Practical Challenges with a PBL Implementation in Engineering Education

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Abstract **- In September 2003, a problem-based learning (PBL) pilot was started in information technology engineering education at Turku University of Applied Sciences. The main goals of the pilot were to decrease discontinuation of the studies and delayed graduations, as well as to improve the students' abilities to work in a team and to learn and think by themselves already from the early phase of their studies. Currently, the PBL method has been integrated into the curriculum focusing on the first part of the Bachelor of Engineering studies. During the past four academic years the structure of the implementation has been developed on the grounds of the students' feedback and the results obtained. Numerous methodological and practical problems have been faced and solved. Issues like the learning environment including proper facilities and furniture, timetables, assessment and evaluation processes and routines, and curriculum adaptation have been tackled. In this paper, the challenges during the PBL implementation process are indicated and discussed. Practical solutions are proposed and analyzed based on the experiences gathered. The main goal of the study is to give an overall real-life perspective to a PBL adaptation process, and thus provide tools for institutions planning related operations.**

Index Terms - Information Technology, Engineering Education, Learning assignments, Learning Environment, Problem Based Learning.

INTRODUCTION

In autumn 2002, Turku University of Applied Sciences announced additional project financing for developing and implementing new pedagogical methods. The teachers in the Degree Programme in Information Technology applied for this financing to launch a PBL pilot. The financial support was received and the first PBL implementation started in spring 2003. This meant many practical problems, such as who of the teachers would start with PBL, which student groups would do PBL and when, how to plan the schedule, how to assess, and first of all how to start PBL.

The structure and early findings of the PBL implementation have been presented by Tuohi and Roslöf, [1] and [2]. The aim of this paper is to describe and analyze the key challenges met and solved during the first academic years with a PBL implementation in information technology engineering education.

FACILITIES AND SCHEDULES

In a traditional school building there are typically large rooms with 30-60 tables and chairs in rows, a teacher's table and chair in front of the room and a whiteboard or blackboard also in front of the room. *How is it possible to build suitable PBL rooms [3]?*

In autumn 2003 it was impossible to make any special arrangements because the rooms were needed also for traditional teacher-centered learning. When tutorials took place, 12 rooms were occupied by PBL teams at the same time. Using traditional teaching methods only 3 rooms had been taken up. This meant a major challenge to the person responsible for schedules and some inconvenience for students and tutors, too. Students had to organize their tables and chairs into a shape of an oval or a circle and reorganize them after the tutorial. There were no computers in the rooms and the students had to leave the room after the tutorial.

In autumn 2006 the activities moved into new facilities. It was also known that even the other degree programmes there needed team rooms. So, it was feasible to organize three traditional rooms for permanent team rooms by heavy screens. Each slot was supplied by ten tables and chairs arranged in a rectangular shape, a computer, a data projector and a whiteboard or blackboard or at least a flap board. For students' own laptops also extra plug points were arranged. The equipment of one team can be seen in Figure 1.

FIGURE 1
A PBL TEAM ROOM

Now, the team members have been able to concentrate on their work without getting too much disturbed by the other teams.

Although there were rooms for 30-60 students in the former school building it was not possible to gather all 90 students to the same place for common lectures dealing with the PBL cycles. So, some PBL teams had the lectures on Mondays and the rest of the teams on Tuesdays. The expert lecturers had to give the same lecture twice, and the schedule became more complicated. The large auditoriums in the new building solved this problem as well.

TEACHERS

Traditionally, co-operation between the teachers had mainly concentrated on planning the curriculum. The teachers worked at their own offices, had lectures on their core subjects and disciplines and talked different jargons. They met each other monthly in a degree programme meeting. Of course, some of them had daily chats in the coffee room during the breaks but they had no regularly planned gatherings in order to discuss, for example, learning and teaching methods or assessment policies. *How is it possible to start PBL with teachers having their old habits?*

The main issue was to strike a chord with the teachers and get examples of PBL implementations. For this reason, research on other degree programmes in Finland using PBL was carried out. Two interesting PBL implementations were found, one in Lahti [4] and another in Jyväskylä. The representatives of those PBL implementations were invited to Turku to a half day seminar. They were enthusiastic about PBL, accepted the invitation and gave exhilarating lectures about their experiences. The speakers showed examples of their learning assignments and pictures of students unraveling them and, for instance, building prototypes. This seminar had a major influence on the opinion among the teachers. It was important that they were exposed to PBL by other teachers in a field close to their own. The whole idea about PBL became plausible with these real examples.

After the seminar a six day tailored training course in PBL started in April and ended in August 2003. In total, twelve teachers from the degree programme attended the course (two thirds of permanent academic staff members). During this course the teachers planned the forthcoming PBL pilot. They had to co-operate to make a continuum from the learning assignments. They wrote and rewrote assignments and asked each others' help. They also made the brave decision to start the PBL with all new students simultaneously, not only with one or two selected groups. They decided who of them were going to tutor PBL teams, who were going to give lectures and who were going to assess the PBL teams' reports. Also, a guide for tutors was written to keep the basic facts and rules in mind.

The tutors had, and actually still have, weekly meetings in order to discuss their experiences and support each other as well as agree upon the same rules, for example, in assessment. In this way, the sense of collectivism has grown among the teachers.

It was not difficult to find teachers who would like to tutor PBL teams. Still, the first year made tutors understand that they need more knowledge in tutoring. So, in summer 2004, after the first PBL year, ten teachers traveled to Aarhus University in Denmark for a three day training course in tutoring. Even in summer 2005 an additional training course in tutoring was tailored for the teachers.

The tutors still found out that it could be possible to stimulate the teams to better learning results and that they could be better in giving feedback. The students want more thorough evaluation than just something like "The session was quite OK. Is it now clear to everyone how to continue?" They want personal evaluative statements from the tutor and also from the observing PBL team member. Very few teachers are used to evaluate the attitude and performance of students but rather their products instead. The tutor should be able to discuss co-operation and interaction as well as learning objectives with the team members. All the time the tutor should act as a good facilitator and create a positive learning atmosphere. [5]

These exigencies mean a radical change in the role of a traditional teacher and it does not happen in a year or two. Actually, a change in the entire degree programme culture was needed. The process has started, but takes time because all teachers should make adjustments to their thinking. It is also clear that there are teachers who act as tutors but are not quite sure if they are doing the right thing, and if PBL really is a good way of learning. Maybe this was also noticed by the students, as this year they asked if it is possible to change the tutors in such a way that tutor A takes group B and tutor B takes group A. The students wanted to see different styles of tutoring. The changes were made at the Christmas break. No major hurray or crying have been heard, though. Still, maybe the students now hear some new aspects about their team work and get new kind of process analysis. For tutors, the change could also give some new ideas because the new team's culture can have interesting subtleties.

One pedagogic goal at the universities of applied sciences in Finland is learning to learn. The students should learn to be capable to collaborative learning and knowledge-sharing in teams and working communities. They should learn how to plan, organize and develop their own actions [6]. Thinking of this orientation, it is obvious that a change in the role of teachers is needed anyway, not only for being a good tutor in PBL. This change can take tens of years.

The human dimension is reported as being one of the most problematic: "People have been used in traditional way of teaching for a few thousand years," points out Mr. Markku Suni. So, preparing the stakeholders for the change, both staff and students, is critical to success. [7]

STUDENTS

In autumn 2003, it was expected that the new students were not familiar with PBL. Also it was known from literature that initial experiences with PBL could be met with resistance from students, who feel confused because they are unaccustomed to the demands of self-regulated problem solving that PBL requires [8]. *How is it possible to start PBL with students who have never heard about PBL?*

A guide as well as a check-list with a description and aim of every stage in the PBL cycle was written for students.

Also a list of the main roles in PBL with the main duties was written, and especially, a hit list for the team chairman was compiled. During the first day the new learning method was introduced to the students and the written material was distributed. The next day, a training problem about the first year curriculum and time utilization was given to the new PBL teams. Twelve PBL teams were formed by tutors and the teams worked the whole afternoon with the assignment. This way the students learned to know their tutor and team members, as well as the basic ideas about PBL and their first year studies. In the first PBL sessions the students felt themselves more comfortable when they could have the check lists with them, and also tutors tried to help the teams in finding their routines.

After the first PBL year, the new students have been familiarized with PBL in just about the same way. Some details have been added to the written material and the necessary corrections there have been made because of the changes in PBL model during the years 2003–2006 ([1] and [2]). In autumn 2003 the introduction to PBL was given by a lecture but after that a dynamic DVD presentation have been utilized [9]. The DVD was designed as a thesis project by two Digital Media students. It was done by young people to other young people, and it works well; probably much better than a lecture given by a teacher. The used music and whole style of presentation appeals to new students and it also serves as a sample of products which the students are going to learn to do.

The students have been asked the same questions about PBL every autumn. The tutors have collected their team members' answer papers during personal discussions. Unfortunately, in autumn 2004 and 2006 two tutors had forgotten to collect the papers. The first question is: How well does the PBL method suits you? Give your estimate in scale 0 - 5 (0 means that the method does not suit me at all with any course and 5 means that the method suits me perfectly with every course).The frequency distributions are given in Table 1. The first mean grade of 80 students was 2.45. In autumn 2004 the mean was 3.49, in autumn 2005 3.43 and in autumn 2006 3.86 respectively.

TABLE 1
HOW WELL THE PBL METHOD SUITS A FIRST YEAR STUDENT (SCALE 0 - 5)
FREQUENCIES IN AUTUMNS 2003 - 2006

	Grade	2003	2004	2005	2006
Valid	0	6	0	0	0
	1	14	0	1	0
	2	**21**	5	11	1
	3	19	22	26	22
	4	17	**24**	**35**	**28**
	5	3	4	6	15
	Total	80	55	79	66
Missing	System	0	0	2	0
Total		80	55	81	66

Another question asked every autumn is: Estimate your learning results with scale 0 - 5 (0 means that according to your experience you have learned nothing and 5 that you have learned every learning objective). In autumn 2003, the mean grade was 3.00. In autumn 2004 the mean was 3.75 and in autumn 2005 the mean grade was 3.47. In autumn 2006, the mean grade was 3.82. The frequency distributions are given in Table 2.

TABLE 2
ESTIMATION OF LEARNING RESULTS BY THE PBL METHOD,
FIRST YEAR STUDENTS (SCALE 0 - 5)
FREQUENCIES IN AUTUMNS 2003-2006

	Grade	2003	2004	2005	2006
Valid	0	2	0	0	0
	1	7	2	1	2
	2	16	3	9	4
	3	23	10	26	14
	4	**28**	**32**	**38**	**30**
	5	4	8	5	16
	Total	80	55	79	66
Missing	System	0	0	2	0
Total		80	55	81	66

Although it is difficult for teachers to adopt the new tutor's role the students adjust to a new situation rather quickly. The student generations change much faster than the teacher generations. In autumn 2004 at least some of the new students already knew about the PBL method before applying for admission to the degree programme. Nowadays, the students admitted in autumn 2003 are finishing their studies. So, the method is known to all students in the degree programme and the change resistance is at least lighter than during the first years, if not totally non-existent.

The new students have also been asked the question: How much do you feel the PBL team has supported your studies? Give your estimate in scale 0 - 5 (0 means that you have experienced no support, 5 that you feel the team support extremely valuable). This question was not asked in autumn 2003 but after that it has been included in the questionnaire. In autumn 2004 the mean grade was 3.94 and in autumn 2005 3.65. In autumn 2006 it was 3.89. The frequency distributions are given in Table 3.

TABLE 3
HOW WELL A FIRST YEAR STUDENT FEELS TO BE SUPPORTED
BY THE PBL TEAM (SCALE 0 - 5)
FREQUENCIES IN AUTUMNS 2004 - 2006

	Grade	2004	2005	2006
Valid	0	0	0	0
	1	1	3	1
	2	1	3	2
	3	10	23	15
	4	**24**	**38**	**32**
	5	12	11	15
	Total	48	78	65
Missing	System	7	3	1
Total		55	81	66

Students who started in August 2003, 2004 and 2005 did not have any special team rooms or computers and data projectors. It was not easy for them to organize team

meetings outside the tutorials. Still, the students' opinion about the suitability of PBL, the learning results by PBL and the team support have changed to a more positive direction. Maybe the PBL model has been developed to a right direction or the method is now taken more as a given fact. The tutors are more confident about the method and they have some years' experience. So, they are able to create a reliable atmosphere. The team control is also better than in the beginning. In the first PBL year, lots of effort had to be used for students who were absent from tutorials. Reports which fell behind schedule disturbed earlier but during the last year the reports have been ready on time.

LEARNING ASSIGNMENTS

The problem statements, or learning assignments, form the core of PBL. They should stimulate the students' interest and motivate them to study and achieve desired learning outcomes. The problems should also follow each other in a reasonable way to make an entity. *How is it possible to create a sequence of weekly problems for an academic year?*

In May 2003, the teachers started to think about the assignments. How many and what kind of problems should they write? The weekly schedule gave a practical solution. A decision was made to have a dedicated PBL day in the beginning of the week and an afternoon for continuing and finishing the PBL work. This meant that the students were going to go through one PBL cycle in a week and thus solving one problem per week. It also meant that nearly one third of the new students' weekly workload was covered by PBL.

The teachers divided themselves into small groups and started to write. Then, a common meeting was held and all problems were considered separately. Actually, nobody had any experience of a good PBL learning assignment. As the teachers represented different subjects (Software Engineering, Mathematics, Finnish, Electronics, Computer design, Circuit Theory etc.) they could somehow identify with students with respects to other teachers' subjects. A list of assignments was ready by the end of August 2003 for the autumn semester, meaning a set of 15 problems. [1]

The learning assignments for the following spring semester were formulated during autumn with the gathering experience and literature-based knowledge. The problem writers had to write also a guide for tutors because they represented different subjects. So, the tutors knew what kind of learning issues the problem should arouse and could intervene if the students had misunderstood the assignment.

At the end of the first PBL year the teachers had a planning day for the following academic year 2004-2005 with a careful analysis of the first set of assignments. Before the planning day the tutors had answered in writing for example to the questions: Which PBL issues did we manage with success? Which things should be done in a different way? How? The answers and the common analysis gave some new ideas for the assignment writers but more crucial and pitiless feedback they received from students.

The students were asked the questions: Which assignments have worked in the best way and why? Which assignments have not worked and why? The answers were analyzed together with all teachers on the planning days. Some problems, which needed to be rewritten, were identified, but, on the other hand, some opinions did conflict with each other.

Anyway, it was noticed that writing learning assignments is not easy and support of the others is indeed needed. Naturally one should also have a good understanding about the students' thinking and knowledge as well as the learning objectives.

INFORMATION SHARING

When there are at least six tutors, at least nine PBL teams and many lecturers involved in PBL cycles, lots of information has to be shared. There are the weekly schedules with timetables and room reservations, the list of all learning assignments of the academic year with respective responsibilities, lists of PBL teams and their tutors, the learning assignments themselves, team and personal reports, guides for tutors and students, questionnaires about PBL for tutors and students, and forms for assessment. *How is it possible to share all the information to right people at the right time?*

At the first PBL incarnation nearly all information was given on paper. Only the weekly schedule was available on the Internet [10]. The tutors had the key role in sharing information. They copied the guides, questionnaires, forms and, of course, the assignments to their PBL team members and shared the copies. The tutors also collected the personal reports after every PBL cycle and delivered them to the teachers responsible of evaluating them.

Some improvement for this situation was needed. For this reason, an external expert was invited to give ideas about connecting the PBL process and Internet-based learning environment. The expert, Anne Rasinkangas from HAMK University of Applied Sciences, gave a whole day presentation about PBL with many practical examples and views to OPTIMA, the learning platform they had successfully used at HAMK. [11] [12]

Already in autumn 2004 the OPTIMA platform was put to use. All information could be located in suitably named folders and all the parties were able to easily reach all information at any time. Also the reports for evaluation could be submitted and the team members could read the teachers' comments of their common reports via OPTIMA. Every team had its own folder with read and write permissions by the team members only. Using these folders, the teams started to save their unfinished reports in the platform, have chats and leave e-mails to each other about their ideas found outside their meeting times. The tutors did not need to take care of carrying reports to other teachers. The lecturers could save their material and references in OPTIMA.

The usage of the platform has helped in sharing information intensely and during the academic years 2004-2005, 2005-2006, 2006-2007 the utilization rate has grown quickly. New features in OPTIMA have been utilized. For example, the assessment data can now be shown directly to those students whom the data concerns. So, the assessment

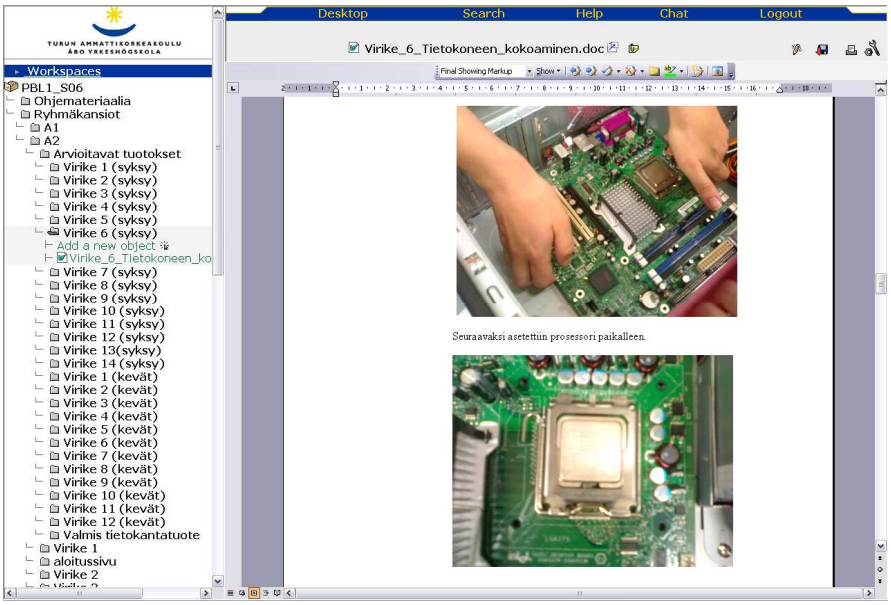

FIGURE 2
A SCREEN SHOT OF OPTIMA

can be more transparent and it can reach the targets immediately after it has been given.

ASSESSMENT

The assessment methods direct the students' activities [13]. The assessment should not be solely a grade-assignment or a ranking tool. Far too often, the learning process degenerates for students into striving to do well on the tests so they will have good grades, rather than focusing on the learning goals instead [14].

PBL makes it possible to assess also the learning process and the team members' activities in seeking, utilizing and sharing knowledge. In the first PBL year, the team members wrote personal reports about the weekly problems. The grades were determined by the marks of the reports and tests. The team observer gave his/her statement after tutorials but it did not have any influence to the course grades. It was purely focused on evaluating and improving the team member's co-operation. Also the tutor's evaluation statements were concentrated in developing the team work and the team member's contribution to tutorials and the discussion.

In the second PBL year the personal reports were mostly left behind and the teams started to write team reports. The main idea was to increase the teams' sense of collectivism and to change the focus from personal efforts to team activities. *How is it possible to be fair to the team members in assessment if the whole team gets the same marks from their common report?*

Some team members might have helped the others whereas some team members might have been quite inactive during the team work. The problem was solved so that the secretary wrote marks for team members about their contribution to the report at the end of it. The observer and the tutor still concentrated on evaluating the team members' activities during the learning process without effects on final marks of the courses.

The students were asked about the assessment system and many students found it rather feasible. The teachers thought that the secretary gave the marks only about the contribution to the report, not about the quality of the contribution to the learning process.

In the third year the team reports were marked by subject teachers as earlier. Now, the observer was obligated to give marks about the quality of the team members' activities in the learning process. The secretary was to give marks about the team members' contribution to the team report and the chairman was to give marks to the observer and the secretary about their activities in their respective roles. All the marks were saved in OPTIMA in a spread sheet so that the team members and the teachers could read the table anytime. This system worked, although there were many actors involved. However, the system was still found too complicated and the students wanted marks also from the tutors.

In the academic year 2006–2007 the assessment was composed of the subject teacher's evaluation on the team reports (also some personal reports were written), the observers' marks about the team members' activities in the learning process and the tutors' marks about the team members' activities during the tutorial sessions. All marks were saved in OPTIMA files readable to all team members and teachers. The observer had to give marks also to himself/herself.

The students' opinions about the assessment were asked also this year. Some students found that the observers and the tutors give too easily the maximum marks and in some teams the maximum marks were easier to obtain than in others. There are rules and forms for the observer in order to bring the right issues to the observer's attention and the tutors have been properly trained. However, still some new ideas have to be tried to get the same and reasonable policy to the evaluation.

CONTINUOUS IMPROVEMENT

PBL was started at short notice. Many actions had to be taken without any experience. Many problems had to be solved in a short time. The teachers wondered if the right decisions were made. *How is it possible to make changes to the right direction?*

The tutors' opinions about PBL have been asked each spring on paper using forms with the following type of questions:

- Which things have functioned well?
- Which things should be handled in a different way next year? How?
- Do you want to act as a tutor next year?

The students' opinions have also been asked in spring using forms with questions such as:

- Which learning assignments have served well and why did they serve well? Give your opinion.
- Which learning assignments did not serve well? Why?
- How could we make a perfect assessment system?
- Give your other comments on PBL.

The answers have been collected and disseminated to all teachers before the evaluation meeting. In the evaluation meeting the answers have been discussed and the changes to the previous practice have been decided. These evaluation meetings have yearly lead to modifications in schedules, the amount of teams, the amount of tutors, the learning assignments and the assessment process. Also the PBL practice by the second year students has turned to be different from the practice by the first year students. The opinions of the stakeholders have influenced to the second year PBL so that the tutors' role is been detracted.

The tutors have a central role in making decisions and following through the reforms. They need to know how to handle the situations and what kind of experience the other PBL implementations have brought. So, the tutors have had training courses and some of them have attended international conferences, too.

CONCLUSIONS

During the past four academic years a PBL implementation has been developed in the undergraduate Degree Programme in Information Technology at Turku University of Applied Sciences. In this paper the encountered challenges have been indicated and discussed from a practical point of view. The main challenges were given as seven questions about:

- building suitable PBL facilities,
- starting PBL with teachers having their old habits,
- starting PBL with students never having heard about PBL,
- creating a set of weekly problems for a year,
- sharing information to right people at the right time,
- being fair in assessment, and
- making changes to the right direction.

The practical activities and experiences in solving the problems have been shared hoping that this article will give new ideas and help the readers who are starting teaching with PBL as well as the readers who study PBL from a theoretical point of view.

ACKNOWLEDGMENT

The financial support of the Turku University of Applied Sciences is gratefully acknowledged.

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