A Problem-Based Thinking Programme

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Abstract

With the growing emphasis on a learning culture that is moving away from knowledge as discrete units to one that attempts to bridge conceptual gaps, curriculum design needs to develop in the same direction in order to enact learning scenarios that encourage integrated thinking and application.

This paper explores the structure of a Problem-Based Learning (PBL) thinking programme that has been designed to foster cognitive skills through problems. The problems engage students in building conceptual frameworks by evaluating their own cognitive and meta-cognitive processes, as well as support their learning in technological, mathematical and scientific domains. Key questions that are addressed are: What can be the pedagogical value of an integrated thinking approach to problem-solving? What can be the result of developing thinking skills in such a setting? How do students manifest their thinking via this integrated mode?

Through an examination of classroom dialogue, reflection journals and student surveys, an analysis of how an integrated problem-based thinking programme promotes conceptual and epistemic learning among post-secondary students will be shared.

Introduction

Thinking is a necessary part of our social and intellectual lives. Fisher argues that the "quality of our lives and of our learning depends on the quality of our thinking" (1998, 6). Thinking is part and parcel of being intrinsic to human development and that we gain pleasure from being exposed to intellectual stimulus and challenge.

Acquiring thinking skills has been increasingly emphasised in education, especially with forces in globalisation demanding its workers to be adaptable over and above being productive. Studies have recommended that students can no longer be "passive recipients of given information" and called for changes in pedagogical and learning environments that are geared towards "developing thinking skills and harnessing creativity" (Yip, 1997, 391). Moreover, the changes in society also imply that the static acquisition of facts cannot adequately prepare students for the world beyond the school environment. Instead, schools should prepare students to be able to learn and think for themselves. And to do this, they need to be able to think "critically and creatively at the highest possible level" (Fisher, 1998, 8). It is a skill that would make for our students being innovative and effective in the modern workplace.

At the Republic Polytechnic (RP), the objective of the Cognitive Skills and Problem Solving modules is to help our first-year students develop the essential thinking skills that will underpin their learning experience at RP. These thinking skills are the building blocks of students' success in their other technical modules, ranging from biomedical sciences to engineering. Complementing the introduction of a variety of thinking skills, the thinking skills modules also introduce students to a problem solving framework and help them to be confident about optimising this mode of learning in their daily interaction with knowledge building.

This paper explores the structure of a Problem-Based Learning (PBL) thinking programme that has been designed to foster cognitive skills through problems. It argues that thinking skills can be enacted through the process of solving problems and demonstrates through evidence collected throughout the process how thinking is encouraged and manifested in the classroom.

Critical thinking

What then is critical thinking and how do schools respond to the call to implement some form of critical thinking programme in their curriculum? This question leads us to examine the value of such a programme within our curriculum and how it aligns with our desired student outcomes.

It is interesting to note that traditionally, critical thinking activities have often been described as a list of the following skills set:

- Comparing/ contrasting
- Analysing
- Evaluating
- Synthesising
- Classifying
- Drawing conclusions
- Inferring, predicting
- Sequencing
- Identifying patterns

This list, commonly found in the content pages of critical thinking texts (such as Epstein, 2002 and Chaffee, 2003) is but a simplistic way of looking at how one thinks critically. We do not employ just one specific thinking skill when we view our understanding of new information or of the world around us. Often we employ a broad array of these skills to interact meaningfully with knowledge. Fisher et al proposes that critical thinking can be better defined as "skilled and active interpretation and evaluation of observations and communications, information and argumentation [around us]…[and] is sometimes synonymous with higher order thinking skills. It implies that the individual is inferring or concluding something based on some specific criteria." (1997, 21)

Brookfield also argues that being a critical thinker "involves more than cognitive activities such as logical reasoning or scrutinizing arguments for assertions unsupported by empirical evidence." It also involves being able to recognise "the assumptions underlying our beliefs and behaviours, …. give justifications for our ideas and actions [and] judge the rationality of these justifications." We are then in a better position to "test the accuracy and rationality of these justifications against some kind of objective analysis of the 'real' world as we understand it." (1987, 13) In other words, critical thinking requires a systematic monitoring of thought. It is thinking that is assessed for its clarity, accuracy, relevance, depth, breadth, and logicalness.

Thinking is also dependent on contexts. Dewey explains that the origin of thinking is some "perplexity, confusion, or doubt" and that it is triggered by "something specific which occasions and evokes it" (1991, 12). Critical thinking is often manifested in settings and domains that is divorced from the school or college classrooms. Hence it is not surprising that some research has shown that when a separate programme is used as the 'sole vehicle' for instruction in thinking, the effectiveness of the transfer of such skills into other academic work and into everyday thinking is less automatic than what we would like it to be (Swartz, 1991, 177). In fact, the problems of thinking in the real world often do not align with the problems of the programmes that teach critical thinking to prepare students to deal with problems that are in many respects *unlike* those that they will face as adults (Brookfield, 1987, 194). For example, in a chapter that deals with checking the validity of claims, Epstein poses some exercises to the students: A claim is considered valid if "All S are P, a is S, so a is P." Students are expected to be able to apply the reasoning to statements like: "All dogs bark, Ralph is a dog, so Ralph barks." (2002, 177) This exercise, although a valid syllogistic argument, is not realistic in the context of real world problems.

Hence, if the ability to engage in content in order to derive meaningful and logical conclusions is our objective, we need to re-examine how we approach the teaching and application of thinking skills in our school programmes such that our students are able to decide what thinking skills are appropriate and how they should be demonstrated for deep learning to effectively take place.

PBL and Thinking

PBL is a pedagogy where problems drive the thinking and learning process, rather than one where a specific thinking skill is 'taught' from the onset. It is an approach that challenges students to confront problems from real world contexts that are vague and often ill-structured. It is this deliberate introduction of Dewey's notion of "perplexity, confusion, or doubt" that triggers a series of exploratory questions to seek a viable solution which provides a stimulus for learning.

Typically, a PBL lesson consists of a session to introduce the problem trigger, collaborative group discussions and a presentation of findings. In PBL approaches, students do not merely learn through accumulating knowledge, but through constructing an understanding of the concepts they encounter. Through a problem trigger, the learner explores ideas within a context, and in doing so, integrates the new concepts with his prior knowledge; through reflection, he constructs a personal understanding of the knowledge.

Lipman argues that inquiry begins when there is an aberration or discrepancy in what we encounter. This captures our attention and demands our reflection and investigation (2003, 21). In using problems to drive the acquisition of cognitive skills, problems are designed to be similar to real world situations. The students engage with the problem and the problem inquiry process creates cognitive dissonance that stimulates learning. In working with real world scenarios, students get to apply the components of critical thought and actions that are interconnected depending on the myriad of audiences and contexts involved.

Other than addressing the skills sets that are built into the problem scenarios, the beauty of working through problems is that the collaborative process of social negotiation allows the student to evaluate the viability of his ideas. In the process, meta-cognitive strategies and self regulation are also exhibited (Tan, 2004, 8). Weissinger argues that the process of self-reflection will then drive and support the development of thinking skills as well as the habits and disposition to use them (2004, 45).

It is with these benefits of PBL in mind that problems are designed specifically for the precise objective of developing awareness of cognitive and meta-cognitive abilities. Students can be guided through a process of facilitation to reflect upon the skills they have employed to solve a problem. In her study of various programmes in teaching thinking skills, Cotton concludes that the "research supports providing instruction in a variety of specific creative and critical thinking skills, study techniques, and metacognitive skills". Moreover, "instructional approaches found to promote thinking skill development include redirection, probing, and reinforcement [and] asking higher-order questions during classroom discussions." (1991) This lends support to using the PBL approach as it enables students to *develop* thinking skills, rather than merely learning *about* them.

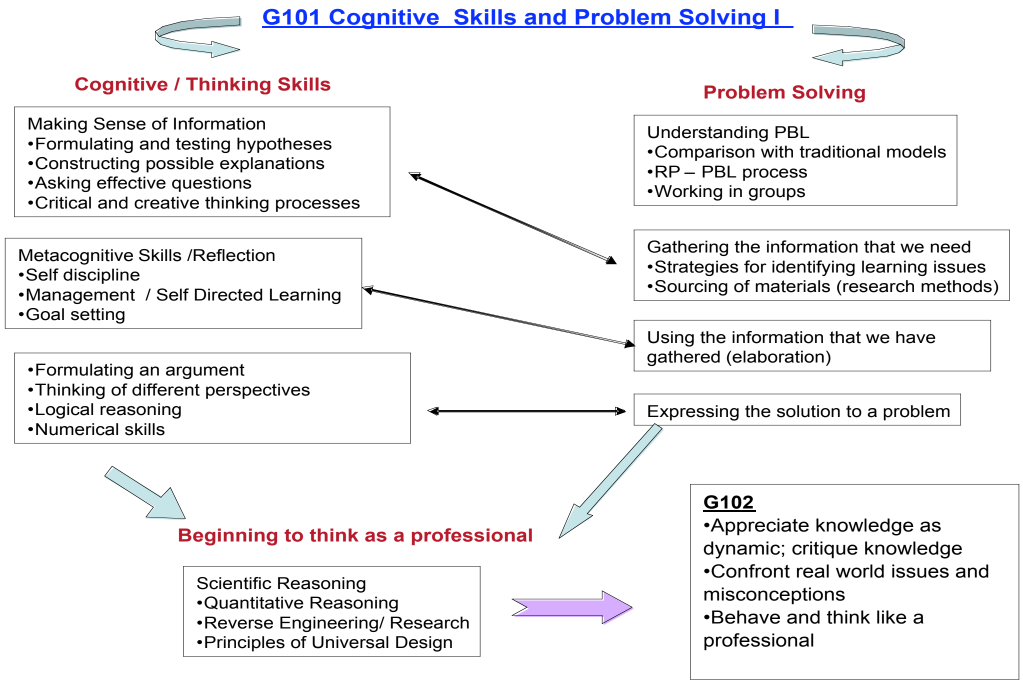
Content Design - Cognitive Processes and Problem Solving Modules

The first year foundation programme at the Republic Polytechnic consists of 2 modules of Cognitive Processes and Problem Solving over two semesters. The modules introduce students to a framework of problem solving and an array of thinking skills to enable them to carry out problem solving effectively.

As a result of completing these modules, students are expected to:

- Derive strategies for thinking and solving problems;
- Become more aware of their meta-cognitive abilities;
- Appreciate knowledge as dynamic by critiquing knowledge and offering alternative ways of perceiving, understanding and organising it;
- Confront real world issues and misconceptions;
- Acquire the mindset, methodologies and skills to be an effective learner; and
- Begin to think as a professional in their own fields through industry-based situations.

Real world problems often require a myriad of problem solving and thinking skills to engage with them. The traditional education system slants towards teaching, and rewarding the acquisition of content and convergent thinking. Costa et al argues for a "shift from valuing right answers ….to knowing what to do when confronted with the paradoxical, dichotomous, enigmatic, confusing, ambiguous, discrepant and sometimes overwhelming situations that occur throughout life." (1997, 2) Hence a problem that students work on often requires them to display a variety of skills, and use concepts from various disciplines to resolve it. This unique feature of problems means that problem designers need to be aware of the multitude of thinking skills and disciplines that can be integrated and used in the resolution of the problem. The approach that has been taken is to firstly identify how the set of thinking skills relate within the problem solving framework that students work in, and how the skills set align with the desired student outcomes. The framework and flowchart below shows how the two modules are set up to achieve this:



Problem designers work with the broad frameworks defined below, in which the specific cognitive skills are then integrated within the exploration space of the problem itself:

- Exploring situations with relevant questions: learning how to ask appropriate and penetrating questions to understand the material or task at hand and integrating this new understanding into their knowledge framework.
- Thinking independently: How did you arrive at these conclusions? How do you know when you have examined and adopted ideas yourself instead of simply borrowing them from others? How do you explain why you believe in them? Can you explain the reasons that led you to this conclusion?
- Viewing situations from different perspectives in order to develop a more complete and complex understanding of a situation.
- Supporting diverse perspectives with reasons and evidence in order to arrive at thoughtful, well-substantiated conclusions.

The role of the student is to analyse the problem and select information and methods appropriate to resolve it. This would involve a review of information and data from a variety of sources in order for the student to synthesise and evaluate the necessary information, and demonstrate the application and practice of thinking skills in the process.

Manifestation of Thinking in the PBL Classroom

If thinking is a cognitively and socially complex process, we need to develop an educational climate that nurtures this process. Curriculum content can achieve only so much unless there is a pedagogical framework that acts as a vehicle for thinking to be manifested explicitly. This "challenge of making students' thinking visible" (Tan, 2004, 7) can happen via a classroom discourse that includes questions, reflection and evaluation.

Classroom Discourse and Thinking

The role of questions is vital in promoting open discussion among our learners (Dillon, 1988) as this encourages divergent thinking, which can be achieved via group dialogue and critical reasoning. However building a questioning community requires a synchronous relationship between a learning context (the problem trigger) and learning structure (classroom process) in order for thinking to be demonstrated and developed.

RP's one-day-one-problem PBL process[1] was designed to fulfill this dual function of a learning context and structure to develop thinking in our learners. Classroom discourse is facilitated by an adult facilitator and is organised around three meetings interspersed by two breakout sessions in a day for students to work on a given problem:

Session	Description	Sample Discourse	Example of Thinking Manifested
Meeting 1	The problem trigger is introduced for the first time, and students explore the scope of the problem in order to generate learning issues. A scaffolding document called the "First Meeting Template" (see next column) helps students structure their initial discussion.	- "What do I know about the problem?" "What seems familiar here?" (activating prior knowledge) - "What am I unsure of?" "What do I not know?" (identifying what one does not know about the problem) - "What do I need to find out?" "What is important for me to investigate?" (prioritising what resources or information is needed in order to resolve the problem)	- Divergent thinking (in exploring scope and dimensions of the problem) - Analysis (of parameters and layers of the problem in context) - Connecting what is known with that which is unknown (via schematic associations and cognitive dissonance) - Inferring types of resources required to investigate the problem (filtering what is relevant from a list of unknowns)
Meeting 2	Students have returned from their first breakout session (self-study time) and will share how they have approached the problem, as well as any learning obstacles they have encountered.	- "What kind of key words did I type into the search engine?" (awareness of selection of information required to solve the problem) - "Why did my team focus on one out of three possible approaches?" (comparing approaches) - "Why did we change our mind about approaching the problem this way?" (reflecting on team processes and approaches) - "Why did I give up reading that particular journal article?" (identifying setbacks so that strategies can be formulated)	- Meta-cognitive thinking (reviewing processes) - Comparing and evaluating hypotheses, approaches and resources (to aid decision-making) - Reflecting on changes and obstacles (to empower learners to manage challenges in a constructive manner) - Supporting claims and opinions with sound research (to strengthen arguments)
Meeting 3	Students have returned from their second breakout session (self study time) and will	- "Why are we confident/ not very confident about our solution?" - "How does our approach	- Synthesising thoughts (consolidating ideas from a myriad of information) - Arguing a case (through

[1]See O'Grady et al (2002) and visit http://discovery.rp.edu.sg/home/CED/home/1-day-1-problem.htm for more information on RP's PBL and one-day-one-problem framework

	share their consolidated findings and argue for the viability of their solution via a presentation.	compare with other teams' approaches?" - "Why are other teams agreeing/ disagreeing with us? - "What is the line of reasoning that other teams are offering?"	examination of resources and logical reasoning) - Identifying gaps and weaknesses in reasoning (with the intention to learn how to develop better arguments) - Developing broader points of views and deeper understanding of concepts (through perspective-sharing and negotiation of meaning)

Table 1: Classroom discourse and thinking in RP's 1-day-1-problem framework

The framework of the three meetings and the types of questions facilitators and students ask allow learners to interact critically with the content and develop more sophisticated arguments and understanding of ideas.

By designing learning contexts that validate meaning through transactional dialogue (Savin-Baden, 2000) and social negotiation (Savery & Duffy, 1998), learners are able to construct meaningful knowledge. Edwards & Mercer also argue that the role of social and intellectual discourse is vital in aiding the construction of knowledge beyond individuals' minds (1987). Hence, with a classroom environment that facilitates the process of thinking aloud and thinking critically about content, our learners experience a more realistic and engaging thinking climate.

Reflection and Thinking

If thinking in the classroom is a valuable component of the leaning process, then how our learners think about their thinking is also just as important. Reflection is a mental process of thinking and learning often used in everyday life. Learning in constructivist terms is about constructing knowledge and understanding of the world around, through questioning, interpreting and analysing information. It is about using the processed information to integrate current experiences with past experience and knowledge. Reflection thus forms the important link between *processing* the new information and *integrating* it with the existing understanding of the world around. The value of reflection in learning lies in its ability to help learners to clarify their thoughts, to gain insights and to deepen their understanding of the information that they receive (Higgs, 1988, 47).

Proponents of PBL recommend a reflective activity at the end of the problem solving cycle. Engels recommends that the tutor should "perhaps once every 2 weeks" call "time out" and "stimulate the group to reflect on how their studies are progressing and how their learning fits together." (1999, 203) Students at this point should be encouraged to reflect not just on the propositional knowledge they have encountered but also on the processes involved in understanding the content. Woods takes the reflection process a step further and suggests getting students to reflect and to write reflection journals as a means to help them to "explicitly see the process skills that they have employed to solve the problem." (1995, 33) The act of reflection allows the student to take apart the process skills involved in solving the problem, and enables the student to feel empowered and confident through integrating and applying the skills.

Problem based learning involves learning by reflective thinking. A problem is a situation which engenders feelings of curiosity, puzzlement and some measure of confusion. Dealing with problems requires the learner to reflect on the questions that arise from the confusion. These questions can then prompt the reflection which generates learning, and the acquisition of content. Learning within the PBL environment occurs when students engage with the processes of reflective thinking. "It is through careful (reflective) application of PBL that students can learn in a deeper fashion, content knowledge, professional skills and cognitive and meta-cognitive processes." (O'Grady et al, 2002, 2)

In the problem solving framework, the student is presented with numerous opportunities to develop and practice meta-cognition. Meta-cognition, often described as "thinking about thinking" is an important part of learning. It is about "consciously making connections between what is known and what is new. It is the intentional structuring and storage of information for later retrieval; self management of learning." (Weissinger, 2004, 50) Reflection can help to develop these skills as well as the habits and disposition to use them. This is because students, through reflection, open their minds and become more confident about using these reasoning skills in dealing with whatever content they come across.

Hence, the reflection journal serves as a window to the learner's mind. It can be as used a monitoring device in a student's understanding in the following aspects:

- The student's ability to understand concepts.
- His analytical and critical thinking skills needed for the discipline.
- His ability to think independently i.e. his meta-cognition (Crowe et al, 1986, 217).

The problem solving process at the Republic Polytechnic requires the students at the end of the day to reflect on the way they have learnt in their groups and record key learning milestones in their online reflection journals. In this way, the post problem reflection is intended to support and make explicit some of the thinking that was manifested while working on the problem.

Case Context - Sample Problem Trigger and Thinking

The following section examines a case study of a problem that 1108 first-year students worked on in during their first semester in August 2004. The average age of the students is 17 years of age; students completed their GCE 'O' Level examinations or an equivalent examination prior to enrolling at RP. Students belonged to one of three schools[2] in RP offering diploma programmes. Classes are mixed in terms of gender and diploma specialisations.

The Problem

An incomplete set of bones was recovered from an abandoned warehouse in China. Investigators strongly suspect that the bones belong to a Chinese male. As part of the Forensic Anthropologist team working to recreate a physical impression of the victim, you are given the femur and asked to gauge the victim's height from it.

More information is given below:

Bone Stats and description
Length – 41cm
Thickness – 7.5cm
Age – Estimated 17 to 21 years
Findings – Bone knobs are grooved and show signs of wear, indicating that the owner might have been physically active. Scarring along the middle portion of the bone (not shown), strongly suggests a hairline fracture sustained in the past. Age of fracture is estimated to be within the last 8 years.

[2] The three schools offering diploma programmes in 2004 are Applied Sciences, Engineering and Information and Communications Technology.

The problem objectives were to see students demonstrate the use of mathematical models to express relationships between two real-world objects, to understand that mathematical models can be used to predict unknowns, as well as realise that mathematical models can be used to support or critique inductive reasoning. In order to achieve these objectives, students were expected to consider what type of data was necessary, how to form meaningful relations between sets of data, and the extent to which their mathematical equations could be relied upon to make useful predictions. Students were also expected to take on the scientific role of a criminologist or forensic anthropologist in order to solve the problem. These objectives are not known to students; students needed to extrapolate the learning issues through their investigation of the problem.

Classroom Discourse

Session	**Sample Discourse**[3]	**Analysis of Thinking Process**
Meeting 1	- "I know that this is like a CSI (Crime Scene Investigation) problem because there is a dead body and no one knows what happened." - "Why is it important to know that the corpse is a Chinese Male?" - "Why do I need to find the height? All I have is a bone. Is that information sufficient?" - "How do I know what the proportion between the femur and height is?" - "Was he murdered? Who killed him? Why was his body found abandoned?"	*(Divergent thinking and sense making)* - Students were looking for analogies to familiarise themselves with the problem. In doing so they were experimenting with how methods of investigation used in a television series could be applied to this context. - Students wanted to see what could be inferred from the given information. They also had to ask themselves what information was relevant to the problem. - Engagement with a problem comes about when students find a purpose for wanting to solve a problem, and divergence is encouraged in the exploration paths so that students study multiple approaches.
Meeting 2	- "We did a ratio calculation between the femur and height by using our classmate from China as a model." - "We found out that males and females have different proportions, and that race is also a factor. But we don't know what this proportion is because we can't find the information on the net." - "We read that forensic anthropologists do lot of lab work, but we don't have facilities to test DNA and all that. We only have the bone." - "Our team decided to measure the femur lengths of all the Chinese males in our class. From there we will come up with some sort of equation, but our Math is quite weak, so we are worried."	*(Meta-cognitive thinking and development of arguments and awareness of approaches)* - Facilitators wanted to find out why students opted for particular approaches, so probing questions were asked to investigate these reasons. The intention was to cultivate a greater sense of awareness of rationale and purpose. - Students who were frustrated that they did not know enough were encouraged to examine certain resources to develop better conceptual understanding of mathematical models and the methods of a forensic anthropologist. - Students who were interested in collecting sample measurements were given a tape measure, and also questioned on how much data they were collecting and how this would help them solve the problem in an effective manner.
Meeting 3	- "How did your team derive at the $y = mx + C$ equation? What does it mean? Why do you call it an equation rather than a formula?" - "What assumptions underlie your use of this equation?" - "How did you come up with the values for the equation?"	*(Solution Critiquing and Evaluation)* - Facilitators and students interacted with the presenting teams as they shared their solution and methods. Questions were asked to check the reliability of the sample size and type (to assess rigour of methods), the confidence level of teams as expressed by their arguments, and the choice of a mathematical model that

[3] The sample discourse is taken from the First Meeting Template students complete in the first meeting, classroom recordings and transcripts, facilitator observations and student presentations.

	- "Why did you use data found about Caucasian males? Is that relevant to our problem today?" - "How do we know if your sample size is enough?" - "How can we be sure that the height prediction for the corpse is accurate? Is there a way we can test this?"	appropriately represented the relationships between the femur length and height. - Teams who used the linear equation approach were asked to explain the underlying concepts of the equation using examples in order to relate abstract numerical language to a concrete context. - Comparisons between methods were also made to evaluate the effectiveness of the methods used to gauge the corpse's height. This also allowed collaborative learning to take place as students had to identify gaps in their solutions and reasoning in order to build a better understanding of the limitations and strengths of different approaches. - Finally feedback from facilitators and peers allowed teams to reflect on their solutions and problem-solving approaches.

Table 2: Classroom discourse and thinking in a problem context "Tattletale Bones"

A combination of learning scaffolds (as set up in the three meetings in the day) and question prompts in this PBL setting allows learners to create their own appropriate thinking contexts such that cognitive and psycho-social processes can be set in motion for meaning to be negotiated and constructed. Classroom observations above showed that students were engaged in a complex process of critical thought, from their first encounter with the problem to the sharing of solutions.

Reflections

Students were required to write a reflection on their day's learning after working through the problem. The reflection demonstrated the students' ability to handle and process information. This was evident through their comments on how they processed information, applying elements of critical thinking to solve the problem. There was also mention of how they were managing their own learning – meta-cognition. Through their reflections, students showed an awareness of the gaps in their understanding, and the need to deal with the cognitive dissonance they faced when encountering the problem. This is critical for learning as the ability to identify gaps in one's own learning is a necessary first step in remedying them. This leads to the student making an attempt to examine his strategies to better understand himself. Below are extracts from students' reflection journals:

Student A begins to approach the problem by first identifying the gaps in his understanding:

> "….at the start, when you asked us to find questions to what the problem was about, I thought about points like: Why could this be a Chinese male? What is the victim's height? Why do they want to find out the height? Are there other signs to show how tall the man was? Examine the strengths and weakness of mathematical models." (*Student A)*

The reflections also demonstrated complexity of the student's cognitive skills. The reflections ranged from how he processed information to an articulation of strategies to solve problems and to work through gaps in understanding. This is evident through the use of words like "analysed", being critical about information received,and making a conscious effort to use critical thinking to reason out a solution. There were attempts to evaluate ideas presented by peers. The following journals from other students exhibit the awareness of these cognitive strategies:

Applying deductive strategies:

> "To me, I found the topic quite interesting today. Studying about old bones, investigation, deduction, solving mysteries... These kinds of subjects really test our powers of deduction. Interesting topics like this just keeps the class working away on the problem." (*Student B)*

Analysis:

"Reflecting on today's problem, I had predicted that all teams will derive a different answer.
Basically, there are many factors concluding to difference in answers.
Firstly, human errors are inevitable to prevent. …..Another factor is that exceptions are also something that cannot be prevented...Teams may also have not read the resources in depth thus lacking in some important information. Teams also may ignore some variables which can make a difference in the conclusion…Teams also came out with different equations thus deriving a different answer." (*Student C)*

Evaluating differing opinions and strategies:

"…Even in the team, we have got many opinions. So, each of us suggested to do research further from the resources given and also from the other websites. There, we have gathered two ways of calculation. How are we going to test it whether either of them works? We measured our own femur lengths and then see which one's result is closest to our real height." (*Student D)*

Analysing and evaluating the reliability of information:

"I feel that the skills I would need to understand a PBL problem is the skill of analysing a problem. From what we had analysed, we could find out what we know and what we are unsure of. In analysing the resources, we could pick out the relevant information in the resources and also check the reliability of the resources. This also helps me in solving the problem. Therefore, I feel that analysing skill is the most important in PBL learning. Of course, there are other skills that would be required in PBL learning, such as evaluating skills and interpretation skills. Evaluation skills will help me to evaluate the problem at the end of the day, so that I can know the learning objective of the day." (*Student E)*

Applying a variety of thinking skills to solve the problem:

"All those mentioned above requires thinking skills. Mathematical models are equations which use symbols…At this level, all of us know what this equation means but…you need time to think how this equation is arrived and how to apply the equation. When one does not understand the concept, he or she will not be able to apply and solve questions which have been turned and twisted. Thus, thinking skills are needed to figure out the relationship of the variables in the equation.
…Logical argument or also known as deductive reasoning is a clear line of reasoning. It requires a certain degree of thinking to have a clear flow of ideas…Before making an assumption, one needs to dissect if there is a pattern or clue which will help him or her make an intelligent guess. Scientific methods obviously require thinking. When an experiment is being conducted, careful observations are needed in order to come up with accurate results and avoid experimental errors. When results have been tabulated, one needs to study carefully the results before having a solid conclusion. PBL requires thinking to solve problems. All problems require planning. At some point of time, when we are solving the problem, contradictions may arise. We need to reason out why certain statements do not agree with one another." (*Student F)*

Meta-cognitive strategies and self regulation are integral aspects of the PBL processes. Meta-cognition can improve with practice. The PBL process provides many opportunities to develop and practice meta-cognition. As students reflect, they open their minds, learn new skills and become confident about the application of their reasoning skills (Weissinger, 2004, 50). The reflection of student G below showed that he was constantly monitoring his actions, his own time management, and even calling for himself to confront the difficult processes and issues that he faced in his learning:

"I feel that in order to understand a PBL problem, one has to keep questioning. Asking myself questions like "why is it like that? What is the reason behind this?", can help me to organise my thoughts on the problem and clarify doubts and queries that I may have on it. And as I search for an answer to my questions, I can check my understanding of the problem. And during this process, I will be able to find out what I am unsure of thus be able to look for an answer. And when we find our own answers and apply it, we tend to retain the knowledge better compared to listening or simply looking at it. This process will enable me to list out the main or important points of the subject and by going through this, it will also indirectly help me to remember better as I can understand it. And at the end of all this, asking simple questions of how one leads to another through maybe creating a mind-map can also help to organise what I have learnt, enabling me to have a better understanding of the day's problem." (*Student G)*

Reflection and thinking are closely related. Reflection as a culmination of the problem solving cycle enables the learner to sort out the processes used in working through the problem. It enables the learner to articulate his thinking and hence construct meaning from the concepts and information that he faces. It can also help the learner to make linkages between old and new knowledge, both content- and procedure-wise.

As learners become more ready to engage in self-directed and collaborative learning, these questions help them become more reflective critical thinkers in the way they organise, evaluate and accept knowledge.

Module Survey

A survey[4] is conducted twice a semester to elicit feedback on facilitator and module effectiveness. The survey is designed to function as a diagnostic tool to enable facilitators and module coordinators to use the student ratings and comments as feedback to improve their teaching methods and course offerings. The questionnaire which looks at the measurement of module effectiveness comprises 11 scale-based questions and 2 open-ended questions. A 6 point Likert scale rating is used. The survey requires students to rate each item on a 6 point Likert scale that ranges from 1: "do not agree at all with the statement" to 6: "agree whole-heartedly with the statement". They can also qualify their ratings via 2 open-ended questions at the end of each section.

Data from the second survey in Semester 1 of Academic Year 2004/2005 was used in this study. It was chosen as the survey was conducted approximately about 12-13 weeks into the semester and the students would have a more concrete experience and understanding of the module. The response rate stands at 83.17% of all the students taking the module. The results of the survey are tabulated below, showing the summarised percentage of responses that indicated agreement or disagreement with the statements in the questionnaire.

No.	***Statements***	***% Disagree (based on Likert scales 1-3)***	***% Agree (based on Likert scales 4-6)***
1	The outline clearly defines the aim of the module to me.	14.96	85.04
2	Teamwork helps me.	10.19	89.8
3	The problem allows me to explore solutions that I feel would work.	13.36	86.64
4	The problems make me think critically about information and ideas.	12.73	87.27
5	I think I can do well in this module.	17.55	82.45
6	The module is interesting to me.	16.39	83.61
7	In this module, the different assessment methods (reflection journal, self, peer evaluation and quizzes) promote my learning.	17.54	82.46
8	I can make sense of the resources provided.	18.57	81.43
9	The module challenges me to develop my ideas further.	12.36	87.64
10	I am able to relate what I am learning to the other modules in my programme.	15.93	84.07
11	I believe that my feedback is being used by the module coordinator to improve this module.	12.84	87.16

Table 3: Consolidated results from module survey of G101 Cognitive Processes and Problem Solving 1 (Survey 2, Semester 1 Academic Year 04/05)

Students generally responded positively in their feedback and felt that the module enabled them to explore and think critically about issues and concepts. Students also felt that the module was able to challenge their understanding of information and not to accept a superficial solution. In the comments, students wrote that the module enabled them

[4] Visit http://discovery.rp.edu.sg/home/CED/research/evaluation.htm for more information on the student evaluation for teaching survey.

to “develop advance thinking skills” and “train [them] to think out of the box”. They also wrote that they were “able to relate what [they] have learnt in this module to other module and also in [their] daily lives.”

Conclusion

Our experience at RP with curriculum design and facilitating the critical thinking process in our classrooms has been rewarding in terms of engaging our students in meaningful learning. The close relationship between problem solving and thinking becomes evident in a PBL context when students extrapolate the type of cognitive skills that are necessary to formulate an acceptable solution. By embedding the thinking skills as learning objectives in a problem trigger, the student is posed with a perplexing and confusing situation which motivates him to want to make sense of it and solve it. Through the process of asking questions and engaging in classroom dialogue to break the problem issues into manageable proportions, the student practices critical thought and analysis. The possibilities of several ways of resolving the complexities in the problem often require him to evaluate his position and solution with respect to that of his peers. The resulting negotiations to clarify ideas seek to construct a better understanding of the issues underlying the problem. The reflection journal enables him to reflect on and articulate his thinking processes. This way it helps to reinforce and to make the student more aware of the thinking that he has used to bridge the gap between the different knowledge in various contexts and negotiate a meaningful outcome for himself.

Hence the delivery of thinking skills through such an integrated problem-based thinking programme can achieve our desired outcomes of nurturing critical learners who are constantly testing and applying knowledge to real-world contexts in order to derive meaningful understanding.

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