Using concept maps to develop lifelong learning skills: A case study

Author: Barbara Stäuble, Director R&D, Curtin University of Technology, Sarawak Campus

By building on a cyclic model of lifelong learning that includes self awareness, self management, meta-learning and self monitoring, this paper reports on attempts to introduce lifelong learning skills to a class of second year engineering students. The unit taught in this case study is Physical Electronics 203. Concept maps, student generated assessment criteria, group interaction and peer assessment were introduced to broaden students' learning experiences. A comparison of the feedback obtained through Unit Evaluation Questionnaires in two consecutive years shows a clear increase in the "Good Learning Scale".

Introduction

Lifelong learners are typically characterised as "self directed" (Merriam & Caffarella, 1999) or "self regulated" (Zimmerman, Bonner & Kovach, 1996). Garrison (cited in Merriam & Caffarella 1999, p. 300) presents a model of self directed learning that "integrates self management (contextual control), self monitoring (cognitive responsibility) and motivational (entering and tasks) dimensions to reflect a meaningful and worthwhile approach to self directed learning".

The model for lifelong learning developed by the author and used as the basis for the present work is an adaptation of Garrison's model (Figure 1).
As shown in Figure 1, lifelong learning is understood as a cyclic process with four key pillars:

- "Knowing the learner (Self awareness)" focuses on understanding the learner's prior knowledge, motivation for and attitudes towards learning (e.g., self-efficacy). The value system of the learner plays an important role in defining his/her identity. Candy (cited in Merriam & Caffarella 1999, p. 309) characterises autonomous learners as "those with a strong sense of personal values and beliefs." The identity of the learner is embedded into a socio-economic context, which will impact his or her commitment to learning at a particular moment in time (Knowles, 1980).

- "Planning for learning (Self management)" refers to the setting of goals and the development of a plan to achieve these goals. Houle (cited in Merriam & Caffarella 1999, p. 54) and subsequent researchers (Boshier, Morstain and Smart; cited in Merriam & Caffarella 1999, p. 54) have identified different typologies of learners, depending on their underlying motivation. The typology includes social relationship, external expectations, social welfare, professional advancement, escape/stimulation and cognitive interest. Tough (cited in Merriam & Caffarella 1999, p. 294) lists key decision points for self-planned learning projects, which include: "Deciding what detailed knowledge and skill to learn". "Deciding the specific activities, methods, resources, or equipment for learning", "Deciding where to learn", "Setting of specific deadlines or targets".

- "Understanding how to learn (Meta-learning)" describes the awareness that a learner has developed with respect to different approaches to learning (deep versus surface learning; rote versus meaningful learning) and different learning styles. James and Blank (cited in Merriam & Caffarella 1999, p. 209) "define 'learning style' as the complex manner in which, and conditions under which, learners most efficiently and most effectively perceive, process, store and recall what they are attempting to learn".

- "Evaluating learning (Self monitoring)" refers to a systematic analysis of all aspects of the learner's performance. "Self monitoring is synonymous with responsibility to construct

**Disclaimer:** The research materials are collated from web-based resources.
meaning ... [and] is very much associated with the ability to be reflective and think critically” (Garrison, cited in Merriam & Caffarella 1999, p. 300). Depending on the goals set initially, the outcomes can be of qualitative, quantitative or affective nature.

While the above pillars are of importance in any effective teaching and learning process, the main characteristic of lifelong learning is the reflective nature of the entire cycle.

**Physical Electronics 203 (PE203)**

The study presented here was performed with students of Curtin University of Technology, Sarawak Campus, majoring either in Electrical Engineering (EE), Computer System Engineering (CS) or Communication & Electronics Engineering (CE). The unit, Physical Electronics 203, was taught in 2003 and 2004 to 30 and 45 students, respectively.

The main goal of the PE203 unit is to develop an understanding of the workings, at a microscopic level, of devices such as diodes and transistors. Thus, the first half of the semester focuses on developing a model of the behaviour of electrons within a solid, which is then applied to explain the internal functioning of devices during the second half of the semester.

Understanding the behaviour of electrons in solids requires a wide range of novel concepts, both from quantum mechanics (Schrödinger equation, wave function, probability density, energy levels, etc) and solid state physics (energy bands, energy gap, density of states, Fermi-Dirac distribution, etc). The only prerequisite for PE203 is a first year unit called Structure of Matter 102, which introduces some basic concepts of modern physics and quantum mechanics. As a comparison, students majoring in physics learn the foundations of modern physics in Physics 102 (Semester 2, Year 1). This is followed by an introduction to quantum mechanics in Quantum and Statistical Physics 301 (Semester 1, Year 3), and finally "Solid States Physics 302" (Semester 2, Year 3).

While students majoring in EE, CS and CE are not expected to develop the same cognitive skills with respect to Solid State Physics as students majoring in Physics, it does not change the fact that a wide range of very new and often non-intuitive concepts need to be introduced and assimilated within a very short time frame to achieve the learning goals set by PE203.

Problems faced by students

Not surprisingly, PE203 students are often overwhelmed by the large number of new ideas, models and theories introduced in PE203 and fail to grasp the underlying relationship between concepts. To complicate matters further, the syllabus does not follow the recommended textbook chapter by chapter. Students are expected to locate relevant information from different sources such as textbook, lecture notes and reference books. This represents a new challenge for many of these second year students. Even though the Unit Outline for PE203 is comprehensive and contains, in addition to the learning goals, one and a half pages describing the topics to be covered during the semester, many students are concerned by the lack of an obvious structure underlying the unit. This is perceived as a lack of clarity in the goals set for PE203.

As a consequence, the "Clear Goals and Standards Scale" on the Unit Evaluation Questionnaire (UEQ) distributed to PE203 students in 2003 reached only an average of 45%. Less than half the

*Disclaimer: The research materials are collated from web based resources.*
students (48%) agreed to the statement "I usually had a clear idea of where I was going and what was expected of me in this unit". Feedback to open ended questions included remarks such as:

- There should be a clearer syllabus
- Have a better outlined syllabus
- More systematic lectures, eg. follow the unit outline so that we know which chapter we are learning.

In the context of the lifelong learning model presented in Figure 1, the above feedback indicates a lack of self management skills: Students do not possess the ability to set goals and, as a consequence, are not able to plan how to achieve these goals. Furthermore, in 2003, only 52% of students agreed to the statement "When I become confused about something I'm reading for this unit, I go back and try to figure it out". This can be linked to low levels of intrinsic motivation, indicating that the learners have not identified what factors would contribute to their self actualisation.

Overall, the "Good Learning Scale" of the Unit Evaluation Questionnaire distributed in 2003 only reached 52%, thus pointing at the need for developing meta-learning skills among students.

Objectives of this study

Based on the realisation of the problems faced by PE203 students in 2003, it became clear that a different instructional approach was required to strengthen the cognitive structure of these students and promote good learning. As a consequence, teaching strategies implemented in 2004 were enhanced with concepts maps, both in lectures and selected tutorials, with the aim of improving students' perception of their learning.

Background information

Concept mapping and advanced organisers

As a strengthening of the internal cognitive structures of PE203 students seemed to be needed, concept maps were introduced in 2004. Concepts maps were first developed in the 1960s by J. D. Novak (Lanzing, 1997) from Cornell University and refined more recently by Nowak and Gowan (Hassard, 2003). Concept mapping is a technique for providing a graphical representation of concepts and links in between them. A related and well known technique is Mind Mapping, which was invented (and copyrighted) by Buzan. As described by Buzan, "a mind map consists of a central word or concept, around the central word you draw the 5 to 10 main ideas that relate to that word. You then take each of those child words and again draw the 5 to 10 main ideas that relate to each of those words." (Lanzing, 1997).

Both concept mapping and mind mapping are based on the learning theories of David Ausubel, who contended, "the most important single factor influencing learning is what the learner already knows" (Ausubel, 1968). In his subsumption theory, Ausubel states that for meaningful learning to occur (as opposed to rote learning), new material must be related to relevant ideas in the existing cognitive structures of the learner. "Learning is meaningful only when it can be related to concepts that already exist in a person's cognitive structure" (Merriam & Caffarella, 1999). To
allow cognitive anchorage to existing concepts and provide necessary mental scaffolding, Ausubel encourages the use of advanced organisers. As discussed in Bowen (2004), Ausubel "emphasises that advance organisers are different from overviews and summaries which simply emphasise key ideas and details in an arbitrary manner. Organisers act as a 'subsuming bridge' between new learning material and existing related ideas."

While Ausubel specifies that his theory applies only to reception (expository) learning, Brunner (1965) emphasises that learning involves "three almost simultaneous processes: (1) acquisition of new information; (2) transformation, or the process of manipulating knowledge to make it fit the new tasks; and (3) evaluation, or checking whether the way we have manipulated information is adequate to the task." Thus, according to Brunner, the acquisition, processing and evaluation of acquired knowledge by the learner are key to a successful learning experience.

**New approach to teaching PE203**

**Lectures**

At the start of each lecture a concept map was developed interactively with the students, by means of a series of questions and answers. The goal of the concept map was to identify the path to be followed to progress from known models (eg. "electron in the box" or "electron inside the hydrogen atom") to more complex models of solid state physics (eg. "many electrons in a solid").

Having clarified the aims of the lesson, the lecture proceeded with a PowerPoint presentation introducing the most important concepts, slide by slide. As it was felt that this "linear" method of introducing new material did not lend enough emphasis to the relative importance of and linkages in between concepts, a second concept map was used during the lecture. This second concept map was more detailed than the first one and was developed with the input of students, on the whiteboard and in parallel to the PowerPoint presentation.

At the conclusion of the lecture, students were asked to study the map and point out the concepts that corresponded to revisions of previously studied material, those that were newly introduced, and the links between them. Students were then given information on additional reading material relevant to the topic studied.

**Assessment**

Bruner, whose focus is more on discovery learning rather than expository learning, states that discovery is "in its essence a matter of rearranging or transforming evidence in such a way that one is enabled to go beyond the evidence so reassembled to additional new insight" (Bruner, 1965). It is to allow this linkage between acquisition and processing of knowledge that a tutorial session focussing on the creation of a "Master Concept Map" by students was held. The tutorial session was scheduled after completion of the first half of the 2004 semester. Students were organised into groups, provided with a large blank poster and asked to compile a "Master Concept Map" (also called "Mega Mind Map" in what follows) that linked all significant concepts Introduced in the first half of the semester. The tutorial session was structured as follows:

1. Students were grouped by the lecturer according to months of birth;

Disclaimer: The research materials are collated from web based resources.
2. During the first 10 minutes of the tutorial, students were prompted to define the criteria against which their work would be assessed. After some brainstorming, students agreed on a marking scheme, which typically included accuracy of the mind map, comprehensiveness, correct relationship between concepts and creativity. Requesting that the students define their own criteria and goals was aimed at developing their self management skills.

3. Students were then given one hour to design a Mega Mind Map within their groups (Figure 2a). The collaborative aspect of this task was aimed at helping students to understand how their peers learn, which would eventually result in a better understanding of their own learning.

4. After one hour, students were requested to evaluate the Mega Mind Maps developed by their peers and to justify their feedback (Figure 2b). The mark for each Mega Mind Map was an average of all marks awarded. A critical analysis of the work of others was seen as a first step to developing self monitoring skills.

5. Students were then allowed to take their concept maps back home, together with the corresponding peer assessment, and were asked to hand in a revised version within a week's time. An example of a final Mega Mind Map is shown in Figure 2c.

6. Each group of students was asked to make an appointment with the lecturer who provided them with feedback on the final version of their Mega Mind Map. The feedback provided focussed on accuracy of the mind map, comprehensiveness, correct relationship between concepts. Typically, each feedback session would last 10-15 minutes.

(Figure 2(a): Mega Mind Map tutorial for PE203 students. Students are seen working collaboratively on developing a concept map that will provide an overview of the topics covered in the first half of the unit.)

Disclaimer: The research materials are collated from web based resources.
Reflection on the effectiveness of the new approach

Lectures

Disclaimer: The research materials are collated from web based resources.
The concept maps introduced in the teaching of PE203 in 2004 are based on Ausubel's principle of "meaningful learning". The use of concept maps is grounded in cognitive learning theories, whereby the locus of learning is internal cognitive structuring and the role of the teacher is to structure content of the learning activity (Merriam & Caffarella, 1999).

Feedback to open ended questions of the Unit Evaluation Questionnaire (UEQ) distributed to PE203 students in 2004 included the following remark: "The explanation is very, very clear. Helps to motivate the students to study and learn this unit. Basically, the interest were built up during the study period".

Thus, the introduction of concept maps in PE203 resulted not only in intrinsic motivation, but also in the building of a cognitive structure by the learners.

According to Smith (1982), "learning how to learn involves possessing, or acquiring, the knowledge and skill to learn effectively in whatever learning situation one encounters". Exposing students to concept maps as a possible form of advanced organisers should have contributed to the development of meta-learning aimed at:

- Clarifying the aim of a unit in general and each lesson in particular;
- Making the organisation of new material explicit;
- Making logical order of learning material explicit;
- Allowing students to establish a link between old and new concepts;
- Emphasising the relative importance of each concept;
- Promoting student engagement in meaningful learning activities.

Whether these goals were achieved will be discussed in the following paragraphs.

**Assessment**

In their report on "Assessing Learning in Australian Universities", James, McInnis & Devlin (2002) state:

The educational benefits of students working cooperatively in groups are well recognised. Among other things,

- studying collaboratively has been shown to directly enhance learning;
- employers value the teamwork and other generic skills that group work may help develop; and
- group activities may help academic staff to effectively utilise their own time.

Disclaimer: The research materials are collated from web based resources.
James, McInnis & Devlin proceed by listing common areas of concern in group work, which include lack of perceived relevance and clear objectives, inequity of contribution, and overuse. For group work to be effective, specific guidelines must be given by the facilitator/lecturer focusing on group membership, roles and responsibilities within the group, scheduling of group meetings and defining group processes. In the case of the Mega Mind Map tutorial, the different aspects of group interaction seemed to have functioned well, leading to an atmosphere of constructive interaction between peers, as illustrated in Figure 2.

Peer evaluation of assessment was introduced as it was seen to have following advantages:

- Getting the students to identify the criteria that are relevant for assessment;
- Encouraging a sense of involvement and responsibility on part of students (James, McInnis & Devlin 2002);
- Helping students to develop skills in independent judgment (James, McInnis & Devlin 2002);
- Providing experience parallel to career situations where group judgment is made (James, McInnis & Devlin 2002).

In general, none of the disadvantages listed by James, McInnis & Devlin (2002) with respect to peer evaluation (ie. increased workload for lecturer, student friendships influencing assessment, system perceived as unfair by students) seemed to have had a major impact on the Mega Mind Maps tutorial.

However, one of the drawbacks of the peer evaluation was a lack of critical analysis by the students resulting in a very homogeneous assessment of the work performed by their peers, despite clear variations in quality the submitted work. The causes for the lack of clear discrimination between good and poor performance could have had the following roots:

- The students are not used to peer evaluation, are cautious about its impact and do not want to expose their peers; or
- The students have difficulties in judging the quality of the work done, despite having set the criteria themselves.

More focus needs to be given in future to this particular aspect of peer evaluation. This is of paramount importance as the ability to evaluate peer performance is directly linked to the ability for self evaluation, which in turn is a critical aspect of becoming a lifelong learner.

**Comparison of Unit Evaluation Questionnaires in 2003 and 2004**

Figure 3 provides a schematic overview of student feedback obtained through Unit Evaluation Questionnaires in 2003 and 2004.
While the "Good Teaching Scale" remains unchanged at 85% in 2003 and 2004, a clear increase is observed in the "Good Learning Scale" (from 52% in 2003 to 71% in 2004), and the "Clear Goals and Standard Scale" (from 45% in 2003 to 60% in 2004).

These results seem to indicate that the new instructional approach was successful in developing meta-learning as well as self management skills among students.

Interestingly, the "Overall Satisfaction Scale" also increased dramatically from 71% in 2003 to 94% in 2004. Considering that external factors linked to the "Good Teaching Scale" remained constant at 85%, it appears that this increase in the "Overall Satisfaction Scale" is linked to factors that are inherent to the students themselves, such as eg, intrinsic motivation. This result seems to point towards increased self awareness of the students.

**Conclusion**

Overall, it can be said that the introduction of concept maps, combined with group interaction, student generated assessment criteria, and peer assessment, has provided students with a rich learning experience.

The strengthening of students' cognitive structure resulted in a better understanding of the goals of the unit, which in turn allowed students to improve the planning and self management of their learning.

The exposure to concept maps as advanced organisers enabled students to develop new learning strategies. Similarly, group interactions allowed students to experience their peers' approaches to learning. Both cases contributed to fostering meta-learning skills.

Student generated assessment criteria and peer assessment were critical in promoting self monitoring skills. As discussed above, the students in this case study lacked the ability to clearly

---

_Disclaimer: The research materials are collated from web based resources._
discriminate between good and performance. Hence, more emphasis will be required in future classes to encourage the development of this important skill.

Last but not least, the increased overall satisfaction with the unit, as reported through Unit Evaluation Questionnaires, is interpreted as an increase in the level of intrinsic motivation and self efficacy experienced by students, thus supporting their self awareness skills. In conclusion, the cyclic model for lifelong learning used as the foundation for the work presented here is found to have contributed positively to the development of the corresponding skills among students in this case study.

Acknowledgment

The author thanks Frank Sheehy for his guidance and lively discussions that lead to this work.

References:


Disclaimer: The research materials are collated from web based resources.