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Although engaging students in the learning process is a daunting task, it is necessary if we want to teach students thinking skills that will help them to be critical thinkers and independent learners. This issue of CDTL Brief *on* ***Engaging Students*** *discusses the importance of engaging students in the process of teaching them thinking skills.*

Teaching Students to Think: A Matter of Engaging Minds

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Thinking skills are valued in all fields. Due to my background in engineering, I will motivate the need for incorporating ways to help students acquire and develop thinking skills into our curriculum by highlighting the rapid changes in chemical engineering. Chemical engineers have witnessed a paradigm shift in the philosophy of manufacturing organisations over the last decade. With dwindling profit margins from commodity products—thanks to increasing global competition—companies realise they have to remain attractive to customers and investors alike by offering differentiated/niche products and becoming more customer-centric. Thus, business growth and profitability are now tied to products and services instead of manufacturing processes.

So, what does the transition from *capital intensive* to *knowledge intensive* mean to universities? Employers will no longer seek people who only have the technical expertise but lack the *thinking skills* that characterise inventors, innovators and technology managers. This translates into a definite and growing need to explicitly teach students to think like inventors, innovators and technology managers. Are we not already teaching our students to 'think'? Yes, we are. However, is it possible to do more and do it more consciously?

Before we examine some possible ways to help students acquire and develop thinking skills, it is worthwhile understanding the kind of thinking skills discussed in this article. Thinking skills, as identified by researchers include critical thinking, creative thinking, lateral thinking, parallel thinking, interpretive thinking, problem solving and so on. As there are significant differences as well as overlaps between them, it is difficult to determine which of these thinking skills are more important. As one would expect, a combination of the above thinking skills may come in handy for a particular situation. However, can thinking skills be taught? Fortunately, research has shown that it is possible for students to acquire thinking skills in the classroom through activities, project work, problem-solving exercises and so on.

"To discern the truth in every thing, by whomsoever spoken, is wisdom" (Thiruvalluvar, circa 100 A.D.). This statement characterises the core idea behind *critical thinking*. Students think critically when they understand and evaluate (according to some specific criteria) an entity (e.g. a book, research article, artwork) using domain knowledge, available evidence and logical arguments. Other activities such as intuiting, clarifying, reflecting, connecting, inferring and judging can also be used to evaluate claims, ideas and policies. Critical thinking is therefore judgement-oriented, analytic, objective and convergent in nature. Engineers use the term *problem solving* in place of critical thinking because the basic skills required for both critical thinking and problem solving are the same.

Creative thinking is based on the premise that the best way to get a good idea is to get lots of ideas. Thus, it is generative (examines possibilities), lateral, divergent, subjective and reserves judgement until the critical evaluation step that will come in later. Creative thinking emphasises possible ways of solving a problem, not the implementation of a particular solution. However, the creative process is not a single stroke of genius as it is often thought to be. During the process, one's thinking could be misdirected, wrong inferences could be made and failures could happen. Despite these risks, creative thinking results in discovery or invention for those who are curious, patient and persistent. In addition, individuals with healthy self-confidence, constructive discontent with the status quo, ability to interact with peers intellectually and a willingness to acknowledge and learn from errors, possess traits that can lead to creative achievements. Creative thinking techniques can be regarded as mechanisms that help the brain move from a local optimal solution (owing to limitations in knowledge, self-imposed constraints and so on) to possibly one or more globally optimal solutions.

Lateral thinking uses random stimulation, humour, brainstorming and even irrelevant information to move from standard ideas to new and possibly improved ideas (de Bono, 1990). Though it focuses on the perception aspect of thinking, lateral thinking leads one to think across different domains, helping one to examine a problem from many different perspectives. The result is a rich bag of ideas from which a preferred solution can be implemented after critical evaluation. On the lighter side, researchers have claimed that sleep stimulates lateral thinking (Wagner, Gais, Haider, Verleger & Born 2004).

Parallel thinking is a way of cooperative or coordinated thinking as opposed to adversarial thinking. All parties think in parallel (i.e. there may be no agreement and the overall direction could keep changing with time but everyone thinks in parallel with the rest of the group members). Once all the ideas including contradictions are laid out in parallel, a solution is constructed for the problem at hand.

Finally, *analogical thinking* involves mapping of one set of ideas onto another. For example, Ernest Rutherford used the solar system to understand and explain the atomic structure by mapping the idea that planets revolve around the sun onto the atom and argued that electrons revolve around the nucleus. Analogical thinking can be useful in conducting experiments and designing engineering systems by mimicking nature.

We can help students acquire or develop thinking skills by either incorporating activities, project work and exercises into existing modules that require students to think or teaching thinking skills as a separate module. Though it is still not clear which of these approaches is better, it takes time (several months) for students to acquire and develop thinking skills. Since the methods used to teach thinking skills to students are likely to be unconventional, a significant amount of faculty commitment (throughout the curriculum) and support from academic administrators would be essential. Students must be provided opportunities to explore and express opinions, analyse controversial topics from different viewpoints and use logic to justify their conclusions. The quality of faculty-student interaction also has a powerful impact on the students' ability to engage in critical thinking.

Project work and open-ended exercises can also engage students in higher order thinking. In the case of engineering departments, capstone design projects and dissertation projects serve this purpose. In these modules, the teacher takes the role of a manager or facilitator during one-on-one meetings, small group meetings and brainstorming sessions with students. Instead of seeing peers as competitors, students learn to collaborate and think laterally. Research projects that balance theoretical and experimental aspects of problem solving and projects of exploratory nature would lend themselves to creative and critical thinking more than narrowly constrained ones. Field trips may serve as a trigger for higher order thinking in certain domains. Another way to help students acquire and develop thinking skills is to get them to participate in activities (e.g. the NUS FSAE Race Car project, RoboCup) organised by national and international bodies. NUS students and project supervisors have won global laurels in these events that provided opportunities for students to exercise thinking skills and exhibit their creativity.

We can help students acquire and develop thinking skills even in large classes if concepts are introduced interrogatively rather than declaratively. Questioning during lectures can engage students effectively (Ip, 2005). However, students should be given enough time to respond so that their answers are the outcome of reasoned thinking rather than subjective reactions. Teachers who are under pressure to deliver content can invite students to respond by email or the IVLE discussion forum. Giving students credits based on their participation in the discussion forums can also be an incentive.

During tutorial sessions (given the advantage of smaller class size) the tutor can get students to discuss the questions among themselves. Unfortunately these days, some tutorials have degenerated into passive sessions where the tutor writes answers to tutorial questions on the board and students simply pen them down. Such passive tutorials represent wasted opportunities and efforts must be made to invigorate them.

Questions in assignments and exams should encourage students to come out with a variety of solutions and credit should be given for quality, originality and variety of ideas. Poorly-defined questions that lack essential data and those that require integration of ideas from different subject areas must be posed to students. The roles can be reversed as well. For example, students could be tasked to come up with a question for the final exam and the grade for this exercise will be based on the quality of the question. Felder (1985) found this role switching assessment difficult, but instructive and enjoyable for his students. Whenever feasible, faculty members should assign a take-home test or assessment where students can be tested in higher order thinking skills rather than a 2- or 3-hour final exam.

At NUS, faculty members are perhaps undone by large classes and the implementation of some of these and other ideas may seem daunting or impossible. In the spirit of the topic, I believe some hard thinking on our part can certainly enhance students' learning experience. Raise the stakes higher and our students will rise to the challenge.

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Academic Culture Online

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For the past two years (AY 2004/2005 and AY 2005/2006), a small team of people has been working on an online 1-MC module (PLG2005 "Plagiarism. NUS") intended to introduce students to academic culture. The module is nearly finished. This short article is a report on some of the problems we encountered along the way, and some of the partial solutions we found for them.

Not all our problems were connected with the module's virtual status. Academic culture is a topic none of us has taught before, and it took a good deal of discussion both for us to understand the norms, conventions and practices of academic culture, and to clarify what we wanted students to learn (the curriculum content). But it is the pedagogical and technological problems we struggled with in working in a new medium that might be useful to others embarking on similar ventures. Those are the focus here.

Navigation

One of our earliest difficulties concerned navigation, and looming behind that was the larger problem of the need to abandon some of our classroom preconceptions. The first version of the first lesson we produced had quite a linear navigational structure, largely because at some level, we were thinking of a lesson as something that occurs in a specific place over a specific time. We planned our first online lessons as we would plan a normal lesson, as a sequence of events, one leading from another.

The responses we received on this were mostly negative. Our first group of guinea pigs experienced the structure as constraining, and the lesson as boring. So, we opened the navigation up, and in doing so, changed the model of the lesson we were creating. Instead of a classroom lesson, it was more like a book, we realised, with a sequence that readers are always at liberty to reject. Or perhaps a closer analogy still is a loose-leaf folder, with some non-binding advice about sequencing.

Modification and Adaptation

Another problem that came in part from our experience as classroom teachers was the tension between flexibility and the finished product. A classroom allows constant, spontaneous modification of materials and approaches. If one thing seems not to be working, a classroom teacher can abandon it, adapt it, try something else or launch a renewed effort the next week.

This kind of modification and adaptation are more difficult when the lesson is created as a more or less finished product. The more elaborate the production and finished the product, the more difficult it is to change and adapt. Our eventual solutions were to use text for large parts of some lessons, since text can easily be changed, and to keep the highly produced and finished elements to a minimum.

Student Engagement

However, the most intractable problem was—and is—that of eliciting student engagement. Although it took us some time to work out exactly what should go into the module, we were clear from the start that any introduction to academic culture should reflect academic values by encouraging students to be engaged critics rather than passive recipients. We should practise what we were preaching, or rather, we should avoid preaching, and instead find ways of persuading students to think critically about topics as far as that is possible.

One solution we have adopted in parts of the module is the use of scenarios and choices. The student viewer watches a scenario which raises a reasonably complex problem—for instance, whether the existence of a plagiarist in a group project turns the whole group into plagiarists? Such a scenario is followed by two branches of choices (Branch A and B) which might lead to further choices, and at some point to feedback. The approach has the advantages of allowing us to ground problems in similar real-life situations and elicit reactions from students. Its limitations are two. Firstly, the number and nature of choices that can be offered are always predetermined and limited. To return to the classroom analogy, there cannot be the range and spontaneity of classroom discussion with the scenario approach. Secondly, there are necessary omissions in a branching structure of this kind. A student who chooses Branch A will miss what is in Branch B, unless the lecturer adopts the clumsy expedient of sending him/her back to try the other branch as well.

Another solution we have tried is the use of textboxes to elicit more complex responses. In the methodology lesson, for instance, we invite students to write suggested methodological approaches to problems or critique suggested approaches. This is both more open and more intellectually challenging than the choices approach, but it also has disadvantages. All the invitations come with a health warning that student's textbox response may or (more likely) may not get an answer from the team. We are working on the assumption that at some point, large numbers of students might access this module and others designed like it. Teacher reactions to all our students' musings will not be possible. So, what the textbox does is to invite students to send their ideas out into an empty, unresponsive space. The problems associated with that need not be elaborated.

Conclusion

Perhaps the most abiding lessons from the experience of working on the module are the following:

- Principles. It is important to keep educational principles alive, even while recognising that an online environment is different from a classroom. That different environment must still be used to make students think for themselves.
- Openness and resilience. If the module is a team effort, team members must be ready both to give and to receive what might euphemistically be called 'robust' criticism.
- Development time. It takes longer—a lot longer—to develop something for an online environment than it does to plan a traditional class.
- The expenditure of time, however, is repaid in the fact that an online module has a potentially huge audience. It can be of benefit even to students outside NUS and outside Singapore. Moreover, once the module is revised and fine-tuned, it does not require much effort is to run it for subsequent years. ■

Thinking Skills: A Discipline-centred Approach

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Are thinking skills innate or acquired? If they are acquired, what is the most effective way of learning them? Should universities mount general purpose pedagogical courses aimed at teaching students to think creatively and critically? These are some questions commonly asked when discussing the need to improve students' thinking skills. Over the past 20 to 30 years, there has been a growing number of pedagogical literature advocating that thinking skills are primarily acquired and that they should be taught in non discipline-specific courses that exist outside college curriculum. Ruggiero (1998) criticises traditional learning for its lack of explicit instructions on thinking (particularly in science and mathematics) and how a new era seems to be dawning where thinking instruction courses will become mandatory in universities and colleges.

In this paper, I shall argue against Ruggiero's view and propose that in science and engineering, thinking skills are best taught using a discipline-specific approach. I will also show how students can learn creative and critical thinking through discipline-specific examples (e.g. getting students to become familiar with great intellectual achievements within the discipline he or she is studying, or by being an apprentice to a successful and experienced mentor) where students can see thinking skills in action. In addition, I will draw on my own experience of teaching and research in science and engineering subjects, my service in inter-departmental/faculty committees that aim to promote better teaching and learning, and my participation in university level multi-disciplinary teaching programmes to show how students can learn to think creatively and critically through a discipline-specific approach.

In my view, there are definite reasons why general pedagogical materials and courses aimed at fostering or acquiring thinking skills are usually not popular amongst those from science or engineering backgrounds. In making this statement, I am drawing not only from my experience, but also the experience of my colleagues and students. I do not think this reaction indicates that those from science or engineering are not interested in teaching methods or thinking skills, but it suggests that problems across disciplines are solved differently.

Compared to subjects taught in the Arts faculty, science and engineering subjects place a greater emphasis on mathematical equations, logical proofs and experimental demonstrations. This is an important point to bear in mind when trying to develop science or engineering students' thinking skills. As experimental data and proofs are the cornerstones of any scientific discovery, it is much more important for science and engineering students to learn the basic laws of physics and how to apply them, than say receive instruction on how to develop, criticise and evaluate an argument. This is because progress in science and engineering is ultimately made through physical demonstrations as opposed to rhetorical arguments. There is no need to tell science and engineering students how they should go about evaluating their own ideas, how they should use certain principles and techniques of creative thinking or how they should persuade others (Ruggiero, 1998). Though written scientific communication is extremely important in science and engineering, it is not the ingenuity of an argument that counts. Experimental data is much more important than the art of persuasion. And, unless the required experimental data is present, no one needs to be persuaded.

On a more general note, there is something self-defeating in teaching a person to think creatively or critically using prescribed techniques and methods. Students only learn valuable lessons in creative and critical thinking when they are free to evaluate something for themselves. Just like a person cannot learn how to ride a bicycle simply by analysing how to do it, creative and critical thinking needs to be experienced rather than analysed. However, this is not to say pedagogical studies on thinking skills are of no value to science and engineering students; it remains largely as a subject students can pursue on their own. However, there may be a much greater synergy between pedagogical studies on thinking skills and disciplines such as Arts or even business.

In Kursheed (2005), I summarised my positive experience in teaching engineering fundamentals through a hands-on/historical approach using historical case studies to put students in the inventors' or discoverers' frame of mind. I also set assignments where students devised their own recreations of classic experiments using their own materials. I found this approach helpful not only for teaching engineering fundamentals, but also for getting students to think creatively and critically. History contains a wealth of ingenious experiments and unconventional ideas that are the results of creative thinking. By learning from both successful and unsuccessful historical examples, students can draw from these resources and learn how to be creative. Numerous great controversies and debates between past and present eminent scientists also constitute powerful illustrations of critical thinking in action (e.g. Einstein-Bohr's debate on the fundamentals of quantum mechanics). Besides learning from history, getting students to work directly under an experienced mentor in the field also allows them to see how the mentor exercises his/her thinking skills through the way he or she solves problems.

I am not proposing that we should keep to what we already have. But at least in the science and engineering context, thinking skills are best taught using a discipline-specific approach. In this article, I have shown how a hands-on/historical approach in science and engineering subjects and getting students to work under an experienced mentor can help science and engineering students develop thinking skills. While a discipline-specific approach might have been effective in teaching science and engineering students thinking skills, the initiatives and means used would vary according to disciplines.

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