Difficulties Students are Having with Cognitive Processes in Problem Based Learning Environments

Som Naidu, PhD
Multimedia Education Unit, The University of Melbourne, Australia
e-mail: s.naidu@meu.unimelb.edu.au

Iain McAlpine, PhD
Institute of Land and Food Resources, The University of Melbourne, Australia
e-mail: i.mcalpine@landfood.unimelb.edu.au

Abstract: For most students inquiry-based learning environments such as problem-based learning (PBL) comprise a major shift away from approaches to learning with which they are most comfortable and familiar. We have been observing PBL students in situ with particular focus on the cognitive processes with which they are having greatest difficulty, the processes that students need help with, and specifically when in the PBL process they require this help. The outcomes of this empirically-based understanding of the cognitive processes with which students have difficulties, is assisting us with the development of cognitive support tools for incorporation into the inquiry-based learning environments.

Research Context and Background

Problem-Based Learning (PBL) which represents a form of inquiry-based learning is being widely adopted as a powerful teaching and learning strategy at all levels of education. Situated in a constructivist paradigm, PBL is a learner-centered pedagogical strategy where the students themselves assume major responsibility for their learning. Generally PBL is divided into several phases spread over periods of small group work and independent study (Barrows & Tamblyn, 1980; Schmidt, 1993). The PBL process begins with an encounter of a problem situation through the use of a case study or incident, which the learners analyze. During this phase learners generate hypotheses about the occurrence of the problem in the case or incident. Based on this exercise learners identify what they already know about the problem and determine what they need to know, and develop plans to research the information. Students then embark on a period of self-directed learning where they research or investigate issues that emerged in the first phase. During the next phase, the findings of individual inquiry are shared with the group, which results in a re-evaluation of the problem and perhaps revision of their first perceptions of the problem. Through this iterative process, students develop the required content knowledge and problem-solving skills. Central to the PBL process are the following cognitive processes: (1) activation of prior knowledge, (2) elaboration of content, (3) restructuring of semantic networks/schemata, (4) development of an intellectual scaffold.

Activation of Prior Knowledge

The first step in PBL involves the presentation of a problem, which the learner relates to his/her prior knowledge. Schmidt (1993) suggests that the extent of prior knowledge about a subject is one of the major determinants of the “nature and amount of new information that can be processed” (p. 424). Ausubel (1968) has suggested that the essential factor in the acquisition of knowledge is that content must be linked to what is previously known. The exchange of ideas between participants of the PBL session, under the guidance of the PBL tutor, assists in activating or mobilizing prior knowledge of students. This has the effect of creating ‘learner readiness’ for subsequent stages of learning by asking students to generate hypotheses for the problem.

Elaboration
This comprises exploration of alternative interpretations of the problem and an understanding of relationships among concepts. The storage and retrieval of information is said to be enhanced when elaboration of the material takes place (Schmidt, 1993). This elaboration of the content by the student may take the form of listening to other students' hypotheses and determining the merit and worth of these different hypotheses. The cognition involved in evaluating these different perspectives begins the process of elaboration. Use of other learning resources such as journal articles, books, multimedia teaching modules and relevant websites should also help elaborate the student’s understanding of the problem.

**Restructuring**

Depending upon the existing knowledge of the student, a process of *accretion, tuning or restructuring* occurs to actively change existing schemata. Gagne (1986) defines schemata as “a set of interconnected propositions centering around a general concept, and linked peripherally with other concepts” (p. 8). Schemata are not static but continually evolving in content and structure. When new learning occurs, new schemata develop or old schemata undergo structural changes. When more information is incorporated into an existing data structure, *accretion* occurs. *Tuning* refers to the adjustment of existing schemata. The continual tuning or modification in categories of interpretation occurs to bring the categories more in congruence with the functional demands placed on them (Gordon & Rennie, 1987). *Restructuring* is an important process for changing existing schemata or developing new schemata to interpret new information (Keppell, Elliott & Harris, 1998).

Group discussion is an asset to this process. Brown and Palincsar (1989) assert that change is more likely when individuals are required to explain, elaborate or defend their positions to others as well as to themselves, which gives rise to cognitive conflict in the individual. Cognitive conflict arises when the learner is exposed to disagreement between existing knowledge and new anomalous information. Through observation and explanation, learners can elaborate and integrate knowledge in new ways. Chin and Brewer (1993) attribute conceptual change to the following: status of the anomalous data in the perception of the students; characteristics of prior knowledge; learner’s perception of the credibility and validity of the new information; and processing strategies. Problem-based learning attempts to create and induce cognitive conflict within learners with the aim of bringing about conceptual change. This conflict may emanate from a disagreement or mismatch between existing knowledge of learners and the knowledge that is generated from the problem situation. In fact this is an axiom of PBL. Typically, alternative explanations are not provided by tutors but are constructed in small group discussions, based on a combination and evaluation of the knowledge of all group members and verified later on, during self study.

**Scaffolding**

In the process of PBL the student will develop a framework for use with subsequent clinical problems. Ausubel (1960) referred to this framework as an “intellectual scaffold”. Intellectual scaffolding is an infrastructure of information to which new material can be anchored (Ausubel, 1960). “By beginning a task embedded in a familiar activity, it demonstrates to students the legitimacy of their implicit knowledge and its availability as scaffolding in apparently unfamiliar tasks” (Brown, Collins and Duguid, 1989, p. 38).

**Challenges and Constraints**

While PBL has substantial advantages for teaching and learning in practice-based professions (Barrows & Tamblyn, 1980; Barrows, 1994; Koschmann, Kelson, Feltovich, & Barrows, 1996), for most educators PBL comprises a significant shift away from approaches to teaching with which they are most comfortable and familiar. For most students, at least in the beginning stages, PBL is somewhat disorienting. So for all its promise, problem based learning poses a number of challenges for both teachers and students alike. A major barrier to the success of PBL is students’ initial discomfort with the increased degree of freedom they experience in a PBL environment. Students have generally been enculturated into a model of schooling in which their role is more or less limited to comprehension and synthesis of instructor-specified information, based on instructor-formulated learning objectives, and participation in instructor-led learning activities. Many students often lack the skills even to know where to
begin when confronted with ill-defined, real-world problems, let alone manage the complex cognitive processes that are part of PBL.

Aims

The aims of this research program have been to observe PBL students in situ.

- The focus of this observation has been the above-mentioned cognitive processes associated with PBL: (1) activation of prior knowledge, (2) elaboration of content, (3) restructuring of semantic networks/schemata, (4) development of an intellectual scaffold.
- Our goal has been to pinpoint the cognitive processes and/or components of these processes with which students have been having difficulties.
- We expect to be able to identify the cognitive processes that students need help with, as well as specifically when in the PBL process they require this help.

Significance of this Research

The use of PBL as an instructional method reflects the rise of teaching and learning programs, which encourage students to take responsibility for their own learning. Such programs commonly present students with an ill-structured subject area and require them to conduct their own inquiry which involves formulating hypotheses, developing questions, gathering and interpreting data, and communicating their findings to peers and tutors (Schank, 1997; Glasersfeld, 1987; Brown, Collins, & Duguid, 1989; Linn, Songer, & Eylon, 1996). Our work seeks to understand the challenges and constraints of these processes so that as educators, we are better prepared to help students achieve the desired learning outcomes. Results from this study should highlight the phases of PBL and the cognitive processes with which students are having real difficulty. These results are being used to develop software-based support tools to help students with their learning. By focussing on cognitive processes with which students are experiencing difficulties, such tools have the advantage of being tailored to the specific learning needs of students. The immediate benefits of this work accrue to students and educators associated with the course principally being investigated. However, we believe that our work has significance for any course which supports student-centered learning in inquiry-based educational environments either here at the University of Melbourne or elsewhere.

Software-Based Support Tools

While a considerable amount of work has gone on in supporting student learning with various types of cognitive tools and strategies (see for example, Jonassen, Peck, & Wilson, 1999; Kommers, Jonassen, & Mayes, 1992; Pea, 1985; Salomon, Perkins, & Globerson, 1991; Naidu & Bernard, 1992; and Bernard & Naidu, 1992), there has been little work carried out on the area of "software-based cognitive support tools or strategies". Existing software-based cognitive support tools for ill-structured learning environments is believed to impose an inflexible structure on students’ learning (see Edelson, & O’Neill, 1994; Scardamalia, & Bereiter, 1991). These support tools can help students organize arguments for presentation after they have reached a critical summary point in their inquiry, but they are less useful in guiding students in cognitive processes associated with PBL. However, before we can begin building any such software-based support tool to provide students with the kind of cognitive support they need for learning in ill-structured learning contexts, we need to know exactly what cognitive processes students have problems with, and what is the exact nature of these problems. These are the preliminary questions, which this research program has been seeking to answer.

Expected Outcomes

The expected outcomes of this research program are as follows:

- An empirically based and reliable understanding of the cognitive processes that students have difficulties with, while engaged in the PBL process.
- To be able to identify the specific stages in the PBL process, where students are having these difficulties.
• Assist students and educators identify areas/phases where learners require assistance and areas/phases where courses require refinement.
• Empirical data from this investigation provides the foundation for the design and development of suitable software-based cognitive support tools. These tools will be incorporated into the PBL curriculum, and their effectiveness will be evaluated in terms of their use as well as benefits to the learning and teaching process.

Research Plan, Methods, and Techniques

Research plan and methods

This research utilizes a "case study" approach. The classes that we observe comprise the case studies. Yin (1994) defines the case study as an empirical inquiry that investigates a contemporary phenomenon within its real-life context. Case studies are able to explain the causal links in real-life situations that are too complex for the survey or experiment.

Study sample and procedure

The study sample is a group of second year Agricultural Science students. An instructional package using multimedia materials designed for Intranet/Internet delivery is under development for application in this subject area. The students will be the first trial group for the multimedia materials. Data from the trial group will be used to formatively evaluate the multimedia package, in preparation for its implementation with students on several campuses. The study will focus on the cognitive processes the students engage in while learning within a PBL framework. The multimedia package introduces the students to a range of real scenarios, presented using photographs and interviews with farmers. Students need to interpret the farmer's conception of the problem, and develop a solution using the range of resources built into the program. These resources include interactive maps, databases, maps, spreadsheets, and a pasture growth simulator developed during a research project, and interactive tutorials on key concepts. Students select whatever they feel they need to solve the problem from this range of resources.

In this trial, students will work individually to cover the conceptual base, and come together in small groups to reach their resolution of the problems. As the students will be all together for this formative trial, group work will be face to face. The multimedia materials, however, are structured to allow computer conferencing for problem solving. This will enable students to work collaboratively with students on other campuses or external students to work in collaborative groups.

Development of data gathering instruments

Data gathering in case study research typically uses multiple sources of data. For this study direct observation, questionnaires and a focus group will all be oriented to the identification of difficulties that the students encounter, that may hinder their problem solving processes. Any technical problems will be identified by observation and, hopefully, rectified at the time. The questionnaire and focus group will address issues relating to the learning method and the resources. The questionnaire will be oriented towards providing some quantifiable data that can be used to identify proportions of students who encounter specific difficulties or, conversely, feel that the range of aspects of the materials work well. The focus group will be oriented towards more subjective issues such as how the group functioned in the problem solving process, and how realistic the experience of working this way is perceived to be.

Data gathering and analysis

Data from direct observation will be analyzed to identify any major impediments to problem solving that the students appear to be encountering. This data tends to reveal significant issues such as technological problems or major misconceptions caused by inadequacies in the project materials or in the students’ perception of the nature of
the task. An example of this is that the students must feel that the topic is important to them, rather than that they are actually testing software. If there are problems of this nature then they need immediate rectification. If the situation cannot be properly rectified however, then direct observation data provides a context for consideration in the analysis of other data. Questionnaire data will be analyzed to reveal trends or tendencies that indicate the effectiveness of different aspects of the program in relation to stages in learning, such as activation of prior knowledge, elaboration, and restructuring. The way the students felt about the PBL process, and how they perceived the effectiveness of the overall learning task will be extrapolated from the focus group data. Following this, all three sources will be considered together to enable an interpretation of major themes and issues, and how these have either helped or hindered effective learning.

Results

This is an exploratory study that is in progress. Results from the trial will reveal a number of aspects relating to PBL as a method, and the use of instructional technology for delivery. As PBL is essentially a way of structuring a learning process, data relating to how students experience the process, and its effectiveness in promoting effective cognitive processes is important. The approach to analysis of the case study is designed to reveal this. It is important that the critical processes of PBL are identified, and more important that the processes in PBL with which students have difficulty with are identified. Too many inquiry-based technology-enhanced learning environments place students in information dense learning situations without appropriate cognitive supports or scaffolding. Our research agenda is to develop a suite of supports that students can use in such learning environments. We argue that the development of these sorts of supports and scaffolding must be based on empirical data, and that is what this research program is all about.

References


