A Problem Based Learning Process Integrated in IT Engineering Education

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Abstract - In September 2003, a problem-based learning (PBL) pilot with ca. 90 students was started in the 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. During three academic years the structure of the pilot has been developed on the grounds of the students’ feedback and the results obtained. In this paper, the resulting PBL-model, now integrated into the curriculum, as well as the reasons and experiences gathered from the students and the teachers are presented. Moreover, a virtual learning environment was developed as a part of the PBL-project. This environment containing dedicated areas for each PBL-group to discuss, process assignments as well as to assess and evaluate the results is described. In addition, the achievements of the pilot’s main goals are discussed and certain guidelines for related trials from the engineering education’s perspective are proposed.

Index Terms – Engineering, Higher Education, Information Technology, Problem Based Learning, Virtual Learning Environment.

INTRODUCTION

Like many other degree programs on the higher educational level in Finland, the Degree Program in Information Technology at Turku University of Applied Sciences has experienced many students dropping out during the first and second years of study. Some students do not simply seem to be as active and motivated as they should in order to study forty hours a week, do the homework and attend the lectures. Accordingly, course examinations are often delayed from the planned schedule. This is one of the main reasons behind the fact that too many students are unable to pass the courses in the planned order and, thus, to graduate within four years. [1]

Naturally, the problem as such has a very complex nature and certain dropouts have a quite acceptable background, at least from a teacher’s perspective. Some students try after the first study year to enroll themselves, for example, in another university that they primarily preferred. Others may have found out that studies in information technology were not their true calling in the first place.

However, despite the rather significant amount of students leaving due to acceptable causes, the problem still exists. Especially for the first and second year teachers the situation is frustrating. They may start their lectures with full classrooms but after some weeks the amount of absent students gradually grows and, finally, too many students do not pass the courses. The postponement of the studies as well as the poor ratio between the students starting their education and the ones celebrating graduation from the original institution affect on the financial situation of the university. The governmental support to the universities in Finland partly depends on the amount of graduates from each program. In addition, a negative impact also exists on national economic level.

In this paper, practical experiences from a development project addressing the described problem by the means of introducing the PBL paradigm are presented. The background and structure of the implementation on its current form are explained and the experiences gathered discussed. Finally, certain guidelines for related trials from engineering education’s perspective are proposed.

BACKGROUND

Prior to any dedicated development project activities several discussions upon the problem took place, and various improvement actions were implemented within the continuous development work of the degree program. For instance, different rules and recommendations for teaching Mathematics and Physics were given because they were experienced as the most difficult subjects for the students.

Moreover, it was realized that the structure of the curriculum was rather theoretical and fragmentary especially during the first two years of study. The students’ schedule included mainly Mathematics, Physics, Circuit Theory and introductory courses in Information Technology accompanied by compulsory language studies [2]. More practical aspects and connections to working life were needed to motivate the first and second year students.

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The management of the university also expressed that discontinuation and delayed studies should be prevented by all means available. In autumn 2002, an additional project financing targeted to development of new teaching methods was announced to motivate the degree programs and their staff [3]. Also the Degree Program in Information Technology filed an application for a teaching method development project for 2003 [4].

The project started in February 2003. The plan was to experiment one kind of problem based teaching and learning to motivate the students. A group of teachers had attended a six day course in PBL organized during the autumn 2002, and the way of connecting the professional reality to studies via problems was found very interesting [5]. A strategic intent towards a PBL-oriented method selection was mentioned even in the pedagogical strategy of the university [6]. So it was natural to at least try these methods. Moreover, the research results concluding that PBL can be successfully applied in engineering programs supported the process [7].

This development process has now been evolving for three academic years. The first phase implementation model, including a description of the pilot project structure, is presented by Roslöf and Tuohi [8]. In this paper, the current, already improved version of an integrated PBL model is discussed.

**PBL Process & Cycle**

Problem-based learning has been applied worldwide for over twenty years in many disciplines in higher education. PBL can be understood as a method of learning, as an educational strategy or even as a philosophy [9].

However, some characteristics for PBL can be specified. First of all, learning is premised on problems that arise from professional practice. In PBL the problem is introduced before the students know how to solve it [10]. Despite of working with different kinds of problems, the main aim is in the learning itself, and not so much in solving the problems as in the case of project based learning [11]. The main characteristics of PBL and traditional pedagogies are given by Gibson [12].

The students work in teams of 6-10 students. The teams stay together many months, possibly the whole academic year. The teams have meetings with their own tutor, a supervising teacher. These meetings are called tutorials. The working process in the tutorials is student-oriented. One of the students is a chairman; one a secretary; one an observer and others are team members. All of these actors have their specific missions in the tutorials. The role of a tutor is not a traditional teacher lecturing or pushing his/her knowledge to the students. The tutor helps in the learning process by asking questions and exhorting the students.

There is a self-studying phase between the tutorials. The length of this phase is typically a few days. Of course, the team members can also collaborate during the self-studying. The goal is to find new knowledge and/or to apply it. Lectures, workshops, interviews, books, television programs and, for example, the Internet can be used as sources for information.

The learning process is assessed. There are not only final exams but evaluation is performed also during the learning process. The tutor can give feedback to the team as whole and, naturally, to the students individually. The team can reflect on the quality of communication, respect to others, overall behavior in the tutorials, individual contributions etc. The students assess themselves also individually.

The PBL way of handling the problem is often described as a cycle. There are several different variations of the PBL cycle. The cycle applied in Turku is illustrated in Figure 1. The self study phase is strengthened with a lecture and group study session.

![Figure 1: The Utilized Problem Based Learning Cycle](image)

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FIRST ACADEMIC YEAR WITH PBL

The change towards PBL started by considering some basic questions:

1) How much of students’ whole weekly workload is desired or possible to cover by PBL?
2) Will PBL be started with all 90 new students or only with a smaller subset of the annual intake?
3) Is it possible to organize the classrooms for the PBL teams and make the timetables?
4) What kind of problems should be written and which disciplines, if any, are still taught using the traditional methods?

The decisions were made in June 2003. At that time the teachers had completed a few days’ theoretical studies on the PBL methodology but had no practical experience in applying PBL. The answer to the first question was one third, i.e. one and a half day of PBL-work a week. The teachers still wanted to have traditional lectures and workshops, too. There were, of course, many reasons for this decision. Many teachers seem to have difficulties to make major adjustments in their thinking in a short period of time, and some of the teachers had just heard about PBL only some months ago.

PBL was decided to start with all new students. This meant trouble with the timetables. It was not possible to reserve the only large auditorium for PBL lectures. So, the same lectures had to be given twice. Because of lack of small rooms suitable for team working traditional class rooms had to be used. The schedules of the tutors became a problem, too. Seven voluntary tutors having their own traditional lessons and workshops, and nine PBL-teams having their tutorials at the same time was not feasible. The tutorials had to be allocated on separate weekdays.

The last question concerning the creation of the PBL-problems and selecting the disciplines meant a significant amount of work. Only one course was decided to be taught totally by PBL. Many of teachers wanted to try PBL but did not want to give up all their traditional lectures. In May, the teachers were divided into groups and started planning the implementation. The idea was to help each other and to get ready before the end of August and before the beginning of the new academic year. Considering the coming summer vacation season, everything was finally done in a hurry. The disciplines selected to be included into the first PBL pilot and the structure of the cases are described in [8].

The first PBL model applied during the academic year 2003-2004 included:

- a tutorial session (2 x 45 min with the tutor)
- lectures (2 x 45 min)
- self-study (3 x 45 min)
- group study session (45 min with the tutor)
- self-study (3 x 45 min)

The tutorial session took place on Mondays at 8.15 – 9.55 (for some teams on Tuesdays at the same time). The tutorial session began with finishing the last PBL cycle and continued by starting the new cycle with a new problem. This was followed by lectures dealing with the topic given by experts and a self-study period of three hours. The students continued the PBL work with a group study session with the tutor on Wednesdays at 12.50 – 13.35 (the Tuesday teams on Thursdays). The meaning of this session was to discuss with the other group members and the tutor, to give and get support and advice, to ask questions and get answers. This session was continued by a three hour self study. Every student worked up a report about the problem solving process. The report was to be handed in during the next tutorial session.

Every report was marked by the teacher to whose course the problem was connected. The mark of the report had influence on the final mark of the course according to the rules given by the course teacher. The rules varied from teacher to teacher and from course to course. Some teachers had significant difficulties to mark reports on time and some students were often late with their reports.

The amount of reports to be evaluated was huge. Although many of them were similar to each other, the work was laborious. Tutors made the observation that students did not always want to share their knowledge with the others during the tutorial and self study sessions. One explanation could lie on the human nature. The students had worked hard to find out something valuable and wanted to have the advantage of it by getting better marks than the others.

The tutors did not find this mutual competition between the team members good at all. Some changes had to be done. Changes were also needed because far too many students did not stay at the university during the self-study hours. Nor did they ask guidance from teachers who were available for them during the self-study hours and, obviously, the quality of the learning results became poor. The teachers had wanted the students to get to know each other in these small groups and to support each other when studying together but the system did not work as planned. However, the students now seemed to work quite a lot but mainly at home and the activities focused to the day (or night) before the reports were due. Actually, a study on the students’ time monitoring showed that the students used 40.6 % of all self study time for working with the PBL problems although it, theoretically, should have been only 33 % [8]. Some teachers groaned about students’ concentration on PBL and not on their other homework.

THE MODEL EVOLVES

Based on the experiences on the first year pilot some changes were made:

1) Common team reports are written, and the secretary is responsible for the reports being ready on time.
2) Teachers are advised to mark and comment the reports carefully and on time and, furthermore, to give clear rules about reports’ influence to the final mark of their courses.
3) The reports are attached as files in a virtual learning environment Discendum OPTIMA [13] and also the comments and marks are given via...
The changes were influenced by teachers’ excursion in Aalborg University [14]. After this visit also oral examinations were experimented with success in connection of the course Professional Growth.

The usage of a virtual learning environment came in handy. All instructions for students (PBL guide for students, PBL cycle, the roles of a tutorial, the missions of actors in tutorials, hit list for the chairman in a tutorial) and for tutors (PBL guide for tutors, advice for every problem given by problem writers), forms (for self-evaluation and peer evaluation), problems, accepted reports etc. could be shared to students and tutors as well as problem writers and all teachers interested in PBL work. The groups were able to build up their own private area with discussions and chat for coexistent conversation.

In spring 2005, the second year students had experienced both PBL models. They were asked the same questions about the pilot as in autumn 2003. The first question was to estimate how well the used PBL method suited the respondent. The scale was 0–5 (0 = the method did not suit at all). Autumn 2003 the mean was 2.5 (80 respondents) and the spring 2005 result was 3.0 (47 respondents). The second question was to estimate the learning results by PBL with scale 0–5 (0 = I learned nothing). The means were 3.0 and 2.8, respectively. These students had used time for PBL work during the first year even too much but during the second year with the new PBL model they used only about 2.8 hours for self study although they were meant to use 5-6 hours a week. These students were asked if the problems were large enough to keep them busy during the cycle; 22 answered no and 25 yes.

The students had now started to work with the problems so that they split the overall task and actually wrote the reports in small pieces. In the tutorial session they could easily share their knowledge and the reports were extensive. However, the learning effect was not better than in the earlier model.

The conclusion after the second round was that the students changed their ground rather quickly but tutors and problem writers could not do the same. In spring 2005 the teachers studied the feedback and made some new adjustments to the PBL model.

1) There are six tutors for the first year students, i.e. one tutor per two teams; and two tutors for the second year students, i.e. one tutor per four teams.

2) The group study session takes place on the same day as the starting tutorial.

3) All first year students have their starting tutorials, lectures, self-study and group study sessions on Mondays and second year students on Tuesdays. The other self-study sessions and concluding tutorials take place on Thursdays (first year students) and Fridays (second year students).

4) The peer evaluation is done using forms in OPTIMA. The evaluation is carried out by the observer, secretary and chairman of the team. Also the reports are evaluated via similar forms. The team members are able to read the evaluation with written comments as soon as they are given.

The teachers had a two days training in tutoring in spring 2005. The teachers thought that by raising the quality of tutoring and intervening in the starting tutorials they could influence the process better and make sure that the items are studied as deeply as possible.

The group study session ends the PBL day started with introducing a new problem. The idea was to encourage the students to stay at the university studying together. The same effect was expected of locating the other self-study session and closing tutorial at the end of a working day. A typical weekly schedule of the first year students is illustrated in Figure 2.

The process evaluation was performed in the teams jointly, or the secretary had given it according to team members’ contributions. In spring 2005 students were asked opinions about evaluation and suggestions to change the system. Many students did not want changes at all; some wanted utilization of the evaluation scale 0–5 (commonly used in the university) instead of 0–3; many suggested that the secretary should always give the evaluation. Some students did not like peer evaluation at all because students give good marks to good friends and not so good ones to the others. Some wanted to be able to read the evaluation in OPTIMA. Thus, it was decided to start using forms in the OPTIMA platform. Every team member can now read the evaluation concerning his/her own team but not the other teams. The secretary evaluates the team members’ work from the report generation’s point of view. The observer evaluates the team members’ work during the tutorial sessions and self-study sessions if the team is working together. The chairman evaluates the secretary’s and the observer’s action during the process. This evaluation is given in a form in OPTIMA and all team members can read it. Teacher’s assessment of the team report is also given by using OPTIMA. The teacher gives his/her reasons and marks for every team member. The marks are influenced by the mark of the team report and marks of the secretary, observer and the chairman.
CURRENT IMPLEMENTATION STRUCTURE

The current model (academic year 2005-2006) is based on weekly problems. Each problem is fitted to involve approximately 12 hours workload for each student. The schedule for the problems is planned by teachers in spring for the next academic year.

Students work in groups of approximately eight students. From the student’s point of view the weekly PBL program includes:

- a starting tutorial (45 minutes)
- lectures (2 x 45 minutes)
- self-study and group work (4 x 45 min)
- meeting with the group members and the tutor (10 to 45 minutes)
- self-study (3x45 minutes), and
- the concluding tutorial (45 minutes).

A first year student has a starting tutorial on Monday morning at 8.15 (or at 9.15). This means a meeting with his/her tutor and group. The students choose a chairman, a secretary and an observer. The main duties for the chairman are to give the floor to the members of the group, take care of the time schedule and to evoke a motivating atmosphere.

The tutor gives the week’s problem, usually on a paper. The group members study the problem, clarify difficult concepts they probably find in the material and discuss and describe the problem in their own words. The session continues with a brainstorming phase during which the students generate ideas based on the problem presented.

After the brainstorming phase, the secretary collects the ideas of the group members and classifies the ideas according to the opinions of the team. Systematic classification after brainstorming helps the group members for example to identify their lack of knowledge. After this stage the students are ready to formulate their learning tasks in detail. The secretary writes down the learning tasks the group finally decides to set to itself. The observer makes notes on the overall progress of the process as well as on the behavior of the members. The group can, before starting the tutorial session, also decide on specific details to be monitored. For example, the observer can keep watch on the quality of the conversation and addresses, or the eye-contacts of the members or the observer can draw a communication diagram in the tutorial [12].

The starting tutorial is followed by a lecture given by a subject expert. These experts are often teachers but also professionals outside the university. After these lectures the team members tend to meet and decide how to continue the self study. They can work by themselves, in pairs or groups of three or all together depending on the problem. In the afternoon at 15.15 the teams meet their tutor and have a short discussion about the learning results of the day and the plan for the other self study session.

The other self study session on Thursday afternoon is followed by the concluding tutorial. The purpose is that students recall and discuss the details in their learning process. At the end of the session the observer has the floor. The chairman also makes sure that the secretary is able to finish the report.

This system has functioned rather well. The final reports have been uploaded to OPTIMA on Monday mornings. The evaluation forms have usually been filled by the students on time too.

In autumn 2005, the new students were again asked to estimate how well the PBL method suited them with scale 0–5. The results are included in Table 1 and the mean now was 3.4. The students were also asked to estimate their learning results using the PBL method. The results in Table 2 give a mean of 3.5. The students also thought that their team had supported them in the studies. With scale 0–5 the mean was 3.7 (0= the respondent experienced no help from the team at
all). That is, the results have turned to a positive direction compared to the answers of the inquiry 2003-2004. Furthermore, now the students say they had heard about the PBL method before admittance to the university, and it was not a surprise for them.

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<th>TABLE 1</th>
<th>HOW WELL THE PBL METHOD SUITS A FIRST YEAR STUDENT IN AUTUMN 2005 (SCALE 0-5)</th>
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<th>TABLE 2</th>
<th>ESTIMATION OF LEARNING RESULTS BY THE PBL METHOD, FIRST YEAR STUDENTS IN AUTUMN 2005 (SCALE 0-5)</th>
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Yet, there is clearly much to be developed further. For example, the tutors need more understanding and training in supervising and coaching skills. But above all, the quality of the problems needs to be improved. The current selection does not always rise from professional practice and the problems do not always give enough challenge for students. Also the evaluation system needs to be reconsidered.

**DISCUSSION**

In this paper, an implementation of the PBL paradigm in the Degree Program in Information Technology at Turku University of Applied Sciences was presented. In order to provide tools for related projects in other institutions, the background of the pilot as well as the experiences gathered during curriculum development were discussed.

The tutor teachers have learned many new aspects about coaching and, moreover, details of the curriculum development. The teachers have discussed pedagogical issues more than ever. The students have learned to learn better. They have achieved more generic competences such as communication and social skills, too.

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**REFERENCES**


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The development of the learning and teaching methods in general and the PBL-implementation in particular continues. The experiences gathered so far indicate that a suitable form in engineering education may be using PBL as one of the main methods during the first half of the studies, and then to focus on a project-oriented way of working as the day of graduation gets closer.