Task Analysis in Problem-Based Learning

Koettingg (1996) stated that the philosophical positions about ontology, epistemology and axiology would direct how we make decisions about education and research inquiry. If we examine the field of instructional technology, the views regarding the nature of reality, knowledge and value have influenced the conceptions of instruction and learning, and further impacted the methods in the ISD process. Wilson and Meyers (2000) pointed out how such impacts on the instructional design were made by the underlying positivist position of cognitive theories. Because cognitive theories are derived from the belief that there is a single reality and objective knowledge, the implication is that knowledge can be transferred from the outside of the mind into the inside of the mind.

“Instructional designers could now think of learning in terms of taking experts’ cognitive structures and mapping that knowledge into the heads of learners. The degree of similarity in cognitive structure between expert and novice was a good measure of whether learning objectives were being met.” (p.63)

The central issues that interest cognitive psychologists are the internal mechanism of human thought and the processes of knowing. The conceptualization of the mind as an active memory system has given rise to a lot of inquiries to finding out the answers to mental structures, such as what is stored and how it is stored, and to mental processes concerning how the integration and retrieval of information is operated. Those inquiries propose different descriptions about memory systems, representations and structures of knowledge in memory. They also proposed different hypotheses about how representations influence and interact with incoming information. In turn, those hypotheses provide implications on how to control the instructional conditions. The assumption is that the correspondence between the instructional conditions and the internal conditions of this active memory system will maximize the effectiveness of the instruction. The fundamental principle that IT borrows to utilize in the process of task analysis and design is to identify the structure of the task at hand in order to develop the
instructional events and strategies that will facilitate the learners’ internal mental process of the task.

If there is a shift on those metaphysical, epistemological and axiomatic beliefs, the challenge lies in what to do and how to do in order to adopt the shift. The practice of instructional design, which was deeply rooted in behaviorist and cognitive learning theories, were challenged with the emergence of constructivism, which views reality as individual construction. The constructivist orientations in the field have resulted in a lot of dialogues in different aspects of ID process as well as suggestions of alternative instructional-design theories (Duffy and Jonassen, 1992; Reigeluth, 1999) From the constructivist perspective, knowledge is neither behavioral changes nor organizational structure resides within the learner. Instead, knowledge is viewed as construction of understanding in a context or is located in the actions of persons and groups. Thus, the ultimate goal of learning is to facilitate the active cognitive reorganization in learners, and their active engagement in the world. Moreover, the focus of design of instruction in the constructivist paradigm has shifted from how to structure instructional events in order to maximize the effectiveness of information transmission to the development of meaningful learning environments that will help students construct their understanding by engaging in meaning-making. Such changes in epistemological and pedagogical beliefs have challenged the practice in the ISD process. Perkins (1992), from a standpoint of cognitive constructivism whose focus is more on the active construction of the mind, has proposed to emphasize on the analysis of the tasks in a meaningful context, on the design of a manipulative space, and on understanding and use of knowledge as assessment measurement. On the hand, Brown, Collins and Dugid (1989), from a socio-cultural constructivist viewpoint, described how participation in social interactions and culturally organized activities influences psychological development. The implications of their descriptions to the instructional design guidelines include (Driscoll, 2000):

• Learning through engaging in authentic activities: this guideline put the emphasis on authenticity and complexity of learning experience
• Change from knowledge dispenser into a learning community, in which teacher and learners work collaboratively to achieve important goals emphasizing distributed expertise
• Assessment In-Situ: assessment requires to indicate person’s performance in the various kinds of situation type. This guideline bring the focus on learning as processes as well as the product

A various instructional models have been viewed as constructivist ones, whose learning environments emphasize both individual and social nature of knowledge construction. I’m particularly interested in an instructional approach, called problem-based learning (PBL). The focus of this paper will explore what types of questions to be asked and the methods to be used in answering those questions in task analysis, especially in designing the problem-based learning environment, which has been identified as a constructivist learning approach (Savery & Duffy, 1995; Jonassen, 1999; Driscoll, 2000). The exploration will start a description of historical development of PBL and its theoretical foundations. Then, I’ll move to examine how the theoretical foundations can help identify the target of task analysis, then describe what existing methods can be used to analyze the target to help develop a PBL environment in terms of PBL pedagogical structure, and finally explore the possible ways derived from the qualitative research methodologies as a task analysis framework in PBL.

**Historical background of PBL**

Problem-Based Learning (PBL) was first introduced as an innovative medical education curriculum. At the McMaster University Faculty of Health Science, the PBL approach was used throughout its entire three-year curriculum (Barrows, 1996). The curriculum has been organized in sequential units with early exposure to patients and case management. In the overview of the use of the problem-based learning on McMaster’s web site, Lee and Kwan indicate that the curriculum structure consists of a series of interdisciplinary blocks or units, which has been designed to involve medical students with a broad range of health problems throughout their education.
Flourishing in medical and professional schools on the curriculum level, the PBL approach has been adapted to be implemented for entire courses or to be used to teach certain parts of course. Rhem (1998), the executive editor of the National Teaching & Learning Forum, recognizes such changes in the implementation of PBL and states that generally advocates accept course long continuity. The scope of the PBL environment is on a course level.

The key features of the PBL program at McMaster are: the analysis of problem as a way of learning, the development of self-directed learning, the use of small tutorial groups, and a faculty tutor in each group (Barrows, 1996). The major factors that initiated the implementation of PBL in the medical education at McMaster University include (Barrows, 1996):

- The dissatisfaction of the learners with the education
- The irrelevance of the learned information to the professional practice
- The learners’ lack of reasoning ability to apply what they have learned to solve problems at the work place.

The proliferation of PBL rises along with changes of demands on college graduates. Because of the explosion of the information and the needs of professional practices, students are expected to develop reasoning and problem-solving skills, to have high level of communication skills, and to be able to work with others.

The claims about its merits on enhancing students’ problem solving skills, integration of basic concepts, self-directed learning and higher order thinking skills have helped PBL has gained a lot of attention in higher education (Hmelo & Ferrai, 1997; Barrows, 1996; Savery & Duffy, 1995). Over the past three decades, PBL has been adopted in a variety of other professional schools, including architecture, business, engineering, forestry, nursing education, law, political science, social work, and education.
Theoretical foundations of PBL

The underlying development and design principles of PBL reflect how people usually solve problems in their everyday lives. In education, PBL has the power to create a problem-anchored learning environment to take up this natural process of inquiry to pursue and use knowledge. Scholars have identified the theoretical foundations of PBL both from the cognitive construction and socio-cultural theories (Schmidt, 1983; Savery & Duffy, 1995; Camp, 1996; Hmelo & Evensen, 2000). The problem as a driving force of the learning process can be explained in Piaget’s concept of equilibration, a cognitive construction process as a learning mechanism, which includes assimilation and accommodation. The assumption is that when the cognitive structure is disturbed, it will assimilate and accommodate to generate new structure because of the human’s self-organization tendency. The problem in PBL serves as anomalies of experience creating a state of disequilibrium (Piaget, 1977), which can only be resolved until a new cognitive structure is adopted. Also, Vygotsky’s sociohistorical development psychology (1986) provides a theoretical grounding for social negotiation of meaning as important part of the problem-solving team structure. Vygotsky explored the dialectic process between the individual and society, and the effect of social interaction, language, and culture on learning proposed. He believes that human mental activity is a particular case of social experience. Thus, an understanding of human thinking depends in turn on an understanding of the mechanism of social experience; the force of the cognitive process deriving from the social interaction is emphasized. Group problem solving process in PBL provides a framework for social interaction, which subsequently is transformed into an internal mental process.

Targets of Task Analysis in PBL

The field of instructional technology has undergone an evolutionary process (Seels & Richey, 1994; Shrock, 1995; Reiser, 2001). Reiser (2001) has proposed a latest definition of the field: “The field of instructional design and technology encompasses the analysis of learning and performance problems, and the design, development, implementation, evaluation and management of instructional and non-instructional processes and
resources intended to improve learning and performance in a variety of settings, particularly educational institutions and the workplace.” In his definition, he identified:

• The tasks and domains involved in the field, i.e. analysis of learning and performance problems as well as design, development, implementation, evaluation of instructional and non-instructional processes and resources
• The function and the goal of the field, i.e. to improve learning and performance
• The settings of practice, i.e. educational institutions and workplace
• The means used in the field, i.e. systematic instructional design procedures
• The foundation, i.e. research and theories as knowledge base that supports practice of the field

Within this structural framework of the IT field, task analysis is one segment of the instructional design process. However, it is the foundation for instructional design. Jonassen, Tessmer, and Hannum (1999) stated the purpose of task analysis as follows:

• It determines what must be learned to achieve the learning goals.
• The results of task analysis can be transformed into statements of learning goals, which determine what actually gets taught or trained.
• It analyzed the learning situation for the purpose of making instructional design decisions.
• It is used as a basis to organizing tasks and task components as well as sequencing them.

The shift of paradigm from behaviorism to cognitivism has changed the focus of task analysis on behaviors to the internal mental representations and processes. From the perspectives of behaviorism and cognitivism, learning is an outcome, either behavioral change as a result of shaping by a series of reinforcement or a reconstruction of knowledge representation as a result of mental process. Under these circumstances, if learning focuses on behaviors, then the target of task analysis should focus on the desired behaviors. Job task analysis, procedural analysis and functional job analysis (Jonassen, Tessmer, & Hannum, 1999) seem to serve the purpose. If learning focuses on transmission of “knowledge” as mental representation, then the target of task analysis
should focus on the required “knowledge” entailed in the task. Methods, such as learning hierarchy, information processing, the methods that Jonassen, Tessmer, and Hannum (1999) classify as cognitive task analysis methods, meet the ends.

But, problem-based learning was developed out of constructivist view of learning. What should be the target of task analysis in design the PBL environment? Also, will those purposes of task analysis that Jonassen, Tessmer, and Hannum (1999) identified still stand in the design of PBL?

To answer those questions, we should examine the concepts of learning and learning from the constructivist perspective more closely. Defining constructivism from the aspects of learning and knowledge, Fosnot (1996) recognize the dynamic of knowledge and the condition of social interaction in learning:

“Based on work in psychology, philosophy, and anthropology, the theory describes knowledge as temporary, developmental, nonobjective, internally constructed, and socially and culturally mediated. Learning from this perspective is viewed as a self-regulatory process of struggling with the conflict between existing personal models of the world and discrepant new insights, constructing new representations and models of reality as a human meaning-making venture with culturally developed tools and symbols, and further negotiating such meaning through cooperative social activity, discourse, and debate.” (p. ix)

In such view of knowledge, knowledge evolves as individual participate in and negotiate in the learning process (Wilson and Myers, 2000). Predetermination of what should be taught becomes impossible. The implication here is that task analysis may not take place only before design of learning, but task analysis should be a continuous process along with the learning process. Moreover, the concept of learning derived from social interaction draws attention to the skills of communication in group dynamics and the context where the interaction occurs. Duffy and Cunningham (1996) explained this change of focus very clearly.
“Traditionally in instruction, we have focused on the information presented or available for learning and have seen the activity of the learner as a vehicle for moving that information into the head. Hence the activity is a matter of processing the information. The constructivists, however, view the learning as the activity in context. The situation as a whole must be examined and understood in order to understand the learning. Rather than the content domain sitting as central, with activity and the "rest" of the context serving a supporting role, the entire gestalt is integral to what is learned.” (p. 171)

So, what is learned is specific to the situation and the activities in which it is learned. The focus of learning is the activity in context. The target of the task analysis should focus on the activity and the context. But, what are the activities involved in PBL? And what components consist of the PBL context? Based on our understanding of PBL form its theoretical foundation, the major activity in PBL is the group problem solving, which provides a framework for social interaction. The premise here is that all learning is problem solving in social situation. Based on the descriptions of the PBL practice in education (Barrows, 1996; Wilkerson & Gilserlaer, 1996), The PBL approach highlights the following major components:

- **Authentic, Complex Problems**: Problems establish the inquiry nature of the PBL environment. Students reason and explore their need-to-know in the direction of solution.

- **Active learners**: In PBL environment, students are encouraged to become responsible for their learning. The PBL approach supports students to construct and produce knowledge in meaningful ways. As the progress through the problem, they engage in question-asking behaviors, and continue to define their own learning issues. They identify what information is needed for a particular application. Also, students identify where and how to seek information, and make good use of appropriate information resources. It is through this active and reflective thinking process that the students become responsible for their own learning.

- **Collaborative Learning**: Students work together to solve problems. The nature of collaborative learning does not only include the division of labor among the learners, but also “mutual engagement of participants in a coordinated effort to solve the problem together” (Roschelle & Teasley, 1996?). The emphasis is on the social
negotiation in the shared meaning, the continuous development of individual
cognition, and team performance toward problem solving.

- **Faculty as facilitators or guides:** The instructor must guide, probe and support
  students’ initiatives. They work together with students. They do not simply lecture
  and provide information. They work as a learning manager, coach and model. They
  need to organize learning environment and resources. They observe and monitor
  students’ learning process, and give appropriate feedback and guide in time.

- **Learning Resources:** In PBL, students are encouraged to explore a variety of
  resources in seeking the information they requires. Thus, the instructor does not only
  have the responsibility to create a learning environment full of opportunities for
  students explore, articulate and reflect what they learn and how they learn, but also
  need to provide knowledge resources and tools to support students to successfully
  engage in such learning actions.

Therefore, in order to facilitate the group problem solving activity and develop the PBL
components, the task analysis in design of the PBL environment should serves the
following function:

- Identify problem and its context in order to give learners the meaningful learning
  experience as well as the authentic physical and cognitive environment
- Identify alternative solutions to the problems to provide resources
- Analyze group problem solving process and communication process to engage
  learners in discourse and reflection, and to provide teamwork guidelines to facilitate
  the collaborative process
- Analyze shared knowledge in the continuous knowledge construction process to
  monitor group progress and to provide in-time support

**Task Analysis Methods in PBL**

Task analysis basically is a process to identify human capabilities that supports the
performance of a task under analysis. Therefore, it usually involves breaking down a task
performance into smaller steps, and identifying different human capabilities that support
the task performance. Chipman, Schrragen, and Shalin (2000) naturally classified task
analysis into two major categories, traditional task analysis, and cognitive task analysis, when they gave an overview of each chapter in their edited book Cognitive Task Analysis. Traditional task analysis refers to breakdown of observable task performance into a series of overt observable behavior that support the performance; cognitive analysis is “the extension of traditional task analysis techniques to yield information about the knowledge, thought processes, and goal structures that underlie observable task performance.” (Chipman, Schrragen, & Shalin, 2000). The distinction mainly lies in overt physical actions and covert cognitive process. The development of cognitive task analysis was initiated because of the evolution from industrial age to information age, which was explained by Reigeluth (1999) as changes in instruction’s supersystems that have impacts on the paradigm of education and training. The needs for standardization and efficiency gave more weights to the mechanistic analysis of the job performance; the demands for customization and effectiveness call for understanding of complex thinking and of process of problem-solving underlying the task performance. In fact, a lot of cognitive task analysis methods arise from analyses of human-computer interaction, which tackle the mental activities distributing and interacting between human and machines in decision-making, critical diagnostic and control tasks.

Jonassen, Tessmer, and Hannnum (1999) described five classes of task analysis:
1. Job/performance analysis, which aims to reduce tasks to their simplest activities so that they can be learned quicker and performed more reliable.
2. Learning analysis, which focuses on the cognitive activities required to efficiently learn. The analysis principle is to identify mental operation into a hierarchical and sequential structure.
3. Cognitive task analysis, which define the associated knowledge states underlying the performances.
4. Content and subject matter analysis, which examines the concepts and relationships of the subject matter.
5. Activity-based method, whose target of analysis is human activity and understanding how humans act in social and cultural context.
Such classifications recognize the differences in the functional purposes of task analysis and the types of human knowledge and capabilities to be analyzed. For example, learning hierarchical analysis, decomposing human cognitive skills into the rules and concepts in a hierarchical structure, could be used to identify topics that need to be taught and the sequence of teaching those topics. Activity theory, exploring the interaction between the individual in the society and the environment in terms of tool, rules and division of labors, could help identify what types of support to be provided in the learning environment.

In the PBL environment, problems were used as a stimulus for students to start the learning process. Students work in groups to solve problems. The problem entails four major problem solving processes: understanding the problem, learning, solution, and reflection (Hadgraft & Prpic, 1994) within a collaborative effort. When students confront a problem, they first analyze the situation, then identify what the problem is, and speculate possible solutions to the problem. Then, students need to investigate the problem further. The power of the problem solving is that the gaps between what students has known about the problem and what students need to know to solve the problem create the room for learning. Students have to inquire the information that they need to know, and come up with better hypotheses and better solutions. One of the major characteristics of the PBL approach is collaborative learning. In this investigation stage, it is important to focus on how they are going to share information in order to solve the problem and how help each other to learn.

Then students have to determine the best solution weighing the pros and cons of the alternative solution. In the end, students also need to reflect and evaluate their learning progress through the problem solving process. It is through this active and reflective thinking process that students become responsible for their own learning. It is the application of their knowledge to the problem that students test and integrate what they learn. In general, PBL aims to motivate students to participate in the learning process and to help foster problem solving skills.
What types of task analysis methods can be employed to design PBL environment in order to support students’ active engagement in those problem solving processes? The specific functions of task analysis have been identified in the design of PBL above. With each of these functions, certain methods and future development are suggested below.

**Goal One:**

*Identify problem and its context in order to give learners the meaningful learning experience as well as the authentic physical and cognitive environment*

Problems lay out the main structure of PBL. The problem serves as a learning mechanism. The major purpose of the problem in the instruction is to use it to identify what are called learning issues, topics for further independent and group study. Barrows (1986) mentioned that the “common denominator” in the PBL approach is the use of problems in the instructional sequence. Problems are essential elements used to motivate and focus students’ learning. But, what problems are appropriate for PBL? Stinson and Milter (1996) suggest that problems should involve learners with the similar or same type of skills and activities in professional practice. In other words, problems should mirror “the same type of cognitive challenges” tasks (Savery & Duffy, 1995) as in the real-world professional practice.
Also, the problems should not be limited to one correct answer; they should be open-ended. In order to design realistic problems in real-world context, the three principles of the PBL problems should be noted: relevance, authenticity, and complexity. Whether the process of solving this particular problem will optimize students’ problem solving and reasoning skills in the knowledge domain related to the subject matter determines the extent of relevance. Authenticity motivates students to take up the inquiry process as well as promotes transfer of knowledge in future problem-solving situations. Moreover, authenticity also implies the opportunities for students to take multiple perspectives into account while solving the problem. Most importantly, the problem must provide students to experience a cognitive conflict so that they can recognize that they are not able to solve the problem with what they have known about the problems.

In practice, several of developing problems in PBL have been suggested. John Cavanaugh, vice-provost for Academic Programs and Planning at Delaware, advises the instructor to take the world problems and essay questions in the exams and make cases out of them (Rhem, 1998). Such suggestion emphasizes the importance of the relevance to the content topics and the functions of the problem as a starting point of the learning process instead of as an end result of the learning process.

There are two other different approaches in design of the PBL problems. One begins with identification of the objectives of the course, and develops a problem incorporating the skills and knowledge that students are expected to learn in the statements of objectives. Bendett (1999) shares the procedure of developing problems in their successful team efforts at the University of Connecticut:

- review / revision of the goals and objectives
- brainstorming of possible problems
- classification of the problems in terms of the skills and/or content topics with which the problems are associated
- selection of a tentative list of problem for use in the coming year
- further definition of the problems by a subgroup from the main team of facilitators
• presentation of the problem definitions to the entire team
• further material development by the subgroup for each problem
• presentation of materials to the entire group followed by serious review by a different subgroup
• preparation of the entire problem "instructor's manual" by the subgroup followed by its distribution to instructors

Duffy and Cunningham (1996), although arguing the philosophical differences in constructivism, did not abandon this traditional analysis approach to begin the design of PBL. Their statements seem to still view knowledge as a product instead of a process.

“In designing a problem-based learning curriculum, as with any curriculum, we must begin with an analysis of what must be learned. However, in doing this, the developer must combine identification of the key concepts, procedures, etc., with an analysis of the professional (or "good citizen") use of those concepts. Identification of key concepts is a matter of expert statements of what is most important for students to "know" (p. 191).

Another begins with identifying the problem solving tasks in the situated, real-world setting. This approach aligns more with the constructivist concept of learning as a process of enculturation. The emphasis is placed on the socio-cultural setting and the activities of the people within the setting. The premise underlying such design is that “learning is not an accumulation of information, but a transformation of the individual who is moving toward full membership in the professional community.” (Hmelo and Evensen, 2000). Thus, the source of the problems should come from the real world, such as case history of a patient or a company, court documents, news or the experts in the field. Find out from the experts what the typical problems which practitioners would be likely to encounter in their career. The development of problems can be individual or team efforts. In order to identify realistic problems in real-world context, the following task analysis techniques are helpful.
PARI (Precursor-Action-Results-Interpretation)
The PARI methodology is a structured think-aloud approach for analyzing tasks engaged in working with technologically complex systems in real world work environments (Jonassen, Tessmer, & Hannum, 1999). Basically, the purpose of PARI is to elicit experts’ knowledge about how they solve problems posed by other experts.

The process identifies experts in the field, determines problems among the negotiation of the experts in terms of criticality, representative, and frequency, develops problem statements, and uses techniques of interviews and diagram drawing to elicit experts’ knowledge of solving problems. In this method, knowledge is conceptualized as mental representations, such as the experts’ conceptual and procedural knowledge, their mental organization of device structure, and their mental model of the tasks. Thus, this method is able to help identify authentic problems, but the degree of complexity may not necessarily demand different expertise and require collaboration. Also, the process of developing problems in this method focuses on the descriptions of the immediate conditions where problems arise, but it does not entail any other rich contextual information, such as who has been operating the system, and what other problems have occurred to the system so far. Therefore, the method seems not to be useful to develop social problems that involve different stakeholders, perspectives, and value judgments.

Case Base Reasoning
Case Base Reasoning (CBR), originated from the field of artificial intelligence, is a formalism for representing what people know and remember (Jonassen, Tessmer, & Hannum, 1999). CBR derives its theoretical support from memory organization and reminding in cognitive science (Shank, 1982; 1990). Shank (1990) asserts that what people know is stored in memory as stories. CBR uses prior experiences in the process of problem solving. CBR argues that the acquisition of expertise is to accumulate experiences with a succession of real cases and to properly index these experiences for later retrieval (Koschmann et al, 1997). It is the aspect of collecting and organizing stories in designing CBR that can be applied to task analysis. The techniques, such as structured interviews and surveys, are used to elicit knowledge from the perspective of a
problem solver about the problem, the actions and the intention behind the actions in the problem solving process. In design of PBL, the data from such case collecting is particularly valuable for identifying different issues and factors in a problem. To embed those issues and factors into the problem can establish its complexity. Also, incorporating the tone of storytelling from different stakeholders into the presentation of the problem adds to its authenticity.

CBR, as a learning model, promotes learning through cases. The access to old cases generates the power of problem solving through the reasoning activities. This implies a potential instructional practice. Kolodner, Hmelo, and Narayanan (1996), in fact, proposed to incorporate CBR with PBL to enhance learning. They suggested that a library of cases that cover an adequate variety of the problem solving experiences from others should be presented at the moment when the cases are needed. It is expected that the case library, providing the experiences that human learners lack, will be able to augment learners’ memory and thus enhance learners’ problem solving and reasoning skills. This utilization of CBR in design of PBL actually accomplish another goal that task analysis methods can contribute to, that is, identifying different views and alternative solution to provide resources.”

**Activity Theory**

Activity theory is claimed to be an interdisciplinary approach to human science that originates in the cultural-historical psychology school of thought, initiated by Vygotsky, Leon’tev, and Luria (Engström, et al., 1999) in the 1920s and 1930s. It is a philosophical framework that explains the structural and functional components of human activities. Its roots can be traced back to the work of Karl Marx. The Marxist theory of dialectical materialism asserts that historical changes in society and material life produce changes in human nature. Such human changes are not only “within the human individual but in the movement between the insides and outside, in the worlds of artifact use and artifact creation” (Engeström, et al., 1999). The implication of activity theory to instructional design is exactly drawn from this constructive dynamics in the dialectical relationship among people, the activity, and its context. The assumption is that “if socially organized
labor activity provides the context for how people to act and think, it also provides an appropriate context for learning” (Driscoll, 2000?). Thus, the design for learning focuses on the activities that people engage in.

The adaptive view of human activity is viewed as consumption with three major dominant aspects: production, distribution and communication (Engeström, 1987). Those aspects place the human activities in the interaction between the individual (subject) in the society (community) and the environment (object). The interaction between these three components is not direct but mediated by tools, rules, and division of labor (see Figure 1).

![Activity System](image)

Figure 1: Activity System (Engeström, 1987)

Activity theory, from this systems view, helps to examine closely the social and cultural context where the task performance takes places. Jonassen and Rohrer-Murphy (1999) pointed out that the emphasis of examining activities in context has provides richest information of different components in the problem context: “the activities in which people are engaged, the tools they use, the social and contextual relationships of collaborators, the goals and intention that drive activities and the objects or outcomes of those activities.”

Exploring another alternative framework for design constructivist learning environment, Jonassen and Rohrer-Murphy (1999) proposed the potential influence of activity theory
on instructional design. Based on Leont’ev hierarchical levels of activity, activity, driven by the social motive, is analyzed into a set of actions that require a conscious goal; then actions are broken down into chains of more routinized or automatic actions carried out by human or machine.

Another theoretical foundation drawn from activity theory to the development of learning environment is Vygostky’s claim that “mental processes can be understood only if we understand the tools and signs that mediate them.” It is this idea of mediation that gives the emphasis on placing learners in the relevant and authentic context for learning. The application of the activity theory to task analysis is valuable in its exploration of the activity within the context and its emphasis on the intention and goal. Such analysis adds authenticity and meaningfulness to support the design of the problem-based learning environment.

**Goal Two:**

**Identify alternative views and solutions to the problems to provide information resources**

As it is mentioned in Goal One, CBR, as a learning model, promote learning through cases. CBR system is laid on Schank’s (1982) arguments on the role of reminding, which coordinates past events with current events to enable generalization and prediction. Thus, problem solving can be viewed as a process of remembering a specific problem-solving instance, adapting its solution to fit the current situation, and storing that adapted solution in the memory. It is exactly the accumulation of the cases that demonstrates the acquisition of the expertise. Learning, in this case, means “extending one’s knowledge by incorporating new experiences into memory, by re-indexing old experiences to make them more accessible, and by abstracting out generalizations from experiences” (Kolodner et al., 1996). Therefore, it is thought to be useful to teach novices, who do not have much problem solving experience, by presenting stories of others in the problem-solving context. However, there are several design issues that we have to pay attention to in providing the cases as information resources.
In case-based reasoning, the degree of relevance of the retrieved case to the new situation is a crucial element to the reasoning process. Thus, the research on CBR is more concerned with the issue of indexing to form correspondence between the new experience episode and a previous one. The index is important because an index for a case allows a reminding strategy to recognize situations in which the case is relevant. Therefore, to use cases as resources in PBL, the designer needs to analyze the interrelationship between the cases and the problem at hand so that the cases can be presented with the relevant problem at an appropriate time.

Another design concern is how to help students to reason through the cases while they are facing the problem situation. The theoretical support for the learning strength in CBR is derived from the ability of reasoning the old problem solving episodes to navigate the new ones. A problem solver or a case-based reasoner demonstrates reasoning ability in the process of interpreting and adapting the solution through analyzing the similarities and differences of similar cases. To refine the expertise in retrieving and adapting stored cases, Leake (1996) proposed to use introspective learning. Learners have to be aware of their own problem-solving process in order to become successful case-based reasoners. Also, Chi et al. (1989) observed that students who explain to themselves problematic aspects of worked example show superior problem solving. Better learners learn by constructing explanations to help understand the presented examples. Reimann and Schult (1996) suggested that a problem solver to take into account the rationale to the example solution when trying to relate it to a new problem-solving task. In other words, in order to learn successfully from examples, one must identify operator-goal relations, i.e. the problem solution steps to each other and to the goals those steps serve. All these propositions bring the design back to the focus on learners’ own active construction of knowledge, and highlight the importance of providing students opportunities to engage in reflective thinking in use of the resources.

**Use of Task Analysis Methods**

In constructivist learning environments, such as PBL, the learning mechanism is not transmission of knowledge from one mind to another’s; it is the interpersonal and
intrapersonal construction of meaning making. Some common task analysis methods in use, such as learning hierarchy analysis, and information processing analysis seems to be out of picture in design of the PBL environment because they still views knowledge as a predetermined product, and aim to identify what to be taught which lead to how to teach and how to assess. However, those methods are still helpful in the design of PBL. It is the way of how we apply the results of such analyses in design needs to be changed. The results of those analyses should no longer serve as learning objectives or evaluation criteria to determine what to teach and how to teach. Instead, they could be used to identify information resources or tools that students may need when they engaged in the problem solving activities. The same principle is applied to all the techniques of engaging experts in articulating their reasoning, such as their hypothesis, actions, plans, and interpretation when they solve problem. The identified knowledge base, thinking processes and problem solving strategies through those techniques no longer predetermine students learning outcomes. They should be used to identify what information and tools to be provided to students, and how to model the problem solving strategies and the thinking processes to support their learning. The issue here is the intention of control of learning. The reason about giving up the control is the premise that construction of meaning is tied to specific contexts and purposes. Knowledge is located in the actions of persons and groups, which is in a constant change.

Such premise reveals the limitation of the knowledge elicitation methods in task analysis in the design of PBL. If we believe that knowledge constructs in the context, the analysis cannot take place without a context. Retrospections, verbal think aloud after task performance, and interviews all detached problem solvers from the original context. Observations and think-aloud during the task also have their limitation on the obtrusive effects. Another problem about knowledge elicitation is that most does not capture the group dynamic in action. If knowledge resides in social interaction, then analysis should capture that interaction in the process.
Goal Three:

Analyze group problem solving process and communication process to engage learners in discourse and reflection, and to provide teamwork guidelines to facilitate the collaborative process

Collaborative structure is a critical component in PBL. Faidely et al (2000) recognized four major learning advantages of collaboration: (1) collaboration distributes the cognitive load among the members of a group, (2) collaboration results in group’s distributed expertise, (3) collaboration enhances reasoning and higher order thinking with challenge of different perspectives, and (4) collaboration facilitates self-reflection. The exploration of collaboration has mainly focused on under what circumstances collaborative learning is more effective, and whether collaborative learning is more effective than learning alone (Johnson and Johnson, 1974; Dillenbourg et al, 1996).

Implication of PBL Research to Task Analysis

The value of PBL is seen in its aim to motivate students to participate in the learning process so that students are able to improve their problem-solving skills, integrate basic concepts, and foster self-directed learning and higher order skills (Barrows, 1996). This view of PBL has elevated a lot of research studies on PBL investigating five major issues: Does PBL work? What are the impacts of PBL on students’ thinking? What elements in the PBL environment make instruction or learning experience successful or unsuccessful? What is the structural model of the problem-based learning process? What is problem-based learning experience? The research specifically on group learning process in PBL seems to also echo the same trend: the effectiveness on students’ achievement (Schmidt & Moust, 2000) and on the effects of their cognitive process (Hmelo, Gotterer and Bransford, 1994).

From this trend of research in PBL, it indicates that although the group problem solving process is important, the investigation of the process itself has been limited. However, the shift of views of learning, from only the cognitive psychological perspective to the inclusion of cognitive psychological, socio-cultural and socio-linguistic perspectives, has created potentials on the research on the group problem solving process.
For example, a panel presentation at the 1996 Annual Meeting of the American Educational Research Association (Koshmann & Evesen, 2000) had shown the vigor of the results of analyzing the group interaction. Five researchers had analyzed a 6-minute data segment of a tutorial session of a group medical students and faculty from different analysis frameworks: cognitive, socio-cultural, and socio-linguistic. Those analyses provided a better understanding of learners’ meaning making process in a social context by identifying (1) how people organize their interaction, (2) how to use representations in the activity, (3) what is the inquiry process, and skills and knowledge base revealed in the process, (4) what are characteristics of transition communities in terms of social and cultural influence on the interaction as well as in terms of the conflicts and the negotiation of different identities in community, and (5) “how people make meaning by codeploying or coordinating different kinds of representation”, i.e. multimedia semiotics. Those analyses of this interaction process seem to benefit the design in different aspects of the tutorial sessions in PBL: to provide guidelines for tutors make decisions in how to coach and guide students’ learning, to identify the patterns of argumentations and reasoning, and to facilitate the process of reaching an solution through a shared model.

Dillenbourg, Baker, Blaye, and O’Malley (1996) points out the efforts on research have shift from building the causal relationship between the effects of collaboration and independent variables, such as composition of the group, size of the group, nature of the task, and communication media, to understanding the role which such variables play in mediating interaction. They proposed an “interactions” paradigm as a framework for analyzing and modeling interaction. The ultimate goal of their inquiry falls in the positivist paradigm, to establish a lawful relationship between the types of interactions and effects of collaboration on learning outcomes. But, the proposed categories of interaction for analysis, i.e. social/cognitive; cognitive/metacognitive, and task/communicative, can be beneficial in understanding the patterns of communication, negotiation and argumentation from the data collected from observation, video-recording or verbal exchanges via computer media when people are in a conflict situation. A
promising possibility to explore the interactions in PBL groups, as they suggested for research in collaborative learning, is “to exploit selective branches of linguistic research on models of conversation, discourse or dialogue to provide a more principled theoretical framework for analysis.” This mode of inquiry in understanding the collaborative problem solving process aligns more with the conception that knowledge arises from action from the constructivist view.

**Cognitive Task Analysis for Team**

As information technology advances, the complexity of today’s job has challenged cognitive task analysis to identify knowledge and thought processes underlying the job. Sometimes the solutions cannot even be identified beforehand. Lesgold (2001), in his discussion on the future of cognitive task analysis identified this challenge directly.

“Today’s jobs often require complex thinking and the solution of problems that cannot be stated explicitly in advance. They often involve groups of people with different knowledge and skills working together to solve problems. They sometimes involve use of intelligent systems, either as part of work teams or for training team members. Those systems require a much more formal and structure specification of the knowledge that is needed to be a coach or member of work team.” (p. 451)

The challenge has increased endeavors of cognitive task analysis in investigating issues such as team decision-making, team training, and team performance measurement (Blickersdefer et al, 2001). The unit of analysis is now group in action. The analysis focuses on the processes of (1) how the group communicates and coordinates to work together, (2) how the group learns from each other and adopt itself to move the group work further, and (3) how the group’s knowledge can be captured in this continuous problem solving process.

“Cognitive task analysis (CTA) for teams differs from that of individuals in two major areas. First, this analysis must identify, define, and describe the cognitive processes and knowledge associated with teamwork processes (e.g. communication, coordination,
adaptability). Second, it must be capable of addressing the issue of team knowledge.”
(Blickensderfer et al, 2001, p. 431)

In design of PBL, the concerns about group work include how to form groups, how
students should work in groups, how to assess group work incorporating individual
accountability and team knowledge, and how the instructor should guide the group
process and provide in-time support. The issues of how to work in groups and group
assessment, specifically communication, team management, distribution and
collaboration of the tasks, and identification of team knowledge, can be better understood
with the help of task analysis in team work.

The analysis framework that Zachary, Ryder, and Hicinbothom (2001) conducted in
building executable cognitive models of a team of human decision makers in a ship-based
combat information center draws attention to the techniques of knowledge elicitation and
to the collaboration process in design of PBL. They criticized that solely using
observations, think-aloud during the real time or interviews after cannot capture the
interaction in team; therefore, they proposed to combine both a recording of all actions in
the problem solving instances and a think-aloud protocol immediately after the problem
session is over. The procedure means to capture cognitive processes in real-time,
multiple-task demands. Aiming to create and maintain a shared team conceptual order,
their analysis focuses on identifying ways of coordination, competition of resources, and
cooperation among team members. Such practice in cognitive task analysis about groups
shed some light on “communication patterns and how they related to accomplishment of
team goals” in design of group work for PBL. (How? How?)

**Analyze shared knowledge in the continuous knowledge construction process to
monitor group progress and to provide in-time support**

In the practice of implementing PBL into the classroom, the issues of assessment remain
in the effectiveness of groups on learning, assessment of team performance and
individual accountability for team performance. The assessment of team performance is
more concerned with the evaluation of the quality of the artifacts created by a team and
the team evaluation of group dynamics and individual contribution to the team. The
rationale behind the assessment of the artifact is that the artifacts represent the group’s
knowledge, a result of collective cognitive efforts. The team evaluation is usually
designed to detect group conflicts in communication, and take care of the issue of
individual accountability. However, seldom does the assessment of team performance
explore an assessment framework that is able to reveal the continual movement of
cognitive conflicts and growths within individuals and between individuals, and the
evolution of the collective group knowledge from the beginning to the end.

From the constructivist view, learning is often characterized by the subjective
reconstruction of societal means and models through negotiation of meaning in social
interaction. Thus, learning occurs in so called “zone of proximal development”
(Vygotsky, 1978), the growing space between the individual independent developmental
level and the potential level under the guidance of or in collaboration with peers as a
result of social interaction. Jonassen (1992) expressed the subjective view of evaluation
from the constructivist perspective in his conversation with the scholars.

“Constructivism holds that the mind is instrumental and essential in interpreting events,
objects, and perspectives on the real world, and those interpretations comprise a knowledge
base that is personal and individual.” (p. 139)

From this view, any rubrics or any kinds of standard subjective criteria cannot truly
indicate the constructivist conception of learning. The alternatives of assessment have
been suggested, such as personal reflections of the learner’s meaning-making process and
a portfolio that shows a continuous development of the learner. But, in what way, should
the learner examine his or her learning process? Also, there is an issue of collective
knowledge representation. In order to assess team performance, will artifacts reflect the
developmental process? Those team assessment issues can be talked down with more
exploration of what team knowledge is all about.
Hierarchical Task Analysis of Team Assessment

Annett and Cunningham (2001) proposed a modified hierarchical task analysis to develop the measurement of team assessment. The hierarchical task analysis identifies three elements of performance: the task goal, the processes required to attain the goal, and an indication of error or attainment as a feedback loop. This classification gives us a conceptual framework to examine the continuous change of individual and team learning. For personal reflection, the learner should keep track on his or her goal of learning, describe his or her planning and evaluation of actions to be taken, and reflect the changes due to any input from the interaction with the learning environment. Group evaluation can take the same position to examine as a group the process of their goal setting, planning and the “input-action-feedback loop”, i.e. goal-process-indicator.

Moreover, this “input-action-feedback” does not only focus on the human capabilities, as the traditional task analysis does, but also on the physical, cognitive and social factors in the environment that learners interact with. Their awareness of such ecological structure in team performance is also revealed in their proposed components in their analysis of three constructs at the cognitive level: the world model, the people model, and the team plan.

“The cognitive constructs, generally referred to as mental models represent the knowledge held by individuals that appears to be relevant to team performance. The world model is the individual’s of the environment or problem space in which the team finds itself…The people model represents the individual’s understanding of colleagues, what they do, what they know, what state they are in, and whether their support can be relied on. The team plan represents the individual’s knowledge of team goals and strategies to attain those goals.” (p.406)

This cognitive task analysis of team skills re-structure the organization of the task from a static uni-dimensional state of knowledge to a dynamic multifaceted fluidity of knowledge; it also expands the scope of analysis from within individuals to the interaction between individuals and the environment. It includes a social domain within the traditional domains of learned capabilities in psychomotor, cognitive, and affective
(Gagne, 1985). Such inclusion corresponds to the structure of social negotiation in the constructivist view of learning.

Annett and Cunningham’s Hierarchical Task Analysis (HTA), as described above, provides an alternative analysis framework, especially in design of the constructivist learning environments. Applied to the design of PBL, besides, to collect information from students’ observable behaviors and attitudes, the assessment can integrate information about the learners’ cognitive model of the world, people, and team plan. Thus, the learners can understand their own learning process more and adjust the process if needed; the instructor can detect learning problems and provide in-time support. In other words, in design of PBL, this task analysis method can be used as guidelines for self-reflection or as an individual evaluation of group process to identify what they have known, done, and achieved, and what they need to know, to and achieve, and what the consequences of the knowing and doing will be. Assessment becomes part of learning in the nature of continuity in social interaction. This method provides the constructive power that drives the feedback mechanism back to the team itself and self-regulate toward the goal. However, one issue about team performance still exists, i.e. what is the collective cognitive and social knowledge? How do we assess it?

Definition of Team Knowledge
Blickensderfer and her colleagues (2001) recognized the importance of identifying, defining and describing team knowledge in team cognitive task analysis. They made the distinctions about “pretask team knowledge”, and “dynamic team understanding”. They defined pretask knowledge as knowledge that exists in long-term memory, which consist of the understanding of the team ‘s objectives, teammate’s roles and responsibilities, and teammate’s characteristic as well as knowledge of the equipment, relationships among equipment, and task operation. On the other hand, dynamic team understanding is the team knowledge that develops when the team is actually performing the task; it is “the degree to which teammates develop compatible assessments of cues and patterns in the situation, the implications of these for the team and task, how the team is proceeding, and particular actions that certain team members need to take” (Blickensderfer et al, 2001).
If we examine the domains that this definition of team knowledge contains, similar to Annett and Cunningham’s HTA, Blickensderfer and her colleagues also recognize the impacts of the social domain of human capacities and the importance of ecological perception to human cognition (Lave, 1988). The analysis looked at the team as organism in relation to their environment. But, different from Annett and Cunningham’s HTA, the target of analysis in Blickensderfer and her colleagues’ view has been shifted from an individual level to a collective one. It is the “shared knowledge” that consists of team knowledge, not an individual reflection or evaluation of the team performance. The reflection and evaluation need to be representation of team mind.

(Possible citations from von Glasersfeld?)

The identification of such team mind, suggested by Blickensderfer and her colleagues (2001), can be tackled down from different information sources: the separate interviews of all team members, observations of the team performing the task, and examination of documents regarding to the team task. A goal-action analysis framework is applied to identify a team structure consisting of goals, means, and the relationships between goals and means. Then, a follow-up group interview should be conducted to validate and supplement the identified task structure. I applaud this utilization of the use of multiple sources to establish the consistency of analysis. However, I will suggest treating the group interviews and the observations of the team performance as the primary data to begin with the analysis, and then check again the individual interviews.

In design of PBL, the variety in ways of knowledge elicitation and the goal-action analysis framework described by Blickensderfer and her colleagues (2001) provide a relatively concrete model to identify dynamic shared understanding of the problem at hand, the group process, and the solution. As it is mentioned, the underlying notion about knowledge in PBL is that knowledge is socially negotiated, i.e. “students’ understanding of the content is constantly challenged and tested by others” (Savery & Duffy, 1995). Coupled with this notion, team knowledge as a joint effort in PBL should be viewed as a
continual construction and maintenance of a shared conception of a problem. The focus is on the mutual engagement.

**Conclusion**

From the ontological, epistemological and axiological views underlying the practice in problem-based learning, the power of learning in PBL is derived from the essential components in its environment: the authentic, complex problems, active learners, collaborative learning, faculty as facilitator or guides, and learning resources. The design of those components can be better conceived if we can get hold of better task analysis tools in to help understand what consists of this group problem-solving phenomenon. Because the constructivist view of knowledge and the team-focused analysis, the investigation of PBL should be undertaken with a more compatible philosophically inquiry with constructivism, and the collaborative learning should be best described in a systems view.

Banathy (1996) identified the major views of a system: open system, holistic view, goal-directedness and self-organized. Team, as an open system, keeps evolving and the characteristics of a team keep emerging through the interaction within itself and its interaction with the environment. Team, as a whole, is bigger than individual. The interaction of the team members is the power to create the team has a meaning on its own. Also, team is goal oriented. Every team member is interdependent with each other and engages in feedback to work together toward the goal. From this system view, measurement of teamwork becomes critical. Activities in team are basically the “acts of control” (Annett & Cunningham, 2001). Unless a team know where its goal lies and where it is in the process from the goal, the activities it engages will be pointless.

Most importantly, team, as a self-organizing system, assesses continuously its own progress, negotiates within team to resolve conflicts and to reach a shared-understanding, and plans further actions to achieve the goal. Thus, task analysis in PBL is a continuous process. The unit of analysis is not a desired observable behavior, knowledge as concepts
and rules, or a state of a knowledge representation. The unit of analysis resides in the
group problem solving process. Knowledge is always in the state of constructing and
interacting with the social and cultural context. When Fosnot (1996) explained
constructivism from Piaget’s concept of cognitive equilibration, the statement entailed
the perfect illustration of the inseparability of structure from construction.

“…the subject (cognitive structures) exists because the being of structures consists in their
coming to be, that is, their being ‘under construction’. (p.?)

How can instruction design capture this continuity in the individual and collaborative
construction dynamics in PBL? It seems that there has not been too much attention in the
practice in PBL. This paper is an initial effort to explore some possible solutions in the
literature in task analysis. The recognition of the inevitability of subjectivity and the
characteristics of continuity in knowledge construction has led me to take Clancey’s
(1995) interactional view of designers to approach the design of PBL. The design process
should involve the instructors and learners who participate in the learning process. Also,
the design process does not take place before learning, but during the learning as well as
after learning.

“We as instructional designers must go into the community of the practitioners, using
ethnographic methods of observation and reflection, and become participant
observers. We develop a focus on how the community learn.” (p. 33-34)

References:


