A Learning Journey in Problem-based Learning

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Abstract: This ethnographic case study describes what happened when a high school biology teacher in Singapore adopted problem-based learning (PBL). Using activity theory, we compare her instructional unit with a reference PBL model derived from the literature. We found disparities in the motives driving these two activity systems, which we attribute to differences between the lived-realities of practitioners and academics. As the researchers collaborate with practitioners through joint reflective practices, our goal is to work towards an equilibrium point whereby PBL could be implemented meaningfully and realistically in an Asian society that has long placed a premium on academic achievement.

Introduction

Most educational theorists now promote "learning in context" (Driscoll, 2000), "activity in context" (Duffy & Cunningham, 1996) or "authentic activities" (Brown, Collin & Duguid, 1989) to engender more meaningful forms of learning. Problem-based learning (PBL) is one such example whereby students work in groups to solve "real world" problems. Popularized during the 1960s, it tries to engage students with ambiguities that prevail in everyday situations, integrating learning across subjects/disciplines through the active construction of knowledge (Barrows & Tamblyn, 1980). Its focus on content knowledge and metacognitive skills made it a popular choice with school practitioners for its promised transfer to real life applications rather than acquisition of inert knowledge.

This paper discusses an ongoing design research in which researchers and teachers work collaboratively on a PBL curriculum. The ethnographic study was conducted in the context of an Asian society (Singapore) where national examinations are highly valued as they are often regarded as the determinants for future educational and career prospects. Driven by this goal, an efficiency model towards learning is usually adopted by teachers and students to achieve the instructional objectives as defined in the national curriculum. Thus far, this strategy has yielded favorable results in international tests, especially in the areas of mathematics and science (Gonzales et. al., 2004). However, the call for a shift to developing critical inquiry by the local Ministry of Education has seen schools attempting alternative learning approaches such as PBL. In part, this move was triggered by the growing realization that innovation and creativity are the key to plugging into the knowledge-based economy. Changing to more progressive forms of instruction requires not only systemic changes to the learning environment but also challenges prevailing beliefs and values inside and outside of school. In the process of change, teachers and students often straddle between the theory-practice divide, which is perhaps a necessary journey towards their end goals.

Through the lens of cultural-historical activity theory, we sought to reveal disparities and contradictions that existed between one school-based PBL learning unit and that described in literature. For example, when PBL was implemented in these schools undergoing change, how did it change the socio-material resources? Would some of these conflicts between the newly introduced practices and old philosophies of learning be so entrenched as never to effect expansive learning? The many contradictions that arose thus serve as useful nodes where we can engage practitioners in critical reflection of their practices and develop their learning trajectory. Similarly, it caused us to reflect and evaluate our original purposes for the research; was it transformatory, exploitative or hegemonic? Were we mindful of the lived realities in school? The ultimate goal is to reach an equilibrium point between theory and everyday school practices so that PBL can be meaningfully and realistically implemented in a society which long placed a premium on academic achievement. In the following sections, we present the methodology, our interpretation of the PBL activity system as derived from the literature, and then contrast it with the PBL classroom in our case study in order to uncover the numerous tensions that Singaporean teachers currently face. We conclude with some suggestions for facilitating the learning journey in PBL.

Methodology

The fieldsite was a public high school that adopted PBL in an attempt to achieve an integrated approach for teaching science. This school launched an Integrated Program, which aimed to engage students in deep learning through problem solving in contrast to the traditional approach whereby science was separated into its main disciplines. Our ethnographic case study focused on a group of four students in a class of 23 high ability and mixed gender students in Miss Chen's (a pseudonym) ninth grade foundation science classroom. In our sample, the students worked on a problem involving the protein structure of hair and went through six lessons, each of about one and a half hours duration, to solve the problem.

We adopted a design research approach to the design of the learning environment. Data from each phase of the design research provided important information for us to work with the teachers in the design of the next phase of the research cycle. It also informed us on the necessary interventions that had to be introduced into the cycle. In this study, we looked at the implementation of the PBL approach in the classroom described above. The activity or discourses of the students were captured on video, transcribed, and then analyzed using cultural-historical activity theory. The components of the activities of both the actual enacted classroom and the theoretical one were compared and contradictions were identified.

The Activity System of Problem-based Learning Environments

Problem-based Learning is a learning approach that was originally developed for medical education (Barrows, 1986). With the goal of developing both students' problem solving strategies and disciplinary knowledge bases and skills, it is a robust, constructivist process, shaped and directed primarily by the students themselves. Since the inception of the PBL model for medical education, it has been adapted for different levels of students for different disciplines (see Gallagher et. al., 1995; Guzdial et. al., 1997; Maxwell et. al., 2001). However, all PBL models share key features such as learning initiated with a problem, exclusive use of ill-defined problems, and collaborative learning among the students with the teacher as metacognitive coach (Savery & Duffy, 1995). It embraces both liberal education and operational curricula, with opportunities for students to construct and refine meaning for themselves as they generate and test their hypotheses while solving real world problems.

In general, PBL follows a process in which groups of four or five students, presented with an ill-structured authentic problem, work collaboratively to generate hypothesis, identify relevant facts and learning issues, investigate hypothesis and gather information, analyze results or information, and present and analyze information. This new level of understanding gives rise to the next cycle of the PBL process until a suitable solution is found (Savery & Duffy, 1995). Through this iterative process, students learn to deal with the complexity that comes with authentic problems, and construct and refine scientific meaning inherent in the artifacts. The process of PBL resembles the inquiry process that scientists use for knowledge creation. Furthermore, the potential for deep understanding of domain-specific concepts and problem solving skills make it a popular choice to break out from traditional methods of instruction.

Problem-based learning, characterized by its language, tools, explicit roles, procedures and regulations, and implicit behaviors and rules, are well reflected within the framework of activity theory. Studying how the tools, rules and roles mediate the activities between the subject, object and community provides a better understanding of the forms of human activity such as cognition taking place in the PBL environment. Figure 1 below illustrates the use of activity theory to describe the activity system of problem-based learning, based on our interpretation of the typical descriptions in literature. We can refer to this as the reference PBL activity system.

The activity of PBL is driven by the motive of acquiring problem-solving strategies, content knowledge and skills. The focus of attention (object) of a group of learners (subject) is the given problem space, attempting to find a solution (outcome) to the problem. Content knowledge is regarded as a mediating tool for the learners in making sense of the problem and refining their hypothesis. Other mediating artifacts can include resources such as information resources (tools), ways of interacting (rules) such as collaboration and negotiation. Everyone in the community, which could be made up of groups of students, teacher and even an expert in the field, is a co-constructor in the learning activity.

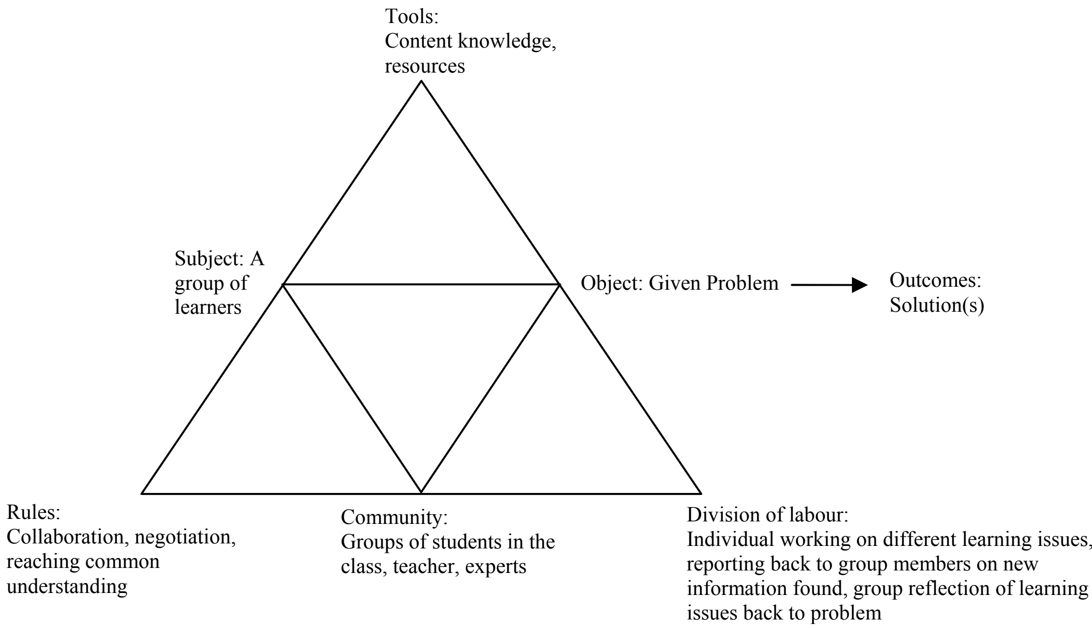

Figure 1. The activity system of the reference PBL environment

Findings and Discussions

In this section, we describe how PBL was implemented in Miss Chen's classroom, in terms of participants' goals, actions and mediating tools. Contrasting that with the typical PBL activity system as discussed above, we analyzed the contradictions and interpreted it in the context of a larger school and society-wide activity system.

The Activity System of Miss Chen's Instructional Unit

The lesson started with an authentic problem presented by the teacher about a teenager who was seeking help for his badly damaged hair, together with the task and assessment criteria to the class. The task was to find a scientifically sound solution for the teenager. In groups of four or five, students spent around five hours of curriculum time over three days to explore the problem, search information about the protein structure, investigate their hypotheses and find a solution to the problem. They were given guiding questions to scaffold their search for protein structure. Given that PBL was completely new to this group of students, and seemingly to allay the fear of the students, the teacher gave the assurance, "Don't worry, I'll do damage control later". This sentence perhaps encapsulates the numerous tensions that Miss Chen experienced as she taught this biology unit using PBL. At a macro level nonetheless, the stages of the instructional process resembled that of a typical PBL in Figure 1.

We then observed what the students did after the problem initiation stage. With the learning issues identified for them in the form of guiding questions, students focused their attention on searching for answers to these questions. They split the task among the group members, trawled the internet for answers, and compiled information by copying and pasting. These actions were carried out with little discussion among themselves as each of them was working on different sub-questions. The data found was then reported back to the teacher when she sat down with the group of students for a discussion in the next lesson. The intellectual discussion was tightly directed by Miss Chen as she called upon each of them to report what they had found. There were some further discussions directed to problem solving among the students until the content knowledge deemed important by the teacher was touched on.

In one instance, one of the group members, Eric, was trying to explain what could cause protein to be denatured (Transcript 1). As he was explaining, the rest of the group members were trying to reach a common understanding as they added information to make the explanation clearer or questioned him in areas which they were doubtful. The interaction was a dialogic one, whereby students negotiated and co-constructed understanding. The voice of the teacher was seldom heard, other than to question misconceptions.

Transcript 1

Eric	It is also said that there are several factors that lead to protein being denatured, which include high temperature and extreme pH values.
Sandra (another student)	Extreme pH values mean that if the sea is too salty, you can't go in?
Eric	Erm, what, what?
Miss Chen	pH and salt?
Eric	It's, I mean, it's true that sometimes in shampoo -
Sandra	Your shampoo consists of acid and alkali?
May	Ya, sometimes they put in citric acid.
Eric	You know, okay, I -
Miss Chen	Don't believe advertisement.
Eric	Okay, this is extra information. You know, when you shower, you know why there's conditioner and shampoo? There are two different reasons, right? Shampoo is acidic lah. So when you wash your hair, everything, right? What happens is the hair, right, that layer layer thing you know, will come up and fray and your hair becomes very rough, right? Maybe guys hair is different.
Sandra	What layer layer thing?
Eric	You know your hair, right? Can I see that picture? Hair has scales, right?
Students	Scales?
Eric	Scales like these, right?

However, the dynamics of this kind of discussion stopped later when the "crux" of the problem was discussed. In Transcript 2, we see Miss Chen playing a very active role in the discussion, acknowledging, expanding and clarifying concepts, and emphasizing the key points of the protein structure as Sandra presented the four structures of protein.

Transcript 2

Sandra	At different levels. And basically, the first one is the primary structure, the second one secondary structure, the third one tertiary structure, the fourth one quaternary structure.
Miss Chen	Okay. Tell me about the primary structure.
Sandra	The primary structure
Miss Chen	**This one ah, time out. This one must know ah.**
Eric	Okay.
Sandra	This is a picture of the protein structure.
Miss Chen	Okay.
Sandra	And it is made up of amino acids.
Miss Chen	Okay. Amino acids.
Sandra	And is made of a chain of peptide bonds. So if I'm not wrong, these are the peptide bonds, is it? (pointing to the picture on the tablet screen)
Miss Chen	Ya. They just show bonds by lines lah. Essentially, your amino acids like that right? (pointing to a simplified version of the protein structure on the screen which she had drawn). Primary structure focuses on the fact that there are amino acids connected to each other by peptide bonds. **Do you know the structure of amino acids? (pause) Okay, you need to know.**

As the reporting back phase went on, the teacher continued to emphasize and stress the importance of the information that they needed to know [in bold] (as stipulated in the official syllabus) as she expanded and summarized the important points. The students were seen to be taking notes as the teacher ensured that they understood the content. After the session, the students organized their notes, clarified understanding with each other, making sure that they had not left out essential information about the protein structure. During the discussion of the protein structure, there were few other instances of sharing of understanding or co-construction among the students.

It is evident from the description that in working towards a solution and presentation, students adopted an efficiency "divide and conquer" model to completing the given task. The presentation turned out to be information giving to the classmates who seem to anticipate that the teacher would do "damage control" at the end of all the presentation. Figure 2 shows the activity system of the enacted PBL classroom.

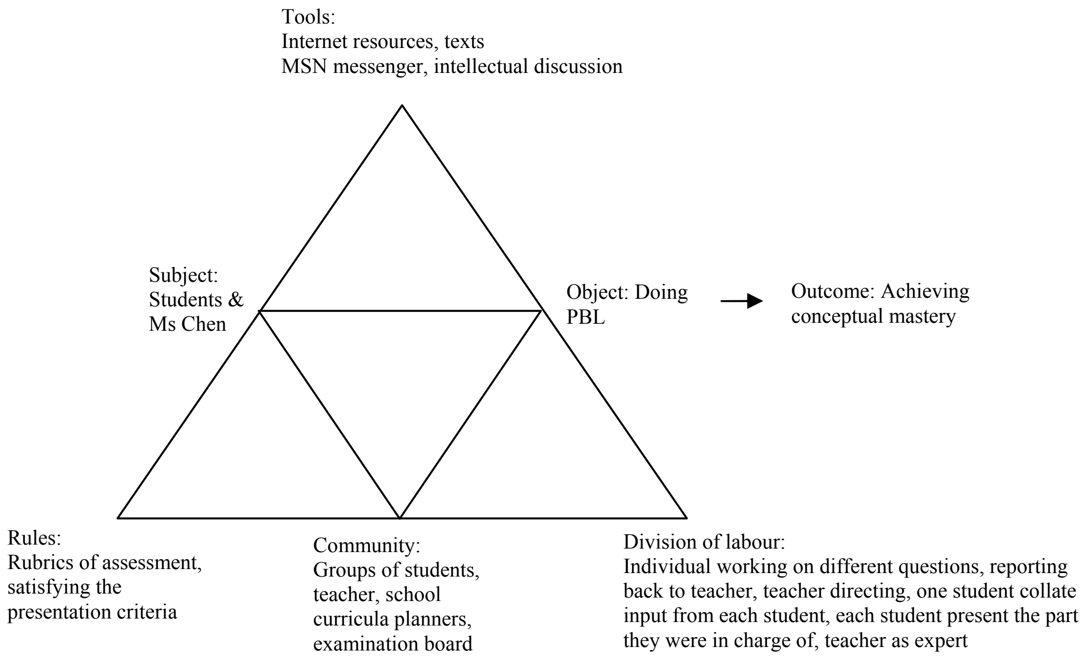

Figure 2. The PBL activity system in Miss Chen's classroom

Contradictions Between the Activity Systems

When we compared the observed activity system in the classroom with a typical PBL activity system, several tensions or contradictions became apparent (in italics) (Table 1).

Table 1. Comparison of activity systems

	The reference PBL activity system	**The observed PBL classroom**
Subject	A group of 4 – 5 students	A group of 4 students and teacher
Object → outcome	*Object: Solving problems* *Outcome: Solution(s) to the problem*	*Object: Doing PBL* *Outcome: Achieve content mastery*
Tools	Resources (cognitive tools, collaborative tools, information resources), content knowledge	Information resources (internet and texts), MSN messenger, intellectual discussion
Rules	*Iterative cycle of hypothesis generation, information gathering as resources to solve problem, investigation and reflection through collaboration, multiple solution*	*Rubrics of assessment*
Community	*Groups of students in the class, teacher, experts*	*Groups of students, teacher, school curricula planners, examination board, societal expectations*
Division of Labour	Group search for *problem space* (applying prior knowledge to the problem, identify learning issues, hypothesis generation), negotiating common understanding of information found, reflection, and investigation. Individual working on different learning issues, reporting back to group and	Individual student worked on different questions and reported back to teacher. The teacher also does her part of the work to achieve *conceptual mastery* by connecting the information found by each student, and expanding and clarifying important concepts. The information compiled by individual student

	self reflection. Teacher acts as the metacognitive coach.	was then compiled together into a presentation slide.

From the above comparison, the main contradiction lies with the motive driving the two activity systems. Every activity is driven by a motive; what distinguishes one activity from another is the object, which gives direction to the activity (Leont'ev, 1978). All actions are hence in relation to this driving "force". In Miss Chen's PBL unit, acquiring and mastering content knowledge seemed to be the primary object whereas ideally in PBL, the problem is the primary focus, with the content knowledge being a mediating tool in problem solving. This is a perfect instance that demonstrates the "strange reversal of object and instrument" in school learning (Engestrom, 1987, p. 74) due to the historical isolation of school from other societal activities. As a result, the primary motive in schools is primarily to learn well and succeed in examinations, rather than to seek far transfer to real life applications.

The object of the activity in Miss Chen's biology PBL class thus (largely) aligned towards content knowledge mastery, as she emphasized the importance of getting the content knowledge "right" by stressing to the students that protein structure is the "crux" of the whole lesson (and through other discursive turns not reflected here). Co-constructing this activity is the group of students whose interaction changed when they immediately sensed the importance of knowing the protein structure (the content knowledge) from teacher talk/actions. They took down notes as the teacher explained the protein structure to them, making clarification when in doubt. Metacognitive skills, problem solving skills and collaborative skills now took secondary importance that stands in contrast to the more interactive discussion when less high-stakes content was taught in other lessons. An efficiency model was adopted in completion of the biology task by splitting up the work and then compiling each person's contribution into a presentation. This inadvertently short-circuited the iterative problem-solving process of hypothesis testing and investigation, which would lead to deep understanding of content knowledge as students applied and reflected on their new understandings. This resulted in low levels of collaboration and reflection as students often worked individually on their assigned parts of the presentation as we observed.

The primary contradiction here can alternatively be attributed to the tension between the exchange value and use value of the object—examination grades (Lave & Wenger, 1991, p. 112). Problem solving skills and metacognition are useful and essential skills in dealing with everyday problems but may not be so crucial in getting by in high-stakes examinations which test mainly recall and procedural knowledge. In other words, Miss Chen's PBL classroom activity is embedded within a larger activity system that values good grades in examinations. Although teacher and students worked through the PBL stages, they were very much constrained by the latter, and seemingly more entrenched activity system. What Miss Chen did was to balance, as well as she could, the ideals of "real/authentic" education using PBL versus the demands of a schooling system slowly undergoing change. Underneath the observable activity system that resembles the PBL approach to science learning lay the "invisible" activity system that ultimately drove the action of *all* the participants—teacher and students alike.

Concluding Remarks

What really counts as true PBL? This paper presents tensions between researchers' and practitioners' perspectives of PBL in a traditional yet academically high-achieving Asian society in Singapore. In the spirit of design research, we do not profess that our interpretation of PBL is superior. What contradictions and expectations Miss Chen faced on a daily basis was not what the researchers encountered as part of their everyday work practices. Rather, what is exhibited as PBL on the ground entails the on-going, contextual interpretations and negotiations of meaning within the team (researchers, students and teachers). Thus, these contradictions should not be taken negatively. Although an activity system is a virtual disturbance producing machine, the contradictions can provide impetus for change, innovation and expansive learning. It is thus crucial for the researchers and practitioners to work collaboratively to find a balance between theory and practice, between the ideal and do-able. One approach we currently adopt is to engage the teachers in professional development programs such as reflection and design experiment so that there is both vertical and horizontal increase in expertise. The ultimate goals and trajectory of learning in PBL have to be negotiated so that there is a balance in theory (academic) and everyday (practitioner) practices—what we term the elusive equilibrium point.

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