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ABSTRACT

Problem-based learning (PBL), initiated when learners meet the problem scenarios, develops learners' skills and subject matter content to make the transition from beginner to more expert problem solver. Beginning students might benefit from simple, well-structured problems, in which the understanding of sets of rules and principles results in a straightforward solution. Facilitators might consider providing learners with more experience with complex, ill-structured problems. However, seldom have reports provided PBL facilitators the solutions for how to design or select problem scenarios so that they open the door to significant learning outcomes consistent with course or program goals. The gray area between well-structured problems and ill-structured problems needs to be further clarified for better learning effect. After a brief literature review, the author outlines a decision model for problem selection that addresses three dimensions: (1) conditions, including learning objectives, prerequisite skills and knowledge, available time, and presentation formats; (2) methods, including the simplifying conditions method and the problem-stimulated/student-centered strategy; and (3) outcomes for well-structured and ill-structured problems. The conclusion suggests that a PBL facilitator should consider the learning strategies both systematically and systemically. Future research is required to further develop this decision model. (Contains 29 references.) (MES)

Problem-Based Learning: A Decision Model for Problem Selection

By:

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PROBLEM-BASED LEARNING: A DECISION MODEL FOR PROBLEM SELECTION

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Abstract

Problem-based learning (PBL), initiated when learners meet the problem scenarios, develops learners' skills and subject-matter contents to make the transition from beginner to more expert problem solver. Beginning students might benefit from simple, well-structured problems, in which the understanding of sets of rules and principles result in a straightforward solution. And for learners with more experience, facilitators may consider to provoke them with complex, ill-structured problems. However, seldom have reports provided PBL facilitators the solutions for how to design or select problem scenarios so that it opens the door to significant learning outcomes consistent with course or program goals. The gray area between well-structured problems and ill-structured problems need to be further clarified for better learning effect. After a brief literature review, the author outlines a decision model for problem selection. Conclusion suggests that a PBL facilitator should consider the learning strategies both systematically and systemically. Future research is required to further develop this decision model.

Introduction

From the instructor's viewpoint, the most important part of problem based learning might be the problem selection. Selecting and crafting the problems represents the major way in which the instructor plans the learning and also portrays the course goals that the instructor wants to reach. No matter whether instructors adapt a well-structured problem or an ill-structured problem, once the students confront a problem, they will start reacting and take ownership for their own learning. Thus, Instructors must carefully conceive the problem scenarios before giving them to students (Stepien W. & Pyke S. L., 1997).

This study will start describing some conceptual issues regarding the nature of problems and their roles in the environment of problem based learning. A brief analysis of whether a well-structured problem or an ill-structured problem could better fulfill students' needs will be presented. Lastly, the detailed explanation of the decision model of problem selection will be categorized in these three dimensions: Conditions, Methods, and Outcomes.

The problem of problem based learning: A few conceptual issues

Nature of the problem

In most PBL environments, two different structures of problem scenarios are used: well-structured problem scenarios and ill-structured problem scenarios. They differ from one another in significant ways.

1. Well-structured problem scenarios

   A well-structured problem scenario is tidy and has little complexity. It is well organized and may lead students to a straightforward solution. Naives might benefit from simple, well-structured problems, in which the understanding of a set of rules and principles leads to a straightforward solution. Bridge (1995) describes the well-structured problem as "The type of problem that most instructors encounter annually and has certain steps for solving the problem".

2. Ill-structured problem scenarios

   An ill-structured problem scenario is formed by undefined problems and incomplete information. It simulates a real-world situation. Because it has no single path to solution (Mason & Mitroff, 1988), students will need to explore the situation they have been given by building hypotheses that initiate inquiry into the numerous aspects of the problem. Bridge (1995) defines an ill-structured problem that is complex, messy, and without clear goals. With the belief of authenticity and fidelity (Brown & Collins, 1989; Dyson, 1993; Duffy & Savery, 1994) to resemble situations in the real world, when students confront a ill-structured problem, they will not have most of the relevant information needed to solve the problem at the outset. Nor will they know exactly what actions are required for resolution. And even after they propose a solution, the students will never be sure that they have made the right decision.

Simon (1978) indicated three characteristics to explain the differences between well-structured and ill-structured problems. First of all, in contrast to an ill-structured problem, a well-structured problem could be solved by correct methods which are obvious and do not conflict. An ill-structured problem often means a complex inquiry process before sets of hypotheses and solutions can be formed. The secondary characteristic is the availability of information for diagnosis. A well-structured problem is well organized, containing the information needed for solutions. Namely, students are led to instructors' desired outcomes. On the other hand, an ill-structured problem is mess and disorder. It supplies less than enough information and requires careful inquiry and numbered trials before students can finalize the appropriate solutions. Lastly, the third characteristic Simon proposed to differentiate well- and ill-structured problems is "legal move generators" (Simon, 1978). In a well-structured problem scenario, routes and procedures are pre-defined by instructors. Unlike an ill-structured problem, the solutions for the problem are not constrained. An ill-structured problem simulates an authentic situation as in the real world, and the "problem space" (Voss, J. F., 1989) is wide enough for people with various backgrounds come up with different solutions for the same problem.

However, the way Simon distinguished well-structured and ill-structured problems is to place each of them at the opposite end of a continuum (Simon, 1978). The ambiguous area for the spectrum of problem representation, is still an open question for instructors and researchers.

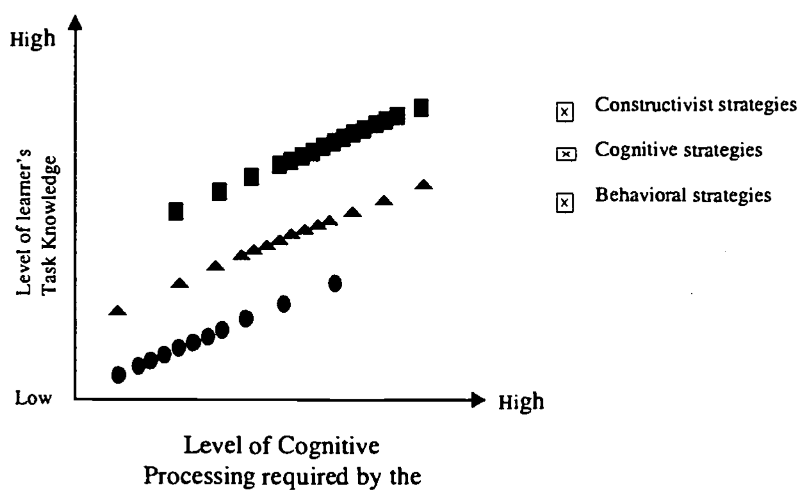
Well-structured VS Ill-structured problem

Some studies advocate that in problem based learning, ill-structured problems could serve all learners' needs no matter their abilities are in what levels. A naïve learner still could benefit from solving a problem with mess situation, incomplete information, and undefined questions. However, a PBL facilitator still needs to consider the scope of a problem. It should be reasonable enough for naïve learners without much experience to complete within limited time and could also achieve the goals fulfilled their needs and facilitators' expectations.

Well-structured problems might be still worthwhile for certain situations during the PBL process. The author would like to analyze this from an epistemological viewpoint. PBL is a learning approach based on the theory of constructivism. With the belief of constructivism, learning is a construction process. Learners have their unique experience to the world. Some constructivists may argue that there could be no ultimate, shared reality (Duffy & Jonassen, 1992) and only has best "description". And the best "description" is developed through social negotiation (Vygotsky, 1978). Instructors should not have the objectives predetermined and contents bounded. However, this issue might not apply to each level of learning. However, in Dick's study (1991), he argues that constructivism is compatible with system theory. Constructivism also could be a micro level theory in a systematic process. Schwen et al. (1993) advocates a similar idea. In the article *Enriched Learning and Information environment*, they proposed the small "c" constructivism by arguing that instructors can put the "idiosyncratic" intellectual thinking of experts into the instruction and allow learners to select according to their needs. It has been suggested that learners at different learning statuses might require different instructional strategies.

Jonnason (1991) points out that there are three levels of learning stages: Introductory, Advanced, and Expert. In the Introductory stage, what learners need is the instruction closer to objectivist. And in the advanced or expert stages, the constructivist approach may become more appropriate. This argument was supported by Ertmert's

Figure 4. (Ertmert, p69, 1993)



study. Ertmert et al. (1993) indicate that there is no single theory that can fulfill the needs of entire instruction design (Figure 4). As learners acquire more knowledge and skills, they will progress along the knowledge continuum from low to high. That is, learners will move up from the knowledge about "knowing what", to "knowing how",

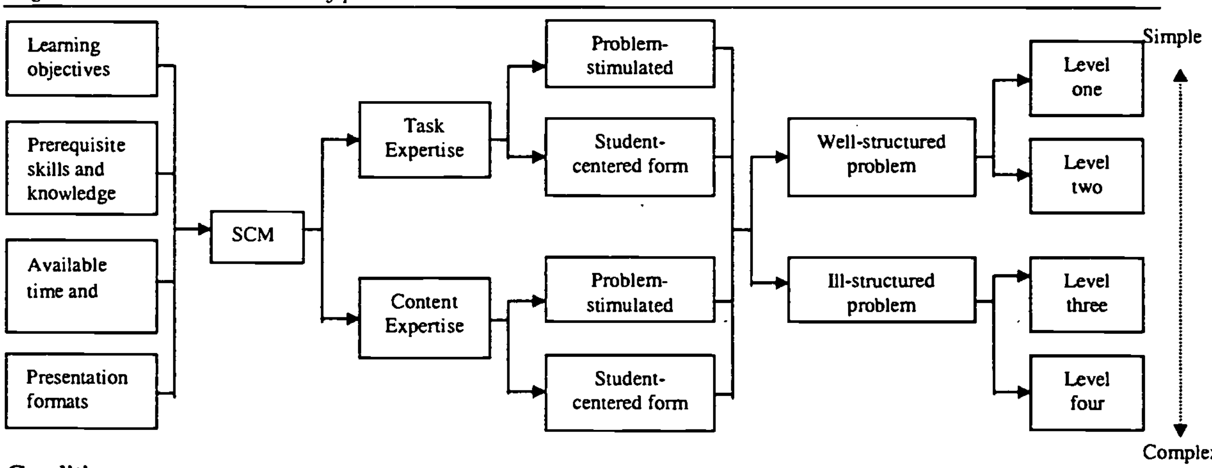
and eventually achieve the "reflection-in-action" level. Learning strategies should be chosen according to where the learners "sit" on the continuum in terms of their knowledge and skills.

Therefore, PBL could still be compatible with the systematic learning process. In other words, a teacher could still be an instructor role for the naïve user during the process of PBL. If it is the need of students, a lecture of a well-structured problem could be helpful for them to establish the basic knowledge domain. Beginning learners could benefit from a simple, well-structured representation (Wilkerson, L & Geletti, G.). And learning objectives for what needs to be learned should be decided jointly by teachers, students, and even parents. In this way, the transmission and adoption become desirable. Students will no longer feel what all they do are for teachers' requirements only. In general, teachers should always remember that to provide a well-structured problem is for students' desires not for fulfilling teachers' expectation.

The decision model of problem selection

Based on above assumptions, this decision model of problem selection (Figure 2) is organized and explained by the following three dimensions: Conditions, Methods, and Outcomes (Reigeluth, 1983). Conditions are defined as the factors that can not be controlled by instructors, while they still have a cause-effect relation with Methods. Methods are manageable and represent various ways to achieve desired outcomes under different conditions. Finally, outcomes could be viewed as "various effects that provide a measure of the value of alternative methods under different conditions" (Reigeluth, p15, 1983). In terms of these three dimensions in this study, the Conditions stage is to provide the facilitator with the things that need to be considered during the diagnosis process. The Methods stage is to provide facilitators the available strategies and techniques which could reflect the needs of Conditions. The Outcomes stage is the criteria of well-structured problems and ill-structured problems listed from simple to complex. PBL facilitators will be able to choose the appropriate problems by thinking through the stages of Conditions and Methods.

Figure 2. The decision model of problem selection



Conditions

As Stepien et al (1997) indicate, to identify an appropriate problem, a PBL facilitator should consider whether it (a) contains significant content; (b) fits curriculum outcomes for a specific course or program; (c) is appropriate for the targeted audience; and (d) can be managed effectively by students in the time available to them.

Bridges & Hallinger (1995) also propose a similar idea that a teacher should consider, such as (a) learning objectives; (b) prerequisite skills and knowledge; (c) available time and time constraint; and (d) presentation formats when trying to choose a problem. Accordingly, the author adopts these four factors and puts them in the Conditions step. It is suggested that PBL facilitators base their diagnosis in correspondence with these factors in choosing an appropriate problem.

Learning Objectives (course goals)

For facilitators of PBL, their consideration is whether the learning objectives are appropriate to the course goals. Certainly, for some cases of PBL, the fit between learning objectives and course goals may not be quite as straightforward as it sounds. Thus, facilitators and learners should jointly discuss and finalize the learning objectives. It needs to be highlighted here that in a PBL context, setting the learning objectives is a continually rolling process during the class period. It is not a must to have learning objectives concretize before the class while PBL facilitators could seed these objectives in mind. The learning objectives that need to be designed or assembled for a problem solving project should allow "to meet the individual learning needs of any student or student group at any level, depending upon their personal career goals, ability, and background knowledge" (David Bond, 1991).

Prerequisite skills and knowledge

Since the learner's need is the first consideration for selecting learning objectives, it will also be helpful for both instructors and learners to preview whether they lack any of the prerequisite skills or knowledge that are explicitly needed for solving problems. If results do show the needs, instructors should act as learning coaches to guide and support students in completing learning issues.

Available time and time constraint

The instructor must consider time constraints relevant to curriculum implementation. Time constraints will influence how complex or messy a problem should be. Instructors can expect to underestimate the time students need to complete a project. Students could experience how they manage their work under stress and time pressure the same as a situation in the real world. In fact, it is suggested that learners work more productively in more substantial blocks of time (Bridge, 1995). Although PBL can be applied in a wide variety of time formats, PBL facilitators should consider the recommended duration of their course schedule for each project as well as consider the format of the course, such as the number of times and length of class meeting per week?

Presentation formats

According to Bridges (1995), instructors can present problems as a written case, a live role-play, interactive videodisk, a taped episode, or even an interactive computer simulation. Each different delivery "vehicle" has different functions. PBL facilitators should choose the most suitable way to transmit singularly different characters of problems.

Method

Strategy 1: Simplifying Conditions Method (SCM)

Simplifying Conditions Method is a kind of sequence strategy that provides guidelines to process course contents. Reigeluth (in press) indicates that "an SCM sequence begins with the simplest version of the task that is still fairly representative of the task until the desired level of complexity is reached." In other words, when an instructor decides to adapt SCM to be the scaffolding tool, the instruction will start by giving students the simplest task first. Although this task may be very simple and basic, it still includes every necessary sub-skill (basic style) and fair representation of the whole task. As students acquire more skills and content knowledge, the next task will require more complex or deeper skills to solve until students achieve the desired level of complexity. SCM does not just include the topical fashion. In fact, it is topical fashion with the concept of spiral fashion.

Technique 1: Task Expertise & Content Expertise

There are two different versions derived from SCM according to their different characters. First, Task Expertise is the sequence that "relates to the learner becoming an expert in a specific task"(Reigeluth, 1995). For instance, a task might ask students to perform as a good writer.

Two subsequences for Task Expertise are distinguished as follows in order to fit different course contents (Reigeluth, in press).

1. Procedural SCM Sequence

   For tasks that need "a set of steps to decide when to do what" (Reigeluth, in press), the Procedural Sequence is appropriate for skill development task.
2. Casual SCM Sequence

   For tasks that need to apply "a set of principle to decide when to do what" (Reigeluth, in press), the Casual Sequence is appropriate for developing tasks like thinking skills or management skills.

Secondary, Domain Expertise applies to the situation which "relates to the learner becoming an expert in a body of subject matter not tied to any specific task" (Reigeluth, in press). It focuses on learners' ability in the knowledge domains. Two subsequences are further defined for use in different course contents (Reigeluth & Darwazeh, 1982; Reigeluth, in press).

1. Conceptual Elaboration Sequence

   Are for the courses which focus on "interrelated sets of concepts" (Reigeluth, in press), for instance, a Biology course that introduces kinds of animals or plants would be well advised to apply this sequence.
2. Theoretical Elaboration Sequence

   Are for the courses which focus on "interrelated sets of principles"(Reigeluth, in press). For instance, a Biology course that emphasizes principles of life cycles and bodily functions would do well to apply this sequence.

Both subsequences under Domain Expertise are similar to those two under Task Expertise. They all lead to a gradual progress of content sequence from simple to complex and happen concurrently once the course includes such kinds of contents described above.

<u>Strategy 2</u>: Problem-stimulated strategy & Student-centered strategy

PBL can be divided into two different forms. One is the Problem-stimulated form and the other is the Student-centered form (Bond, D & Felett, G., 1991). The major differences between the two center on who defines learning objectives, resources, and questions. In the Problem-stimulated form, the instructor is supposed to be responsible for identifying learning objectives, providing available resources, and guiding questions. However, instructors should be notified that they still act as a learning coach role whereas they just supply more directed guidance in this stage. In contrast, in the Student-centered form, students are obligated to be responsible for these three components. That is, when students confront a specific problem, they are able to identify their own learning objectives, locate the relevant resources, generate hypothesis, and evaluate solutions. Although Student-centered form requires fewer instructors' time and efforts, there are certain weaknesses that challenge instructors. First, when given the opportunity to choose their own learning objectives, students may pick ones that only partially overlap with those objectives considered important to the instructor. Second, since students are generally less knowledgeable than the instructor, they may fail to locate the correct resources within the available time. Third, students may cover less of the content deemed desirable by the instructor.

Technique 2:

1. The selection of tasks and content domains

   Instructors need to determine which tasks or contents should be combined into the problems. Instructors will need to keep asking themselves: "Is this task the right one that can reflect students' needs?" There are several methods to help instructors make such decision so. The author adopts the following criteria suggested by Bond, D. and Felett, G. (1991) and Bridges, E. M. (1995). Instructors can select tasks in their area which meet these characteristics:

- Tasks, or conditions that have the greatest frequency in the usual practice setting
- The tasks are suitable for integrating knowledge from a variety of disciplines
- The tasks are ones that have high potential impact; that is, they affect large numbers of people for an extended period.
- The tasks might expose students to "discovered" and "presented" problems.
- The tasks that emphasize or underline important basic concepts in a specific area

Then, instructors can rate each task with a score from one to five based on each of three different factors: frequency, potential impact, and the effectiveness of intervention (Bond, D. & Felett, G., 1991). With the multiplied product of these scores, instructors can determines the position of each condition on a list. Accordingly, instructors will know which task or when it should be selected.

2. Locating resources

   Students can search the relevant information from the following resources: articles, films, computer information networks, and consultants. Besides, since students often bring specialized knowledge and skills to a problem-solving project, they should be encouraged to inventory the resources existing within their knowledge background and to exploit these resources. For instance, the student knows a convenient information resource that is seldom utilized or recognized by others.

3. Generate questions

   In the Problem-stimulated form, PBL facilitators can use the following principles to guide learners forming questions (Bridges, 1995):

- to direct students to key concepts,
- to assist students in thinking through the problem, and
- to stimulate students to view the problem from alternative perspectives.

For the Student-centered form, learners discuss in a small group format and decide which learning issues to pursue, and subsequently which resources to utilize in order to obtain the necessary information. According to Duffy and Cunningham (1997), this step is not complete until each learner has an opportunity to reflect verbally on his or her position in the problem, and to assume responsibility for some of the learning issues identified. Hence, ownership extends from buying into the problem to buying into the learning issues identified. The process to generate questions (learning goals) basically fall into three categories (Stepien, Gallagher, & Workman, 1993; Mardziah et al., 1995):

- What do we (students) know

  Information always confined learners' thought as they face problems for the first time in the real world. This category refers to learners' prior knowledge that may be applied to help evaluate the ideas generated. At this point, learners need to challenge any ideas or knowledge presented for accuracy and understanding.

- What do we (students) need to know

  This category refers to topics or issues that need further investigation to yield information that would help learners evaluate the ideas generated. As information is collected, gaps and conflicts within the problem are noted.
- What should we (students) do

  Learners will start to analyze and revise the list of questions under the heading "What do we need to know". The reasoning process will keep cycling until learners are satisfied with the exact questions that need answering.

Outcome

As Simon (1987) proposes to place two types of problems (well- and ill-structured) at the opposite end of a continuum to describe and differentiate them, PBL facilitators might feel difficulties in forming problems without defining the "gray area" in between. A clear classification for problems with various levels of complexities is considered necessary. Both Bashook (1976) and McGuire (1980) describe valuable systems to solve this problem. Berner (1984) values Getzels' dimension (1982) to be a major structural way for problem classification. Getzels' problem typology attempts to categorize well-structured and ill-structured problems into four levels.

Well-structured Problems

1. Level one

   This type of problem is that both information needed for problem diagnosis and appropriate solutions are known to the problem solver. In addition, the instructor often encounters this type of problem annually. Berner (p630, 1984) indicates "This type of problems may be pattern recognition tasks with a standard solution, or they may be ones for which a standard algorithm is used".
2. Level two

   This is the problem that exists, but remains to be identified. Once it is identified, the solution is clear. The instructor might know what is wrong in the problem but needs to face the situation with alternative ways for solving the problem. That is, the students may pick problems and solutions which are different with the instructor's expectation. This class of problems involves a sacrifice or a tradeoff of important personal and organizational goals.

These two types of problems could serve for learning objectives such as memorized facts or known processes They present a comparatively easy task for instructors to teach and for students to master. However, unlike the above two types of well-structured problems, there are some problems that can not be solved by such a simple way. Problem solvers might even face a tradeoff situation for the solutions they chose.

Ill-structured Problems

3. Level three

   "The problems are those which, even if the diagnoses are known, there is no agreed-upon method of solution" (Getzels, 1982). Considered strategies may each have their associated risks and benefits. For instance, clients' values might conflict with methods that agents choose although these methods might be able to solve clients' problems. This class of problem is the generalized mess that is so complex. Problem solvers need to go through a careful diagnosis process for decision making. Their previous experience might provide better help than the standard answers from their textbooks (Berner, 1984). It is the type of problem scenario that even the instructor has difficulty in getting a handle on what the problem is.
4. Level four

   This type of problem is the one that is just invented or conceived recently. And a solution may or may not be available yet. For instance, an instructor is assigned a new project from his department. He / she asks the problem-solving groups in the class to work on parts of this project. However, the situation is that even said the instructor himself / herself still need to figure out how to complete this project.

Instructors and facilitators could have a better idea for choosing problems based on the above framework, while it is worth to know that what is unknown for a learner may be known for others. For instance, a level 2-problem for learner A might require complicated decision analysis that is akin to a level 3-problem, while for learner B, this problem might be like only a level 1-problem.

Conclusion

Generally, this model shows not only the complexity of problems that can help structure the instructor's course objectives and cultivate students' problem solving skills, but also that the whole environmental structures should be considered to work the same function. For instance, for naïve learners, it is better to choose the Procedural SCM Sequence, the Problem-stimulated Format, and a well-structured problem. This type of well-structured environment helps non-experienced students to become familiar with the basic knowledge of subject domain and prepares them for the next more complex problem and more ill-structured context. In conclusion, learning should not just be considered in a systematic format but should also be weighed in a systemic matter. In other words, PBL facilitators should realize that the student ability used to solve the problem is dependent on the problem's structure, subject, and context. In this decision model, a total of thirty-two different PBL structures are arranged from simple to complex. Instructors can combine different levels of sequences (four subsequences), formats (Problem-stimulated and Student-centered), and problem structures (four levels) to conduct the PBL context. However, this decision model should just work as a reference. An experienced PBL facilitator should decide his / her own instructional environment after considering both the course goals and students' needs.

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