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USING THE PROBLEM-BASED LEARNING (PBL) APPROACH TO TEACH SCIENCE

Ho Boon Tiong
Toh Kok Aun
Nanyang Technological University, Singapore

As a curriculum development and pedagogical model, Problem-Based Learning (PBL) provides an alternative strategy to engage and motivate student learning. This is done by placing the students in the active role of problem solvers, confronted with an "ill-structured" problem that mirrors real-world problems. In a recent collaborative effort with the Teachers' Network, PBL was implemented in two secondary schools. Using an example from classroom teaching, this paper briefly outlines the steps in designing a PBL unit and shows how content teaching could be integrated into the PBL approach. Concerns over the alignment of curriculum goals, strategies and activities, authenticity of assessment, implementation constrains and the viability of PBL as an alternative classroom practice will be explored. The challenge is to develop the mindset of looking at problems not as they are but as learning opportunities.

INTRODUCTION

Problem-based learning (PBL) was originally used with medical students (Barrows, 1988). In learning through problem-solving, young physicians were given more experiences in handling real-world dilemmas when making diagnostic and treatment decisions. More recently, efforts have been made to apply PBL in education (Stepien & Gallagher, 1993). The emphasis is also to learn the content (i.e., facts, concepts and ideas) *through* the process of solving "real-world" problems. Far from the notion that teaching is telling and learning is listening, PBL actually turns instruction topsy-turvy through the initiation of learning with a problem, the use of "ill-structured" problems and the role of the teacher as a metacognitive coach.

WHAT IS PROBLEM-BASED LEARNING?

Problem-based learning inverts the usual order of most classroom problem-solving approaches (Gallagher, Sher, Stepien & Workman, 1995). Instead of having students encounter problems only after they have been presented with a body of information, in PBL, students meet an "ill-structured" problem before they receive any instruction. As with real-world problems, they will have to define the problem before gathering relevant information to solve it. At the same time, any change in problem definition will necessitate a change in problem resolution. In this way, the students know why they are learning since the information they gather is learned for the purpose of resolving the problem. This increases their motivation to learn now that they have a stake in the problem.

Using "ill-structured" problems is a key element in PBL. Designing them often proves to be a pedagogical challenge. They contain initial "meet-the-problem" (MTP) scenarios that do not supply all of the information necessary for problem definition or problem resolution. The students would need to source for additional information and there are multiple pathways to unravel the various components of the MTP. Ill-structured problems also have the added advantage of being almost inherently interdisciplinary.

DESIGNING A PBL UNIT

There are seven steps in designing a PBL unit:

1. Know your students and the curriculum.
2. Open umbrellas (i.e., link the MTP to the curriculum).
3. Design the problem.
4. Draw the concept map.
5. State the anticipated problem statements (APS).
6. Plan assessment strategies/activities.
7. Seek a second opinion.

An example of a PBL lesson conducted for a lower secondary class will serve to illustrate how these steps are used in designing the lesson (see Appendix 1). Prior to the PBL lesson, a teacher from the school concerned had gone to Inner Mongolia under the Raleigh Singapore-China 1999 Inner

Mongolia Community Service Expedition, to help build a school there. The class teacher, knowing that his students were excited about the expedition, capitalised on it to link it to the topic on "Heat" that he was teaching for that term. The objectives for this topic were also clearly stated. The extreme climatic changes in the weather in Inner Mongolia provided a platform for discussing the various modes of heat transfer and their applications in designing a building. How can we effectively retain heat in a building? What kind of a wall structure prevents heat loss? How can we ventilate a room to dissipate heat? These and many other questions were asked not by the teacher but by the students themselves. This is indicative of the high interest and motivation PBL can generate to enhance student learning.

Designing the ill-structured "meet-the-problem" (MTP) took many drafts in order to ensure that it met the criteria of a good MTP (see Appendix 2). Even then, it was considered sufficiently good only at that point in time. With each implementation and feedback gathered, the MTP might be further improved. Step 7 (seek second opinion) means exactly this. Invariably, the process of implementing PBL is a PBL experience in itself. To explore and define the scope of the problem, a concept map was drawn (see Appendix 3). The concept map would be used to guide the student discussion later. For example, the teacher, when facilitating the discussion, could use the concept map to delineate areas where, due to constraints of time or resources, might not want to go into. From all these, we write out the anticipated problem statements (APS). The APS is phrased specifically as "*How can we* (and you state the problem here) *in such a way that* (and you state the necessary conditions here)." A good MTP enables the generation of multiple APS. It is this multiplicity dimension that chaterised the ill-structure nature of the MTP. One other step would be to plan the multiple assessment strategies and activities to ensure and assess students' learning.

ADDRESSING CONCERNS OF PBL IMPLEMENTATION

Some of the concerns encountered when implementing PBL include the alignment of curriculum goals, strategies and activities, authenticity of assessment, implementation constraints and the viability of PBL as an alternative classroom practice. PBL as a curriculum development tool represents a radical departure from the traditional teaching model. In PBL,

the students collaboratively set out the curriculum goals with the teachers. This means that the strategies and activities must be aligned with the goals.

> *"Rather than stating, and they trying to teach and assess rigid and detailed lists of knowledge, skills and attitudes, the teacher prepares a list of guiding questions, which students should be able to answer after their study of a particular problem, unit of instruction or course. Students should be encouraged to generate lists of guiding questions for themselves during the study and discussion of the problem. Such a list can be compared to that of the teacher after a period of student-directed work, to ensure that students have tackled the major issues in the problem. This approach allows the teacher to provide a sense of direction, without giving answers and discouraging inquiry on the part of the students" (Wilkerson and Feletti, 1989, p. 57).*

However, teachers are used to giving answers and they do have a prescribed syllabus to teach within a specified time frame. This make adopting the PBL approach difficult, especially when teachers are so accustomed to the didactic teacher-centered teaching model. Even if they agree with the curriculum goals, they may not necessarily employ strategies or design activities to be consistent with the constructivist student-centred approach required in the PBL model. To the teachers, this radical departure represents more than just a pedagogical shift but a philosophical one as well. As one teacher puts it:

> *"It's like eh… may be because in our education system, all the while that we have been actually very specific when we go to class. OK, specifically, we tell them today what will be the objectives of our lesson, you see… I can tell you, I would tell them everything. I would tell them everything, you know Truly, you know" (Interview transcript I, 6 July 1999).*

PBL assesses learning in ways that demonstrate understanding and not the mere acquisition or recall of facts. Such assessment modes are more authentic and varied. Teachers encourage students to assess their own learning through journals, thinking logs, experiments, portfolios and peer discussions. During the discussions, the emphasis is on articulating thinking fully rather than producing the final "right" answer. Instead of being experts or didactic instructors, teachers take on anew role as metacognitive coaches. They help students understand and generate questions as the students themselves go through an iterative process of assessing what they know,

identifying what they need to know, gathering information, collaborating and evaluating the hypothesis in the light of the data collected. Here, the concern is that, while the teachers were "quite happy" using the PBL approach, they felt constrained to assess students using the traditional paper-pencil tests. One teacher said,

> *"… actually I want to raise this point. Next week, I want to schedule a test quickly because actually for the other class I actually covered radiation and stuff like that so that at least I know… I want to feel secure. So that if they are not OK, then I would like to maybe revert back to the traditional way, just to help them catch up" (Interview transcript 8, 22 July 1999).*

On a separate occasion, the same teacher expressed the same concern:

> *So actually I'm, yeah lah, I'm quite happy with what I'm seeing at the moment. So hopefully, on Thursday, when I give them the test, everything is OK. To me, a lot depends on the results. At the end of the day when I mark the scripts, then we will see how" (Interview transcript 9, 26 July 1999).*

A third concern relates to implementation constraints such as time factor, resources (curriculum materials, finance, and resource personnel) and support from the school administration. One teacher who valued using the PBL approach also recognised that it was more time consuming.

> ***Teacher:***
>
> *I think if this had been a cross-discipline stuff, it would be better. Because I mean, may I use the word 'wasted', it took us 50 minutes before we derived into the science part. But let's say if I were given also the curriculum time of geography and English, then those front parts would have been more like English and geography lessons. I may have added one period to go into science actually. So, that's the constraint I felt. If it had been a inter-disciplinary kind of thing, then it would be good because that would have been considered under the English curriculum thing whereas my science time has only been used up, maybe, 15 minutes only.*
>
> ***Interviewer:***
>
> *Now, it is interesting to hear you say that, you know, as you say, may I say wasted. What makes you say that?*

Teacher:

In the traditional sense, then I have so-called wasted two periods today. Whereas I did the control group 2B, I taught 2B this morning, 35 minutes, I already finished conduction.

Interviewer:

So, in the non-traditional sense, what does that mean?

Teacher:

I will be much faster, I mean, the direct feeding…

Interviewer:

Yeah, traditional sense, you would have been faster. But in this case, in the non-traditional sense, what would it be for you?

Teacher:

It takes a lot of time for them to grape around, to fine the right questions to ask.

Interviewer:

But do you see that the students are gaining some other things?

Teacher:

In this sense, of course, they will be gaining other things; knowledge about Mongolia, knowledge about how to really plan something, knowledge about categorising. I thought we were categorising today, thinking skills. So they do gain things.

Interviewer:

So you put 'wasted' within inverted commas.

Teacher:

Yeah.

(Interview transcript 5, 15 July 1999)

The viability of using PBL as an alternative classroom practice would therefore depend on the resolution of these constraints. At the same time, there is a need to train a critical mass of teachers who are well equipped to use such an approach.

CONCLUSION

This paper describes the use of Problem-Based Learning (PBL) as a curriculum and pedagogical model. Using an example from a lower secondary science lesson, the seven steps in designing a PBL unit are briefly outlined. Concerns over the alignment of curriculum goals, strategies and activities, authentic of assessment and implementation constraints are examined in discussing the viability of using PBL as an alternative classroom practice. The research points to real constraints that are not easily resolved. Nonetheless, in true PBL spirit, we ought to develop the mindset of looking at problems not as they are but as challenging learning opportunities.

APPENDIX 1

Topic: HEAT (Conduction, Convection and Radiation)

Level/Subject: Secondary 2/Science

Specific Instructional Objectives:

- Explain what is meant by "conduction".
- List some good and poor conductors of heat and their applications.
- Explain what is meant by "convection".
- Describe the formation of convection currents in liquids and gases.
- List some everyday applications and consequences of convection.
- Explain what is meant by "radiation".
- Infer the type of surface that makes it a good or bad absorber/radiator of hear energy.
- List some applications of good and bad absorber and radiator by conduction, convection and radiation.

Meet-The-Problem

Mr. Chong is presently working on a very meaningful project. He is now in Inner Mongolia and is helping to build a school for the children there. He corresponds closely with the school through emails. Right now, he needs YOUR HELP! A sub-committee has been set up to plan and decide on the best design and layout for the school. The local mayor has requested for a conducive learning environment and has kindly agreed to provide all necessary building materials. Mr. Chong heads the sub-committee and he invites you to help him in his task. Remember, your contributions, no matter how small, will be valued ad appreciated.

Anticipated Problem Statements:

1. *How can we* help Mr. Chong *in such a way that*
   - a school is built for the Mongolian children?
   - the design and layout of the school are considered?
   - a conducive learning environment is provided?

2. *How can we* make contributions (ideas, labour, finance) *in such a way that*
   - they are relevant and appropriate?
   - they cover various aspects of planning for building a school?
3. *How can we* ascertain what Mr. Chong needs *in such a way that*
   - we understand his needs?
   - we understand our own capabilities and limitations in meeting those needs?
   - our contributions would be useful to meet his needs?

APPENDIX 2

MTP Checklist

Categories & Criteria	MTP	Remarks
Characteristics of MTP		
• Easy solutions?		
• More than one problem?		
• Captivate students' interests?		
• Want to solve problems?		
• Relevant?		
• Curriculum links possible?		
• Resources available?		
Approach		
• Invite genuine inquiry?		
• Require investigation plan?		
• Small group work possible?		
• More student-centred?		
Role of Teachers		
• Facilitator?		
• Mentor?		
• Coach?		

APPENDIX 3

Problem-Based Learning

Concept Map on HEAT