and as such is an irregular procedure, and not done in sequence like studying. Apart from those already discussed, resolving has two new strategies: *retracing* the appropriate sections of the subject, and *outsourcing.*

1) Once a lack of knowledge had been determined, the student needed to *retrace* the appropriate sections of the subject so that the missing parts could be fitted in. Often the students used a dictionary or a textbook glossary to fill in any perceived lack of knowledge. Several students used the exercises to identify and resolve problems

.

2) Outsourcing was necessary when the students could not find or understand material in their study guides. Prescribed and other textbooks were the next source. If these failed then a few would simply bypass the topic and let the information already gained age for a day or two. Using the university library was not popular since it took time, and in many cases a suitable alternative library was not available. Some students would use the Internet, but most were unsure of the accuracy of information obtained this way. Students who worked in scientific organisations indicated that the scientists at their place of work were a useful source. In most cases the final resort was to ring the lecturer concerned, but there was a reluctance to do this.

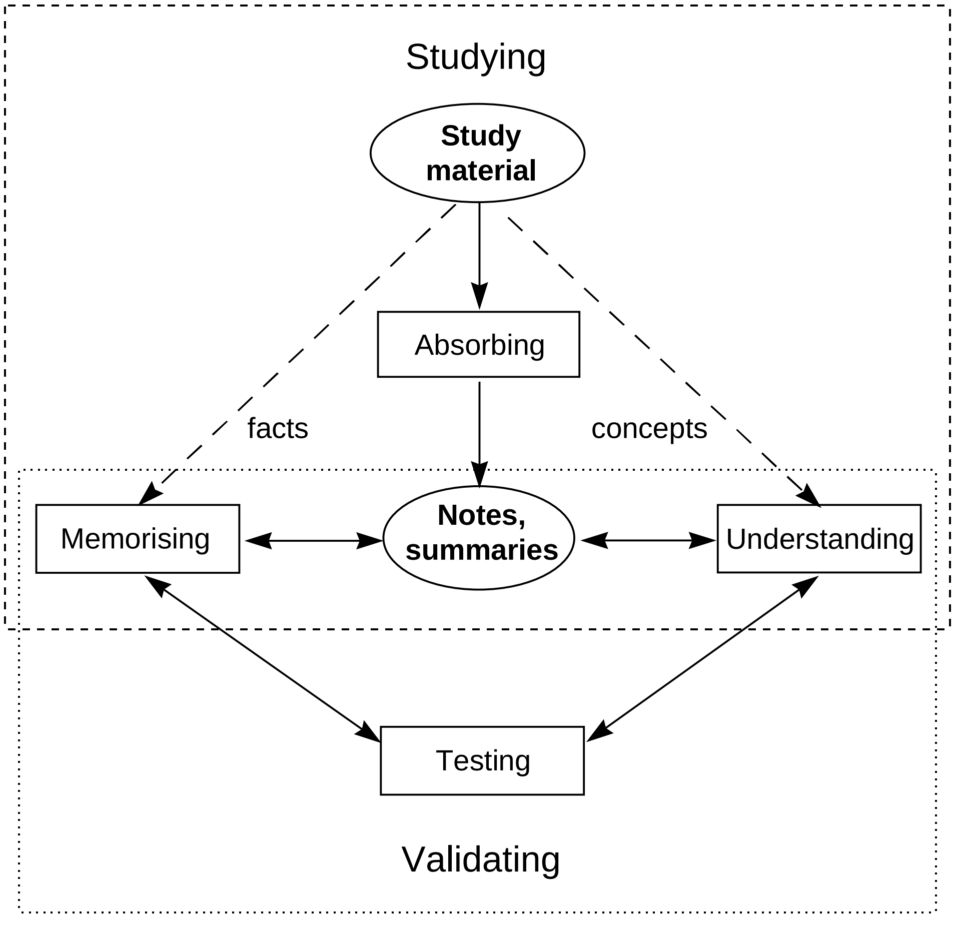
The learning model

The strategies employed by the students for learning from the study materials were very similar. The students studied sequentially, by going through the study guide page by page, using three distinct types of learning strategies, absorbing, memorising and understanding, which were based on producing their own notes from the study guides and textbooks.

The sequential nature of the learning process may have been due to the way the study guides had been written, but it was also the way the students expected to learn, that is, building up their knowledge by adding to their existing knowledge base and experiences. This coincides with the view that science is strongly hierarchical where advanced knowledge is based on previously learned material (Bennett et al., 1995).

This, and the fact that they produced their own notes, written in their own words, would indicate that the students were using a constructivist-cognitive model of learning where the learners construct their own meanings and are therefore actively participating in the learning process. However, in this case the preferred dialogue, which is considered so important (Garrison, 1993 and Jonassen et al., 1995) in this type of learning model, was mainly between the learner and the study material rather than with the teacher.

Figure 4: The learning model for distance education chemistry.



It has been suggested that chemical content can be divided into facts, concepts and rules, each of which requires a different set of strategies for learning (Middlecamp and Kean, 1988). Facts are statements about how the world is and how it is to be represented, and they cannot be determined or worked out they just 'are'; concepts are ideas about matter where each concept is related to other concepts, and rules are generalisations about how things behave or how they relate to one another. For example, a fact would be: 'glacial acetic acid is a colourless liquid at room temperature'. A concept would be 'an acid is a compound which donates a proton to another compound called a base'. A rule would be 'an acid cannot exist unless a base is present'.

The students were able to distinguish two different types of chemistry content: facts and concepts. They recognised that there were different methods for learning these, memorising strategies for facts and understanding strategies for concepts. However, students did not accept rules as separate entities, regarding them more as a subset of concepts, which could be learnt by doing examples (which is a strategy associated with understanding).

The way the students utilised the three types of learning strategies as they proceeded through the study material was reasonably straightforward, although it is important to note that all three processes were usually being carried out at the same time. The core activity, around which the other three revolved, was the making, and remaking, of notes and summaries. In many cases the notes ended up as lists of key points or memory triggers, which could be readily memorised.

Absorbing strategies were generally used first, and students typically read sections of the study guide several times, making notes as they went. After this the content was recognised as facts or concepts to enable the appropriate learning strategies to be utilised. The process of deciding whether a particular content was a fact or a concept was not a conscious deductive activity by the students, but appeared to be an inductive decision where the student claimed they could 'just recognise' what the content was. Overall, the interviewees were accurate when asked to nominate whether sections of content were facts or concepts.

Generally, the memorising and understanding strategies were applied mainly to the student-prepared notes and summaries, although students would sometimes return to the study guide for this. A few interviewees did not use the notes at all, but applied their memorising and understanding strategies directly to the study guides and textbooks.

Once the studying process had been carried out, students then validated their knowledge by testing themselves by various means, and then attempting to resolve any problems by returning to the studying process and reapplying some of the memorising and understanding strategies. There was a very definite hierarchy involved in resolving problems. First the student would consult the study guide, then the textbooks, sometimes other sources of information such as the library and then, as a last resort, the lecturer.

The memorising, understanding, testing process was a limited cyclic one, that is, students would (say) memorise, test, then memorise again, and test, a few times until they considered they had either retained the knowledge or could not afford to spend any more time on that topic.

That this model was a successful one is indicated by the success rate of the students interviewed. Only three failed their subject and about one-third of them were in the top 25%.

Implications for electronic delivery

It would appear from this study that for a computer based learning program to be immediately acceptable to the current distance education chemistry students it would need to follow the pattern of a book in its design. Only such a pattern would be able to match the existing strategies of these students. In particular the key strategy of making notes and summaries is one that could be done better on the computer, due (rather unexcitingly) to its word processing capabilities. However, this would depend on the students being able to learn as well from the computer screen as from the printed page, a key question that was not addressed here.

One of the most significant advantages of such a computer program would be the linking of relevant concepts together to promote the learning process of building up of knowledge. Whilst the students expect this to be a linear process, and it is designed into the study guides as far as possible, the learning of chemistry is not, and cannot be, entirely sequential. It is inevitable that at some time in the learning process students will need to revisit a previously studied concept. In this case a glossary may be all that is needed, otherwise the student may need to retrace the original material (a validating strategy). For instance, the concept of ionic and covalent bonding is introduced early in the semester following on from a discussion of electronic structure. The study guides then concentrate on ionic bonding, inorganic compounds and reactions, equilibrium, acids and bases etc, which is a logical and linear progression. It is not until late in the semester that organic chemistry is studied and the students need to refer back to the original concept of covalent bonding studied several months before. Both operations can be done with the click of a button on the computer without the student losing his or her place in the learning program.

A further advantage of a computer program is in the presentation of exercises, problems and self-assessment questions, which can be embedded in the program and hidden to varying degrees until required by the student.

Whether or not the student will see these advantages, let alone be prepared to use them, is a vexed question. A previous study (Lyall and McNamara, 2000a) has shown that distance education chemistry students are reluctant to move out of their "zone of comfort" and use a different mode of delivery. The current study serves to reinforce this view. These students will need to be convinced that they can use their existing learning strategies and will not have to relearn how to study.

When the results of this study are integrated with those of the previous one on orientations of learning (Lyall and McNamara, 2000b), which was conducted on a similar cohort of students, some interesting observations can be made. First is that the students are not interested in the interactive nature of the computer insofar as it can make use of non-linear teaching strategies. These might include, for instance, online tutorials, accessing the web or databases for information, or self-selection of concepts to be studied depending on their perceived knowledge (self-paced learning). Nor do they regard the graphical and motion capabilities of programs to be critical to their primary learning, as for example, Rasmol in which molecules can be rotated and manipulated to better show their bonding etc. To use these attributes would require the students to change their learning strategies.

This is not to suggest, however, that computer interactive programs using graphics and motion do not have a place in the learning program. Whitnell et al. (1994) espoused the use of multimedia in chemistry lectures because it allows the lecturer to portray complex chemical concepts and processes, particularly those which occur at the molecular level, by the use of computer animation, three dimensional graphics and video. Kirkwood (2003) pointed out that distance students recognise the benefits of having learning materials presented a in a variety of media. This was also shown in our previous study (Lyall and McNamara, 2000a) when a few students, who moved out of their comfort zone and used an alternative CAL program, which presented a basic course in organic chemistry, enjoyed their experience, all regarding it as an equal or better way of learning.

Any synchronous activity with instructors or other students, even when computer generated and therefore more likely to be accessible to a distance student, was rejected. Even non-synchronous communication, which involved other students (bulletin boards), was not popular as a means of solving academic problems, although they were used in a limited way for social contact. Even the more private email contact with the lecturer was used only as a last resort. This observation is in direct contrast to the widely held view that distance education students require interaction with their teachers (Boyle 1995; Lemmer et al., 1997; Garrison et al., 2001; for instance).

Most of the previous studies were conducted in disciplines in which social interactions are essential, such as business studies and teacher education. In science this may not be so important. However, it is suggested that a more important reason for this is that the students regarded the working out of their own problems as a very powerful learning strategy. In reality it is a set of strategies categorised under understanding and resolving. This explains a personal observation that computer regulated bulletin boards and discussion group activities are not popular with science students even when actively encouraged by the instructor by posting material such as problems and answers. If this material is used at all it is used by 'sleepers', students who read the discussions but very seldom make comments themselves.

Design of a suitable computer program

To overcome the reluctance of students to move to a new form of learning (CAL) the following approach is suggested. The computer program would present the major study material in a linear format giving written explanations and moving from screen to screen as in the printed study guide. The written text, however, would not necessarily be the same as in the study guides, since full advantage would be taken of the computer's ability to show demonstrations in both graphics and animation as appropriate, to support, but not replace, the textual information. The use of lists to summarise material in the text is recommended (for both electronic and printed study guides).

The computer program would have a facility where the students could write their own notes and summaries without exiting from the screen. The notes pages should also be able to be accessed in a linear way, that is, the students could follow the content from notes page to notes page without reference to the main text, if required. The ability to print out notes and to highlight text on the screen would be an advantage.

Specific objectives, and other resource material such as the Periodic Table, lists of functional groups etc. relating to the text, and worked examples of problems would be accessible from each screen.

A glossary of terms should be included with brief (one or two line) explanations of each term to be accessed from the main text by using a pointing device on the term itself to activate a hypertext link. Links would also be provided between the text and previous related text, or where appropriate, simpler and more basic explanations.

Wherever appropriate, problem exercises would be accessible from the main screen. The answers would be hidden and only accessed after the problem has been completed. If the student's answer is wrong they should be able to make a choice of repeating the exercise, revising relevant material through means of a hypertext link or accessing the worked answer.

A CAL program following this design would take advantage of most of the students' existing learning strategies and they would be less inclined to reject it on the grounds that they needed to learn a new way of studying. Furthermore, the program introduces new media such as graphics and motion, ready access to previous concepts and embedded exercises, which have the potential to enhance the learning of the students without interfering with their already established methods. That this can be done at the click of a mouse without the student leaving the main body of text may prove to be attractive to the student. However, satisfactory progress through the course would not depend on the student accessing this enhanced material.

Conclusion

This study has identified the important learning strategies used by distance education chemistry students, with the expectation that these could be used to improve instructional material. The implications of the study for the design of alternative delivery methods using electronic technologies are mixed. Whereas a computer based learning program would have some advantages over print, it would need to support the cognitive linear style of learning adopted by the students. It is suggested that a package containing printed notes, student selected textbooks, CAL, email and telephone communication would be a powerful educational tool which would satisfy most of the students present learning strategies and encourage them to adopt new ones which could be advantageous to their learning.

References

Bennett S., Metcalfe J., Ross S., Scanlon E., Thomas J. and Williams D., (1995), Opening up science: the teaching of science at the Open University, UK, in: D. Sewart (Ed.), *One world many voices: quality in open and distance learning*. The Open University, London.

Biggs J.B., (1993), What do inventories of student's learning processes really measure? A theoretical review and clarification, *British Journal of Educational Psychology*, **63**, 3-19.

Boyle R., (1995), Language teaching at a distance: from the first generation model to the third, *System,* **23**, 283-94.

Christensen C.A., Massey D. and Isaacs P., (1991), Cognitive strategies and study habits: an analysis of the measurement of tertiary students' learning, *British Journal of Educational Psychology,* **61**, 290-9.

Dhanarajan G., (2001), Distance education: promise, performance and potential. *Open Learning,* **16**, 61-68.

Garrison D.R., (1993), A cognitive constructivist view of distance education: an analysis of teaching-learning assumptions, *Distance Education,* **14**, 199-211.

Garrison D.R., Anderson T. and Archer W., (2001), Critical thinking, cognitive presence, and computer conferencing in distance education, *American Journal of Distance Education,* **15**, 7-23.

Gladieux L., (2000), Global on-line learning: hope or hype?, *Higher Education in Europe,* **25**, 351-353.

Hara N., (2000), Student distress in a web-based distance education course, *Information, Communication and Society,* **3**, 557-579.

Jonassen D., Davidson M., Collins M., Campbell J. and Haag B.B., (1995), Constructivism and computer-mediated communication in distance education, *The American Journal of Distance Education,* **9**, 7-26.

Kirkwood A., (2003), Understanding independent learners' use of media technologies, *Open Learning,* **18**, 155-175.

Laurillard D., (2002), *Rethinking university teaching: a framework for the effective use of learning technologies*, Routledge Falmer, London.

Lemmer E.M., Bergh A.M., van der Linde N., van Niekerk P. and van Wyk N., (1995). *Distance learners and their experience of text***,** Pretoria: University of South Africa, Institute for Educational Research.

Lyall R. and McNamara S., (2000a), Learning tool or pot plant stand? Students' opinions of learning from a CAL program, *Australian Journal of Educational Technology,* **16**, 126-146.

Lyall R. and McNamara S., (2000b), Influences on the orientations to learning of distance education students in Australia, *Open Learning,* **15**, 107-121.

Middlecamp C. and Kean E., (1988), Problems and that other stuff: types of chemical content, *Journal of Chemical Education,* **65**, 189-98.

Petrides L., (2002), Web-based technologies for distributed (or distance) learning: creating learning-centered educational experiences in the higher education classroom, *International Journal of Instructional Media,* **29**, 69-77.

Richardson J.T.E., (1994), Cultural specificity of approaches to studying in higher education: a literature survey. *Higher Education,* **27**, 449-68.

Rumble G., (2001), Reinventing distance education, 1971-2001, *International Journal of Lifelong Education,* **20,** 31-43.

Strauss A. and Corbin J., (1990), *Basics of qualitative research: grounded theory procedures and techniques,* Sage, Newbury Park.

Vidovich L. and Porter P., (1999), Quality policy in Australian higher education of the 1990s: universities perspectives, *Journal of Educational Policy,* **14**, 567-586.

Whitnell R.M., Fernandes E.A., Almassizadeh F., Love J.J.C., Dugan B.M., Sawrey B.A. and Wilson K.R., (1994), Multimedia chemistry lectures, *Journal of Chemical Education*, **71**, 721-5.