

The enlightenment of science education in Western universities

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Abstract

Three main science education theories in the West are introduced; these are behaviourist, developmentalist and constructivist theories of learning. In addition, there are six student-centred teaching strategies to be discussed. Both the theories and strategies are used to foster deep level learning approaches and lifelong learning skills.

Key words: Science education theory, student-centred, teaching strategies, deep learning, lifelong learning skills.

Introduction

Three Main Science Education Theories in the West

Behaviourist theory is the traditional approach to teaching Science. It ensures mastery of each step before going on to the next, using practice, examinations and many examples to do this. If mastery is not demonstrated, then we take them back to a previous step and work through it again, which is a learning loop.

A behaviourist approach to teaching and learning in Science is very boring for the learner. It's just a list of things that are hard to remember. You can make people remember things by repetition, practice and testing, but you can not make them understand it. At best it is only surface level learning. The most important things we learn are those things we remember when all the facts have been forgotten.

Quality teaching should be aimed at promoting deep level processing of information in the mind of the learner. The developmentalist view sees learning as the process of developing a learner's personal schema towards a more complex and sophisticated conceptual structure. That is concept mapping. Concept mapping might identify and develop networks of ideas in the minds of students. That is, concepts change teaching. Concepts changes learning.

The third view on teaching and learning in Science is 'The Constructivists'. This view sees the university teacher's job as assisting students to construct new meanings. There are three main principles of Constructivism.

1. The learning outcomes of any teaching depend not only upon the teaching you do, but also on the knowledge, purpose, motivations and beliefs that the learners bring with them to the classroom.
2. Learning is an active process in which the learner must be actively involved.
3. Learners have the final responsibility for their own learning. Responsibility for learning is the learner's, not the teacher's [1].

To sum up, different theories are of equal importance and of equal use, but the major theoretical development is a greater awareness of, and a move towards, the constructivist perspective and view of how people learn science.

'Learning is chaos,' said Richard Feynman, the Nobel Prize holder in Physics. 'There is no "one-way" that people learn Science. All students are different. Therefore there is no "one right way" to teach it. Learning is best when it is the result of a real life experience and can be applied to the real world.' [2].

So the teachers' responsibilities are:

1. the curriculum: what we teach;
2. the teaching strategies used: how we teach it; and
3. the learning context: Relationships, motivation, attitudes to learning, atmosphere and the overall nature of the Science learning experience.

There are lots of strategies to achieve quality learning, only six of them are discussed here.

Six new teaching and learning strategies

Predict-observe-explain (POE) strategy

Giving a lecture is the most frequent method we utilise in teaching, so introducing some changes in it is most essential. We can use the strategy of POE, that is Predict-Observe-Explain [3]. For instance, we teach gravity in a Physics class. The following one is likely the best amongst a range of methods.

At first, let students make predictions. When two metal balls with different weights fall down at the same time and from the same height, which one hits the floor first? Students may generate three different assumptions. Then, three to five people in peer groups discuss and argue them. One person in a group is required to give their answer. In this case, the teacher demonstrates the experiment with the signal: ‘Ready-steady-go!’ Impact. You finally explain why.

Using this strategy, the question will become very interesting and challenging. Nobody can fall asleep or feel bored. On the contrary, they become active. As the result, the demonstration as well as the explanation will be fixed in their brains. Here, the processing of information is through POE strategy, not by memory. So this strategy should work for deep level learning.

Deep level teaching and learning approaches

Deep learning doesn’t depend on what they remember, but on what they really understand. This is directly related to the system of assessment of students. Assessment drives learning. Suppose that most content in an examination required students to memorise lots of things, such as formulas and principles. This kind of evaluation would only drive students to surface learning. After examinations, they might forget everything.

So the shallow approach is what students do in order to pass the examination, while the deep approach is used when students try to understand the subject matter. I observed the questions designed in students’ examination paper in the School of Physics on the library’s web site in The University of Sydney. The formulas were given out to students in the examination. Usually, students need to not only give the answers but also write down the reasons. This kind of assessment can encourage students to deep learning.

Talking in a lecture for two hours is just like spoon feeding, and constantly providing correct answers may well work against the skills needed to become lifelong learners. This is because it makes students passive recipients of information, spoon feeding them and not making them active seekers after knowledge and information. So when our mentor Professor Tim Bedding quoted ‘Content is the enemy of understanding. Too much content encourages surface learning’, it really makes sense.

Concept mapping

Concept mapping is a technique used for representing knowledge graphically. Knowledge graphs are networks of related concepts and ideas that are interconnected [4]. For example, Figure 1 is the concept map of ‘Imperfection in Crystals’ in the course on Crystallisation.

There are three main types of imperfection: point, line and surface. Point defects are divided into five kinds: substitutional impurity, vacancy, interstitial, Schottky imperfection and Frenkel imperfection. However, these are interconnected. Schottky imperfection is a pair of vacancies. Frenkel imperfection is a single vacancy and a single interstitial.

By the map, we can easily master the relationship between different concepts. Otherwise, they are easily confused. Besides, concept mapping integrates the separate knowledge into a complete cognitive understanding.

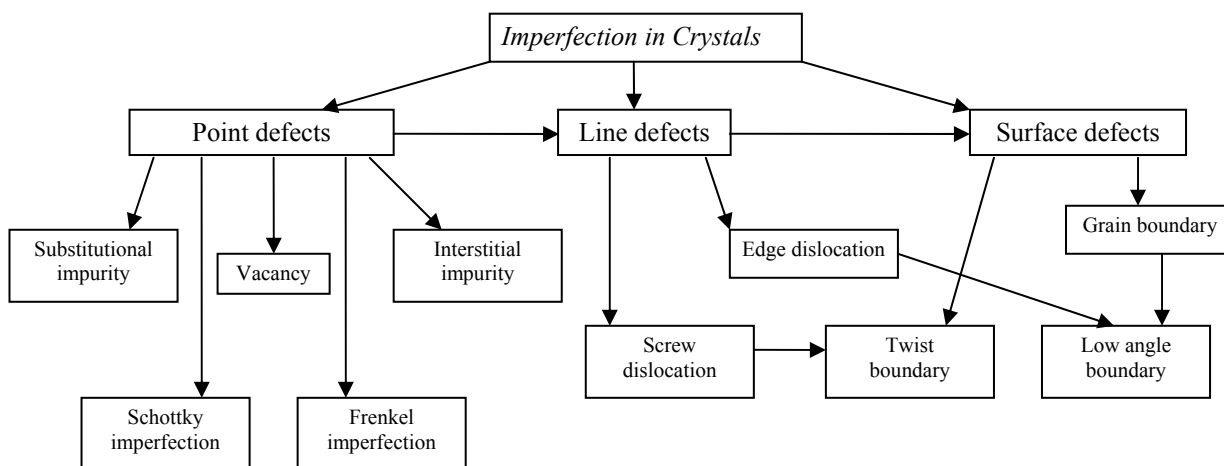


Figure 1. The concept mapping of *Imperfections in Crystals*

E-learning

There is a growing awareness that e-learning activity needs to be embedded in the learning and teaching system at the university. E-learning is influencing students' learning in the Faculty of Science in The University of Sydney. The survey of undergraduate science students in 2005 showed that 80% of students thought the resources on The University of Sydney web sites (*WebCT*, degree course sites, faculty sites) support their learning [5]. An example is shown in Figure 2.

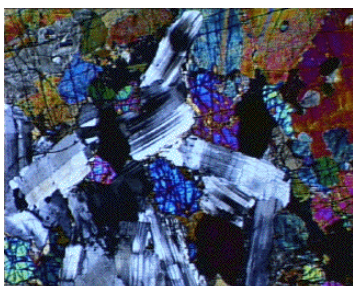


Figure 2. Thin section in cross-polarised light

<http://www.odp.usyd.edu.au/clarke04/hyperpetmag/Datafile/HYPETMAG.htm>

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By linking to the above pictures and function keys below on the web pages [6], you can make the pictures rotate and produce correspondingly different phenomena under plane light and cross-polarised light, respectively. However, the pictures in the textbook can't be used in this way.

Problem based learning (PBL) strategy

Let us make an example of PBL [7] in the course *Crystallisation*. First, we tell a true story about the purple crystal necklace I bought in India in 2001. I preferred the deeper purple one. However, the deeper the purple colour is, the much more expensive it is. Then the problem is if we grow the crystal how can we make the purple colour of crystal deeper?

Let our students use the knowledge and skills they learned in the context of study to solve the problem. In this case, the problem is taken as an initial challenge and motivation, the teacher becomes a coach, and the students become active problem-solvers. Opportunities for combining conceptual understanding of crystallisation with critical-thinking skills occur when the students encounter the real-world applications. There is great diversity of ideas generated by the groups to solve the crystallisation problem and to design their own experiments. This reinforces the idea that there are a variety of ways to solve the same problem. This will help students build an integrated and coherent view of the crystallisation world. Group work is a critical part of this approach, reinforcing the fact that all science is now collaborative in nature, and peer reviewed. They should analyse, synthesise and evaluate rather than simply define and explain. Group work requires that students not only know the answer but also have to explain it to others. Students will achieve a high level of understanding of the crystallisation principles [8].

Nonverbal communication

Last but not least, we use body language to reinforce meaning. This is emphasised by our English teachers, who also act a good example in this aspect. Being a teacher is just like an actor on the stage. A good actor must know how to absorb the audience's attention. Also, a good teacher must have some strategies to interact with the students in her classes [3].

Although nonverbal communication can stand alone, it frequently works hand in hand with speech. Our words carry part of the message, and nonverbal signals carry the rest. Together, the two modes of expression make a powerful team, reinforcing, and clarifying each other [9].

For example, when Professor John Hearn gave us the lecture about animals, he put his two hands into a circle in front of his stomach while talking of the pouch of Kangaroo. At once I knew what the pouch means, even if I never knew this word.

Therefore, if we want to establish credibility with listeners, we also need to manage four aspects of our nonverbal behaviour: eye behaviour, gestures, posture and voice [10].

Conclusions

Six teaching strategies have been discussed in this paper, they are:

1. predict-observe-explain strategy;
2. deep level teaching and learning approaches;
3. concept mapping;
4. e-learning;
5. problem-based learning; and
6. nonverbal communication.

All the above are student-centred strategies. All the strategies are used to foster deep learning approaches and lifelong learning skills. If our students can master the lifelong learning skills, they can not only do Physics, but also other things successfully in the future.

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