Problem Based Learning: An instructional model and its constructivist framework

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It is said that there's nothing so practical as good theory. It may also be said that there's nothing so theoretically interesting as good practice. This is particularly true of efforts to relate constructivism as a theory of learning to the practice of instruction. Our goal in this paper is to provide a clear link between the theoretical principles of constructivism, the practice of instructional design, and the practice of teaching. We will begin with a basic characterization of constructivism identifying what we believe to be the central principles in learning and understanding. We will then identify and elaborate on eight instructional principles for the design of a constructivist learning environment. Finally, we will examine w hat we consider to be one of the best exemplars of a constructivist learning environment -- Problem Based Learning as described by Barrows (1985, 1986, 1992).

Constructivism

Constructivism is a philosophical view on how we come to understand or know. It is, in our mind, most closely attuned to the pragmatic philosophy of Richard Rorty (1991). Space limitations for this paper prevent an extensive discussion of this philosophical base, but we would commend to the interested reader the work of Rorty (1991) as well as vonGlaserfeld (1989). We will characterize the philosophical view in terms of three primary propositions.

1. Understanding is in our interactions with the environment. This is the core concept of constructivism. We cannot talk about what is learned separately from how it is learned, as if a variety of experiences all lead to the same understanding. Rather, what we understand is a function of the content, the context, the activity of the learner, and, perhaps most importantly, the goals of the learner. Since understanding is an individual construction, we cannot share understandings but rather we can test the degree to which our individual understandings are compatible. An implication of this proposition is that cognition is not just within the individual but rather it is a part of the entire context, i.e., cognition is distributed.

2. Cognitive conflict or puzzlement is the stimulus for learning and determines the organization and nature of what is learned. When we are in a learning environment, there is some stimulus or goal for learning -- the learner has a purpose for being there. That goal is not only the stimulus for learning, but it is a primary factor in determining what the learner attends to, what prior experience the learner brings to bear in constructing an understanding, and, basically, what under standing is eventually constructed. In Dewey's terms it is the "problematic" that leads to and is the organizer for learning (Dewey, 1938; Rochelle, 1992). For Piaget it is the need for accommodation when current experience cannot be assimilated in existing schema (Piaget, 1977; vonGlaserfeld, 1989). We prefer to talk about the learner's "puzzlement" as being the stimulus and organizer for learning since this more readily suggests both intellectual and pragmatic goals for learning. The important point, however, is that it is the goal of the learner that is central in considering what is learned.

3. Knowledge evolves through social negotiation and through the evaluation of the viability of individual understandings. The social environment is critical to the development of our individual understanding as well as to the development of the body of propositions we call knowledge. At the individual level, other individuals are a primary mechanism for testing our understanding. Collaborative groups are important because we can test our own understanding and examine the understanding of others as a mechanism for enriching, interweaving, and expanding our understanding of particular issues or phenomena. As vonGlaserfeld (1989) has noted, other people are the greatest source of alternative views to challenge our current views and hence to serve as the source of puzzlement that stimulates new learning.

The second role of the social environment is to develop a set of propositions we call knowledge. We seek propositions that are compatible with our individual constructions or understanding of the world. Thus, facts are facts because there is widespread agreement, not because there is some ultimate truth to the fact. It was once a fact that the earth was flat and the sun revolved around the earth. More recently, it was fact that the smallest particles of matter were electrons, protons and neutrons. These were facts because there was general agreement that the concepts and principles arising from these views provided the best interpretation of our world. The same search for viability holds in our daily life. In both cases, concepts that we call knowledge do not represent some ultimate truth, but are simply the most viable interpretation of our experiential world. (See Resnick's, 1987).

The important consideration in this third proposition is that all views, or all constructions, are not equally viable. Constructivism is not a deconstructivist view in which all constructions are equal simply because they are personal experiences. Rather, we seek viability and thus we must test understandings to determine how adequately they allow us to interpret and function in our world. Our social environment is primary in providing alternative views and additional information against which we can test the viability of our understanding and in building the set of propositions (knowledge) compatible with those understandings. (Cunningham, Duffy, and Knuth, 1991). Hence we discuss social negotiation of meaning and understanding based on viability.

Instructional Principles

The constructivist propositions outlined above suggest a set of instructional principles that can guide the practice of teaching and the design of learning environments. All too often when we discuss principles of teaching we hear the retort, "But, we already do that..."While that assertion may well be accurate, too often the claim is based on the principle in isolation rather than in the context of the overall framework. Indeed, everyone "does" collaborative groups; the real issue is what is the goal in using collaborative groups since that determines the details of how it is used and how it is contextualized in the overall instructional framework.

We think Lebow (1993) has hit upon a strategy for summarizing the constructivist framework in a way that may help with the interpretation of the instructional strategies. He talks about the shift in values when one takes a constructivist perspective. He notes that:

...traditional educational technology values of replicability, reliability, communication, and control (Heinich, 1984) contrast sharply with the seven primary constructivist values of collaboration, personal autonomy, generativity, reflectivity, active engagement, personal relevance, and pluralism (1993, p.5).

We agree with Lebow and would propose that this value system serve to guide the reader's interpretation of our instructional principles as well as the interpretation of the problem based learning environment we will describe. The instructional principles deriving from constructivism are as follows.

> ***1. Anchor all learning activities to a larger task or problem.*** That is, learning must have a purpose beyond, "It is assigned". We learn in order to be able to function more effectively in our world. The purpose of any learning activity should be clear to the learner. Individual learning activities can be of any type -- the important issue is that the learner clearly perceives and accepts the relevance of the specific learning activities in relation to the larger task complex (Cognition an d Technology Group at Vanderbilt (CTGV), 1992; Honebein, et.al, 1993).
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> ***2. Support the learner in developing ownership for the overall problem or task.*** Instructional programs typically specify learning objectives and perhaps even

engage the learner in a project, assuming that the learner will understand and buy into the relevance and value of the problem (Blumenfeld, Soloway, Marx, Krajcik, Guzdial & Palinscar, 1991). Unfortunately, it is too often the case that the learners do not accept the goal of the instructional program, but rather simply focus on passing the test or putting in their time. No matter what we specify as the learning objective, the goals of the learner will largely determine what is learned. Hence it is essential that the goals the learner brings to the environment are consistent with our instructional goals.

There are two ways of doing this. First, we may solicit problems from the learners and use those as the stimulus for learning activities. This is basically what happens in graduate schools when qualifying exams require the student to prepare publishable papers in each of several domains (Honebein, Duffy, and Fishman, 1993). Scardamalia and Bereiter (1991) have shown that even elementary students can initiate questions (puzzlements) that can serve as the foundation of learning activities in traditional school subject matter. In essence, the strategy is to define a territory and then to work with the learner in developing meaningful problems or tasks in that domain. Alternatively, we can establish a problem in such a way that the learners will readily ad opt the problem as their own. We see this strategy in the design of the Jasper series for teaching mathematics (CTGV, 1992) and in many simulation environments. In either case, it is important to engage the learner in meaningful dialogue to help bring the problem or task home to the learner.

3. Design an authentic task. An authentic learning environment does not mean that the fourth grader should be placed in an authentic physics lab, nor that he or she should grapple with the same problems that adult physicists deals with. Rather, the learner should engage in scientific activities, which present the same "type" of cognitive challenges. An authentic learning environment is one in which the cognitive demands, i.e., the thinking required, are consistent with the cognitive demands in the environment for which we are preparing the learner (Honebein, et.al. 1993). Thus we do not want the learner to learn about history but rather to engage in the construction or use of history in ways that a historian or a good citizen would . Similarly, we do not want the learner to study science -- memorizing a text on science or executing scientific procedures as dictated -- but rather to engage in scientific discourse and problem solving (See Bereiter, 1994; Duffy, in press; Honebein, Duffy, & Fishman, 1993). Allowing the problem to be generated by the learner, an option discussed above, does not automatically assure authenticity. It may well require discussion and negotiation with the learner to develop a problem or task that is authentic in its cognitive demands and for which the learner can take ownership.

4. Design the task and the learning environment to reflect the complexity of the environment they should be able to function in at the end of learning. Rather than simplifying the environment for the learner, we seek to support the learner working in the complex environment. This is consistent with both cognitive apprenticeship (Collins, Brown, & Newman, 1989) and cognitive flexibility theories (Spiro, et al. 1992) and reflects the importance of context in determining the understanding we have of any particular concept or principle.

5. Give the learner ownership of the process used to develop a solution. Learners must have ownership of the learning or problem solving process as well as having ownership of the problem itself. Frequently teachers will give students ownership of the problem, but dictate the process for working on that problem. Thus they may dictate that a particular problem solving or critical thinking methodology be used or that particular content domains must be "learned". For example, in some problem based learning frameworks, the problem is presented along with the learning objectives and the assigned readings related to the problem. Thus the student is told what to study and what to learn in relation to the problem. Clearly, with this pre specification of activities, the students are not going to be engaged in authentic thinking and problem solving in that domain. Rather than being a stimulus for problem solving and self directed learning, the problem serves merely as an example. The teacher's role should be to challenge the learner's thinking -- not to dictate or attempt to proceduralize that thinking.

6. Design the learning environment to support and challenge the learner's thinking. While we advocate giving the learner ownership of the problem and the solution process, it is not the case that any activity or any solution is adequate. Indeed, the critical goal is to support the learner in becoming an effective worker/thinker in the particular domain. The teacher must assume the roles of consultant and coach. The most critical teaching activity is in the questions the teacher asks the learner in that consulting and coaching activity. It is essential that the teacher <u>value as well as challenge</u> the learner's thinking. The teacher must not take over thinking for the learner by telling the learner what to do or how to think, but rather teaching should be done by inquiring at the "leading edge" of the protégé’s thinking (Fosnot, 1989). This is different from the widely used Socratic method wherein the teacher has the "right" answer and it is the student’s task to guess/d educe through logical questioning that correct answer. The concept of a learning scaffold and the zone of proximal development as described by Vygotsky (1978) is a more accurate representation of the learning exchange/interaction between the teacher and t he student.

Learners use information resources (all media types) and instructional materials (all media types) as sources of information. The materials do not teach, but rather support the learner's inquiry or performance. This does not negate any kind of instructional resource -- it only specifies the reason for using the resource. Thus if domain specific problem-solving is the skill to be learned then a simulation which confronts the learner with problem situations within that domain might be appropriate. If proficient typing is required for some larger context, certainly a drill and practice program is one option that might be present.

7. Encourage testing ideas against alternative views and alternative contexts. Knowledge is socially negotiated. The quality or depth of ones understanding can only be determined in a social environment where we can see if our understanding can accommodate the issues and views of others and to see if there are points of view which we could usefully incorporate into our understanding. The importance of a learning community where ideas are discussed and understanding enriched is critical to the design of an effective learning environment. The use of collaborative learning groups as a part of the overall learning environment we have described provides one strategy for achieving this learning community (CTGV in press, Scardamalia et al, 1992, Cunningham, Duffy, & Knuth 1991). Other projects support collaboration by linking learners over electronic communication networks as they work on a common task, e.g., CoVis (Edelson & O'Neil, 1994), LabNet (Ruopp et al, 1993), provide an alternative framework.

8. Provide opportunity for and support reflection on both the content learned and the learning process. An important goal of instruction is to develop skills of self-regulation -- to become independent. Teachers should model reflective th inking throughout the learning process and support the learners in reflecting on the strategies for learning as well as what was learned (Schon, 1987; Clift, Houston, & Pugach 1990).

In the next section we will explore how these eight instructional principles are realized in the problem-based learning approach.

Problem-Based Learning

The instructional design principles, implemented within the framework of the values outlined by Lebow (1993), can lead to a wide variety of learning environments. A number of environments reflecting these principles are described in Duffy and Jonassen (1992) and Duffy, Lowyck, and Jonassen (1993). Further, the elaboration and application of these principles to specific contexts is described in Brooks & Brooks, 1993; Fosnot 1989; and Duffy (in press). In our own examination of learning environments, however, we have found one application that seems to us to almost ideally capture the principles -- the problem-based learning model of Howard Barrows (1985; 1992).

Problem-Based Learning (PBL), as a general model, was developed in medical education in the mid-1950's and since that time it has been refined and implemented in over sixty medical schools. The most widespread application of the PBL approach has been i n the first two years of medical science curricula where it replaces the traditional lecture based approach to anatomy, pharmacology, physiology etc.. The model has been adopted in an increasing number of other areas including Business Schools (Milter &am p; Stinson, 1994), Schools of Education (Bridges & Hallinger, 1992; Duffy, 1994); Architecture, Law, Engineering, Social Work (Boud & Feletti 1991); and high school (Barrows & Myers, 1993).

As with any instructional model, there are many strategies for implementing PBL. Rather than attempting to provide a general characterization of PBL, we would like to focus on Barrows' model (Barrows, 1992) to provide a concrete sense of the implementation of this process in the medical school. First we will present a general scenario, using the medical environment as the focus, and then examine some of the key elements in some detail.

When students enter the medical school they are divided into groups of five and each group is assigned a facilitator. The students are then presented a problem in the form of a patient entering with presenting symptoms. The students' task is to diagnose the patient and be able to provide a rationale for that diagnosis and recommended treatment. The process for working on the problem is outlined in Figure 1. The following paragraphs cover the highlights of that process.

STARTING A NEW CLASS

1. **Introductions**
2. **Climate Setting** (including teacher / tutor role)

STARTING A NEW PROBLEM

1. **Set the problem.**
2. **Bring the problem home** (students internalize problem)
3. **Describe the product / performance required**
4. **Assign tasks** (Scribe 1 at the board, Scribe 2 copying from the board, and reference person)

IDEAS (Hypotheses)	FACTS	LEARNING ISSUES	ACTION PLAN
Students' conjectures regarding the problem--may involve causation, effect, possible resolutions, etc.	A growing synthesis of information obtained through inquiry, important to the hypotheses generated	Students' list of what they need to know or understand in order to complete the problem task	Things that need to be done in order to complete the problem task

5. **Reasoning through the problem**
   What you do with the columns on the board

IDEAS (Hypotheses)	FACTS	LEARNING ISSUES	ACTION PLAN
Expand / focus	Synthesize & re-synthesize	Identify / justify	Formulate plan

6. **Commitment as to probable outcome** (although much may need to be learned)
7. **Learning issue shaping/assignment**
8. **Resource identification**
9. **Schedule follow-up**

PROBLEM FOLLOW-UP

1. **Resources used and their critique**
2. **Reassess the problem**
   What you do with the columns on the board

IDEAS (Hypotheses)	FACTS	LEARNING ISSUES	ACTION PLAN
Revise	Apply new knowledge and re-synthesize	Identify new (if necessary)	Redesign decisions

PERFORMANCE PRESENTATION

AFTER CONCLUSION OF PROBLEM

1. **Knowledge abstraction and summary** (develop definitions, diagrams, lists, concepts, abstractions, principles)
2. **Self-evaluation** (followed by comments from the group)
   - reasoning through the problem
   - digging out information using good resources
   - assisting the group with its tasks
   - gaining or refining knowledge

PBL

Figure 1. The problem-based learning process. Taken from Barrows and Myers (1993).

The students begin the problem "cold" -- they do not know what the problem will be until it is presented. They discuss the problem, generating hypotheses based on whatever experience or knowledge they have, identifying relevant facts in the case, and identifying learning issues. The learning issues are topics of any sort which are deemed of potential relevance to this problem and which the group feels they do not understand as well as they should. A session is not complete until each student has an opportunity to verbally reflect on their current beliefs about the diagnosis (i.e. commit to a temporary position), and assume responsibility for particular learning issues that were identified. Note that there are no pre-specified objectives presented to the students. The students generate the learning issues (objectives) based on their analysis of the problem.

After the session, the students all engage in self directed learning. There are no assigned texts. Rather the students are totally responsible for gathering the information from the available medical library and computer database resources. Additionally, particular faculty are designated to be available as consultants (as they would be for any physician in the real world). The students may go to the consultants seeking information.

After self-directed learning, the students meet again. They begin by evaluating resources -- what was most useful and what was not so useful. They then begin working on the problem with this new level of understanding. Note that they do not simply tell what they learned. Rather, they use that learning in re-examining the problem. This cycle may repeat itself if new learning issues arise -- problems in the medical school program last anywhere from a week to three weeks.

Milter and Stinson (1994) use a similar approach in an MBA program at Ohio University and there the problems last between five and eight weeks (See also Stinson 1994). In our own implementation, we will be using one problem that will last the entire semester. Of course, in the MBA program and in our own program, the problems have multiple sub-problems that engage the students.

Assessment at the end of the process is in terms of peer and self-evaluation. There are no tests in the medical school curriculum. The assessment includes self and peer evaluation (with suggestions for improvement) in three areas: self directed learning; problem solving; skills as a group member. While the students must pass the Medical Board exam after two years, this is outside of the curriculum structure. However tests as part of the PBL curriculum are not precluded. For example, one high school teacher we know who uses the PBL approach designs traditional tests based on what the students have identified as learning issues. Thus rather than a pre specification of what is to be learned, the assessment focuses on the issues the learners have identified.

That is an overview of the process in the medical school. Now we will comment on a few of the critical features.

Learning goals The design of this environment is meant to simulate, and hence engage the learner in, the problem solving behavior that it is hoped a practicing physician would be engaged in. Nothing is simplified or pre specified for the learner. The facilitator assumes a major role in modeling the metacognitive thinking associated with the problem solving process. Hence this is a cognitive apprenticeship environment with scaffolding designed to support the learner in developing the metacognitive skills.

Within the context of this cognitive apprenticeship environment there are goals related to self directed learning, content knowledge, and problem solving. To be successful, students must develop the self-directed learning skills needed in the medical f ield. They must be able to develop strategies for identifying learning issues and locating, evaluating, and learning from resources relevant to that issue. The entire problem solving process is designed to aid the students in developing the hypothetico-deductive problem solving model, which centers around hypothesis generation and evaluation. Finally, there are specific content learning objectives associated with each problem. Since the students have responsibility for the problem, there is no guarantee t hat all of the content area objectives will be realized in a given problem. However, any given content objective occurs in several problems and hence if it does not arise in one, it will almost certainly arise in one of the other problems.

Problem Generation There are two guiding forces in developing problems. First, the problems must raise the concepts and principles relevant to the content domain. Thus, the process begins with first identifying the primary concepts or principles that a student must learn. Milter and Stinson working in the MBA program and Barrows working with medical education polled the faculty to identify the most important concepts or principles in their area. This, of course, generates considerable debate and discussion -- it is not a matter of a simple survey. In developing high school PBL curricula, Myers and Barrows (personal communication) used the learning objectives identified by the state for grade and content domains.

Second, the problems must be "real". In the medical school, the patients are real patients. Indeed, Barrows worked with the presenting physician in gathering the details on the case. Milter and Stinson in the MBA program use problems such as "Should AT &T buy NCR?" These problems change each year so as to address current business issues. For example, the above problem is now "Should Merck buy Medco"? At the high school level, Myers and Barrows have developed problems such as:

- Do asteroids in space pose a problem, and if so, what should we be doing about it?
- What caused the flooding in the Midwest last year and what should be done to prevent it in the future?

We are still developing problems and sub-problems for our Corporate and Community Education program. One of the problems currently being developed relates to the numerous PCB sites around Bloomington and the general public apathy about cleaning up these sites. The problem is basically:

- What do citizens need to know about the PCB problem and how should that information be presented to encourage them to be active citizens in the discussion?

There are three reasons why the problems must address real issues. First, because the students are open to explore all dimension of the problem there is real difficulty of creating a rich problem with a consistent set of information. Second, real problems tend to engage learners more -- there is a larger context of familiarity with the problem. Finally, students want to know the outcome of the problem -- what is being done about the flood, did AT&T buy NCR, what was the problem with the patient. Th ese outcomes are not possible with artificial problems.

Problem Presentation There are two critical issues involved in presenting the problem. First, if the students are to engage in authentic problem solving, then they must own the problem. We have been learners with the Asteroid Problem and we have been facilitators in two contexts: with a group of high school students; and, with a group of our peers who were attending a workshop at AECT to learn about constructivism. In all three cases, the learners were thoroughly engaged in the problem. F rankly, we were amazed at the generality across these disparate groups. In presenting this problem, we used a 10 minute video that described asteroids and showed the large number of sites on earth where they have hit and the kind of impact they can have (the diamond fields in South Africa, the possibility that an asteroid caused the extinction of dinosaurs, Crater Lake, etc.). We also talked about recent near misses -- one in Alabama within the last year and one three years ago that could have hit Australia or Russia. Thus, the problem clearly has potential cataclysmic effects (we have past history) and it is a current real problem (we have had near misses quite recently). This step in the PBL process of "bringing the problem home" is critical. The learners must perceive the problem as a real problem and one, which has personal relevance. Of course, also central, is the fact that the learners have ownership of the problem -- they are not just trying to figure out what we want.

A second critical issue in presenting the problem is to be certain that the data presented does not highlight critical factors in the case. Too often when problems are presented, the only information that is provided is the key information relevant to the desired solution (end of a chapter "problems" are notorious for this). Either the case must be richly presented or presented only as a basic question. For example, Honebein, Marrero, Kakos-Kraft, and Duffy (1994) present all of the medical notes on a patient while Barrows (1985) provides answers generated by the presenting physician to any of 270 questions the learners might ask. In contrast, Milter and Stinson (1994) present only a four word question and rely on natural resources to provide the full context.

Facilitator Role In his discussion of the tutorial process Barrows states:

> "The ability of the tutor to use facilitory teaching skills during the small group learning process is the major determinant of the quality and the success of any educational method aimed at 1) developing students' thinking or reasoning skills (problem solving, metacognition, critical thinking) as they learn, and 2) helping them to become independent, self-directed learners (learning to learn, learning management). Tutoring is a teaching skill central to problem-based, self-directed learning."(1992, p. 12)

Throughout a session the facilitator models higher order thinking by asking questions which probe students knowledge deeply. To do this, the facilitator constantly asks "Why?" "What do you mean?" "How do you know that's true?" Barrows is adamant that t he facilitators interactions with the students be at a metacognitive level (except for housekeeping tasks) and, that the facilitator avoid expressing an opinion or giving information to the students. The facilitator does not use his or her knowledge of the content to ask questions that will lead the learners to the "correct" answer.

A second tutor role is to challenge the learner's thinking. The facilitator (and hopefully the other students in this collaborative environment) will constantly ask: "Do you know what that means? What are the implications of that? Is there anything else?" Superficial thinking and vague notions do not go unchallenged. During his introduction of the Asteroid Problem, Barrows noted for the group that saying nothing about another member's facts or opinions was the same as saying "I agree". Similarly, the responsibility for a flawed medical diagnosis was shared by everyone in the group. During the first few PBL sessions the facilitator challenges both the level of understanding and the relevance and completeness of the issues studied. Gradually however, the students take over this role themselves, as they become effective self-directed learners.

Conclusion

Our goal in this paper was to present PBL as a detailed instructional model and to show how PBL is consistent with the principles of instruction arising from constructivism. We sought to provide a clear link between theory and practice. Some of the features of the PBL environment are that the learners are actively engaged in working at tasks and activities, which are authentic to the environment in which they would be used. The focus is on learners as constructors of their own knowledge in a context, which is similar to the context in which they would apply that knowledge. Students are encouraged and expected to think both critically and creatively and to monitor their own understanding i.e. function at a metacognitive level. Social negotiation of meaning is an important part of the problem-solving team structure and the facts of the case are only facts when the group decides they are.

PBL as we described it, contrasts with a variety of other problem or case based approaches. Most case based learning strategies (Williams, 1992) use cases as a means for testing one's understanding. The case is presented after the topic is covered in order to help test understanding and support synthesis. In contrast, in PBL, all of the learning arises out of consideration of the problem. From the start, the learning is synthesized and organized in the context of the problem.

Other case approaches simply use the case as a concrete reference point for learning. Learning objectives and resources are presented along with the case. These approaches use the case as an "example" and are not focused on developing the metacognitive skills associated with problem solving or with professional life. The contrast is perhaps that the PBL approach is a cognitive apprenticeship focusing on both the knowledge domain and the problem solving associated with that knowledge domain or profession. Other problem approaches present cases so that critical attributes are highlighted, thus emphasizing the content domain, but not engaging the learner in authentic problem solving in that domain.

Finally, this is not a Socratic process; nor is it a discovery learning environment in which the goal for the learner is to discover the outcome the instructor wants. The learners have ownership of the problem. The facilitation is not knowledge driven, but rather it is focused on metacognitive processes.

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