INNOVATION-ORIENTED EXERCISE IN PHOTOGRAMMETRY USING PROBLEM BASED LEARNING METHOD

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ABSTRACT

The education of surveying sciences is facing new challenges due to the technical developments and new application areas in the field. Different kinds of requirements are met in the working life compared to the time ten years ago, which leads to the need for some changes in educational methods, too. Developments and different possibilities in educational procedures have been studied and tested in several countries around the world during the recent years. The aim is that new teaching methods would prepare the students better for the working life and increase motivation on the subject. One of these new teaching methods is Problem Based Learning (PBL). This article presents our experiences in utilizing PBL in one exercise related to developing suggestion for an innovation for a real company. The results show that the motivation among students towards photogrammetry grew during the exercise. The main reasons were the presence of the real company and the authenticity of the exercise task.

1. INTRODUCTION

During the last 20 years, the research and method development of different teaching procedures have been fairly active. Pedagogical aspects of education are recommended to be taken more into consideration while planning courses and other student related activities. It is also verified that more practical, student-based teaching methods will often lead to better learning results compared to the traditional lectures. Furthermore, the trends in the educational methods are partially connected to the changes in the working life. Enemark (2009) has discussed the future of surveying profession and the challenges, which will be faced in the education.

One of the key factors is the motivation of students. The motivation is usually divided in two main types as intrinsic and extrinsic motivation. Intrinsic motivation means that the doing is inherently interesting or enjoyable, and therefore results in high-quality learning, positive curiosity and creativity (Ryan and Deci, 2000). However, also extrinsic motivation, coming from the outside factors, may have a significant influence on the learning process. In many cases, students doing their Bachelor's degree have not yet managed to decide on which Masters they will focus. Therefore, it is not guaranteed that a student participating in a course has any initial intrinsic or extrinsic motivation on the subject. The earlier the motivation starts to grow, the easier it is for a student to continue with the studies and to concentrate to the fields of interest.

Motivation, both intrinsic and extrinsic, can be quantitatively and systematically measured with "Motivated Strategies for Learning Questionnaire (MSLQ)" –method (Pintrich et al, 1991).

Marra and Wheeler (2000) have explained one example of the use of MSLQ, where the impact of authentic student-centered project work towards motivation was studied. Due to practical and real life tasks, and by giving students also responsibility of their actions, the motivation was higher among the students compared to the traditional course with no authentic work. Although the course itself didn't offer much extrinsic motivation, such as a large amount of study credits, the real world project was intrinsically motivating the students. In addition, Benson (1998) has referred to several studies, where MSLQ has been utilized.

Problem based learning (PBL) method is an active way of teaching and learning. The purpose of the method is to learn with student-based approach and having a close connection with real life cases. The study material, as well as the study tasks, should be as realistic as possible. During the study process, the students are encouraged to use team work and communication skills, find information to solve problems, and have mind open for several aspects of thinking.

Innovation is, usually, considered to be something that is totally new or significantly improved. Innovations begin with creative ideas, but should include also successful implementation within an organization (e.g. Edwards et al., 2009). At the level of an individual company, for example, this could mean that the creative ideas are incorporated in products, processes, services, management systems, work organizations, or marketing systems (e.g. Rogers, 1998). A successful innovation creates also added value either directly or indirectly for customers of a company.

In the Institute of Photogrammetry and Remote Sensing, Helsinki University of Technology, Finland, PBL has been utilized with second year students. One larger project work as part of a course has been created in order to offer students new kinds of learning experiences. For students, the task in the project work was to create a suggestion for an innovation for the real company in the field of photogrammetry. By involving companies to the exercise, the students had also an opportunity to get familiar with the real working environments. Even if the implementation of new ideas was not included in the exercise because of limited time resources, the aim of the exercise was innovation-oriented. In other words, the companies would be able to implement suggested new ideas into their working processes.

The aim of this paper is to share our experiences of applying the PBL method in an innovation-oriented exercise within a photogrammetric course, which belongs to the Batchelor's level. The rest of the paper is organized as follows. The basics of the PBL method are explained in Section 2. In addition, the suitability of the PBL method for the engineering field is discussed and compared against the project based learning method, which is more directed to the practical project tasks. Section 3 gives examples of realizing PBL in surveying studies in Portugal and Denmark. The case in Finland is described in more detail in Section 4. Finally, the results, discussion and conclusion are presented in Sections 5, 6, and 7, respectively.

2. BASICS OF PROBLEM BASED LEARNING

Problem based learning was first implemented in medicine education in 1969 at McMaster University in Canada (Perrenet et al., 2000). Later on, it has been successfully applied to other fields as well, like economics, law, psychology, and engineering. The core idea of the PBL method is that problems are the starting point of learning. By solving problems, one will learn the required processes and skills connected to the certain topic. In addition to the adoption of subject related skills, problem based learning method is a good way to prepare the students with other

abilities like teamwork, problem solving, handling larger entities, and multidimensional thinking skills.

Lectures and other educational methods are the supporting elements of the learning process. However, the PBL method is more student-based instead of teacher-based. In other words, the teachers are supporting and guiding the study, but the students have an important role in acting, carrying out the practical tasks and being active in other aspects (Perrenet et al., 2000).

A study process is often as followed. At first, students encounter a problem, which may not even be directly given to them. This may be confusing for the students, who are often used to follow direct instructions. The problem is usually very closely related to the real cases and it creates a starting point for the whole learning process. After that, students start to search appropriate information, how to solve the problem. This phase consists of studying the theoretical part of the topic. With the help of related materials and studied facts, they continue with the problem solving process.

One way to proceed with PBL is to use predefined seven steps (Wood, 2003) divided into prediscussion in the group, individual work, and postdiscussion in the group (Figure 1). Depending on the extent of the problem, it can be divided into smaller pieces, where each piece is handled individually, for example, within one circle of the seven step chain. Hence, during the project work, the chain can be repeated several times.

1. Prediscussion: Clarify text and terms
2. Prediscussion: Formulate problem statement
3. Prediscussion: Problem analysis
4. Prediscussion: Inventory of problems and solutions
5. Prediscussion: Formulating self-study objectives
6. Individual: Self-study
7. Postdiscussion: Conclusion

Figure 1. Seven steps of PBL (Wood, 2003).

Lecturing is probably the most common way of teaching, and it is an effective method in transferring the knowledge to the students. However, it doesn't pay attention to the student's ability to absorb this information. Problem based learning method offers more practical and functional way of learning. There are many research studies showing that people learn more by doing compared to hearing and seeing. For example, Prince (2004) has refered to various researches, where PBL has been noticed to improve student's positive attitude and study habits, and to give a good environment for students to develop problem-solving and life-long learning skills. PBL focuses also more on understanding the studied subjects, instead of just memorizing things. This will be helpful in the modern world, where the amount of knowledge, available material and other information is increasing continuously. Kiley et al. (2000) has expressed the fact as following: "*Students cannot learn all the material, but they can learn how to learn the material.*"

The most effective case seems to be a combination of team-based and individual studies. Especially in engineering fields, it is usually believed that the basic knowledge about the study area is required before the students are able to solve problems and carry on with more advanced group assignments. Therefore, in many cases, the curriculum emphasizes the theoretical studies at the beginning and offer more applied and specific knowledge later on. However, also the early

stage courses should involve practical and applied studies in order to enhance learning and to motivate students.

Typically in PBL, advisors are necessary to lead the work to the right direction. Perrenet et al. (2000) have studied the suitability of PBL for engineering education. They have pointed out the fact that together with the PBL method, the engineering education needs also other kinds of study practices. Respectively, the term project based learning instead of problem based learning would be more suitable for solving larger engineering problems (Gadala, 2005). According to Gadala, project based learning is more directed to the application of knowledge, whereas problem based learning is more directed to the acquisition of knowledge. Project based learning also encourages more on management of time and resources. However, it is difficult to separate and compare different methods with each other. Although the general definition exists, the implementations of PBL vary widely (Woods et al., 2000).

Problem based learning is nowadays utilized widely, mainly in medical education (Wood, 2003). In the engineering field, it is also used in some extent, but it is still far away from the medical status. The main reasons are probably the differences between study branches. In medical area, the problem based learning method is easily fitted to the case studies and other educational situations. The engineering field contains lots of basic knowledge, like mathematics and physics, where calculation exercises and traditional lectures play an important role. However, more advanced knowledge relating on applications and such can be better dealt with PBL.

3. EXAMPLES OF REALIZING PBL IN SURVEYING STUDIES

3.1. Portugal, Escola Superior de Technologia e Gestão de Águeda, ESTGA

A new curriculum has been developed around PBL in a polytechnical school in Portugal (Escola Superior de Technologia e Gestão de Águeda, ESTGA) in Geo-information Engineering (Gomes Pereira and Oliveira, 2004). The three year study program is organized in such a way that the whole information flow in the production of geographic information will be handled. The photogrammetric education is given during the second year in one semester as a theme name "photogrammetric restitution". After that, the students continue with the cartographic production theme, where the photogrammetric data is used. This way the students go through all the subjects under the production of geographic data in the correct order, which is happening in the real working environment, too.

The photogrammetric studies comprise of associated disciplines and a project work. Associated disciplines give the basic knowledge and training, which are necessary for understanding the facts needed for starting with the project work. At the beginning of the semester, the disciplines have a significant role in studies, but as the semester goes on, the project work is the one which the students focus on. At the end of the semester, the project work is evaluated based on a report and in a public defense in front of a jury.

PBL in ESTGA has received positive experiences among students. The similarity of the studies with the real working life has increased motivation for the studies. However, also some negative thoughts were noticed, such as the large workload and difficulties in planning and keeping work schedules. In addition, the new role division between students and teachers was, at first, considered a bit confusing. However, during this new curriculum, the students learned all the skills necessary in order to work in a production environment.

3.2. Denmark, Aalborg University

The education in Aalborg University in Denmark is well-known of its pedagogical structure, based on group work and problem-centered, real life projects, already since its establishment in 1974. Among others, the curriculum in Surveying is now based on project organized and problem based model, instead of a subject-based education (Enemark, 2009). This means that the focus is on problem based learning, and the aim is to give the students a broad understanding of interrelationships and the ability to deal with new and unknown problems. This is important nowadays in working environment, since the technology is evolving and the methods are changing. One should have good problem-solving skills as well as capability to adapt to the new situations. Entrepreneurial and managerial skills are also highly appreciated. The new way of learning things prepare the students better for the working situations in the future.

Similar to the Portugal case, the studies consist of lectures and project works. Lectures give knowledge of the core elements of the subjects, and the project work will teach the practical part. One theme is processed during one semester, and the semesters have been organized in such an order that the whole complex will create a consistent workflow through surveying topics.

4. PBL IN PHOTOGRAMMETRIC EDUCATION IN FINLAND

The Department of Surveying at Helsinki University of Technology (TKK) has designed new ways to carry out inspiring and motivational education for students of Geomatics. Similar methods, as described in the cases of Portugal and Denmark, have been utilized, only in a smaller scale. The case explained here in more detail is an innovation-oriented exercise executed as a part of the course "Fundamentals of Photogrammetry", which is the second course containing photogrammetry within the study programme. In addition, the course has lectures and couple of other exercises that are significantly smaller than the innovation-oriented exercise. The extension of the entire course was three credits. The credit is equivalent to the ECTS point (European Credit Transfer and Accumulation System). The course lasted seven weeks, and the innovation exercise took place during the whole period of seven weeks. The course was held in the first study period in spring 2009, and most of the students were second year students of Geomatics.

For the organization of this project work, relatively large amount of resources were used. Since nothing similar had ever been done before in the Institute of Photogrammetry and Remote Sensing, everything had to be designed from scratch. Several companies in the field of photogrammetry were also asked to be part of the work, which naturally required extra effort. Part of the research staff at the Institute was helping by advising student groups and tutoring them through the exercise.

The innovation-oriented exercise was executed as a group project work. The estimated amount of time to spend for the work was 24 hours (Table 1). The average number of students in a group was four and each group got a named staff member as a personal tutor. In total there were 27 students attending the exercise. The students were asked to get familiar with production processes of a real company and to create some new ideas and how to develop them into innovations that could improve existing processes. However, the actual implementation of the innovation was not included in the task, because of a limited time frame. The exclusion of the actual implementation or practical data processing task gave students also the freedom to create ideas related to more complicated and even futuristic innovations. New ideas were supposed to relate to company's products, application areas, activities, services etc., and were asked to include photogrammetry.

Because the aim was not to limit the imagination of students, also non-feasible ideas were allowed, which gave extra freedom for the exercise. One important thing emphasized was that the work should also be fun and creative, even though real companies were involved. Otherwise, the exercise would have felt too overwhelming and serious for the young students.

Table 1. Time schedule and tasks to be done in the exercise

Week 1	- *Starting event for the exercise*
	  o *Group creation*
	  o *Company selection for each group*
	- *Contact to the company during the next days*

Week 2	- *1-2 group meetings* - *Collect data of the company, it's activities, applications, clients, and products from the web* - *Preliminary conversation within the group about the innovation possibilities*
Week 3	- *Visit the company* - *1 group meeting* - *Select the area, where to start generating the innovation* o *preliminary conversation about the topic*

Week 4	- *1 group meeting*
	  o *Focus on the area of innovation and work on it*
	- *Visit in the company again during this or next week*
	  o *Find out more about the selected innovation area*

Week 5	- *1 group meeting* o *Work on innovation*

Week 6	- *1 group meeting*
	  o *Work on innovation*
	  o *Prepare a report*
	- *Return the report*

Week 7	- *Closing event for the exercise* o *Each group presents their innovation and acts as an opponent for the work of another group in a seminar* - *Present the innovation to the company as well*

At the beginning of the innovation-oriented exercise, each group selected one hosting company. There were several companies and public organizations involved from the field of photogrammetry, such as Blom Kartta Oy, Pöyry Environment Oy, and National Land Survey of Finland. In practice, the groups visited the company a couple of times during this exercise. In this way they got to be in touch to the scope of the innovation. Every week, there was also a possibility to gather together to work with the group, where also someone from the Institute's research staff was present. Many student groups used this option, since it was an easy way to find time and place to meet within the group, and it was easy to get help from the tutors, as well. As the PBL method was applied, the main purpose of the meetings was either to prediscuss, which leaded to formulating self-study objectives, or to postdiscuss, in which the results of self-study were collected (Figure 1). Students updated a blog about the progress of the exercise during the entire course. This way the staff was able to observe the progress. At the end of this exercise, the groups prepared a report, which they also presented to their hosting company. The report included the explanation of the new ideas and a plan for the possible implementation, which would lead to the real innovation. In addition, the groups presented their results to each others in a seminar, in which each group also acted as an opponent for some other group. The opponent's

task was to study the innovation report of another group and to provide questions and comments related to it in the presentation session.

Altogether seven groups of students carried out the photogrammetric innovation exercise. The students were relatively free to select the subject of the work. However, it was supposed to have connections to the company's field of interests, one way or another. In addition, the relation to photogrammetry was required. Here, some examples and results of the work have been described. It can be noticed, that most of the subjects deals with currently interesting or forthcoming applications.

One group started to develop new ideas to visualize and examine laser scanning point clouds. Instead of presenting the points on the screen in a normal way, they started to think possibilities to visualize the data in a stereographic mode. The students had knowledge of stereographic measurements from aerial images. In this exercise, they expanded the technology to be utilized with point cloud data. The group studied the different possibilities to conduct the stereo view of the point cloud. The students also listed pros and cons related to the idea. In addition, they had created a couple of anaglyph images from a point cloud data, even though no implementation was required. During the innovation process, the group found out that there was already a similar procedure in use. This, however, only proved the usability and realistic implementation of such a system.

Another group created ideas to produce 3D city models based on the company's existing data. In such a way, there would be no need for additional effort to acquire the data, but the existing resources could be utilized. They described the basic steps to create 3D model, presented the possibilities for various level of details, and proposed benefits and application areas related to 3D models.

The third example describes the creation of new and more efficient data acquisition methods for one company. Instead of mobile mapping with laser scanner, the UAV (unmanned aerial vehicle) with a laser scanner could be a more versatile tool for data collection. The students had searched information about the possible applications available for the moment, the limitations related to the aviation law and examples concerning the end products of similar applications.

5. RESULTS

The students' opinions of the exercise were collected with a feedback form, which included several questions about organization, workload, companies, group working, and motivation during the exercise. Because the main reason for this exercise was to improve students' interest towards photogrammetry and introduce them with new ways of studying, a special attention was focused on the motivation of students.

An extensive feedback was collected both from the students and from the companies involved. The feedback form for the students included both multiple choice and free-field questions. The companies were able to give their opinion more freely and their answers are not included to the statistics below. Overall, the experiences of the innovation exercise were positive among all the parties (students, companies, and course staff).

In the feedback form, the students answered the multiple choice questions with scale 1-5 (1 = strongly disagree, 2 = disagree, 3 = don't know, 4 = agree, 5 = strongly agree). There were 32

questions related to the success of the exercise so that a higher score meant greater success. The questions were divided into five groups related to organization, workload, companies, group working, and motivation. In the case of workload, the questions were also formulated in a way, that the higher the score, the more appropriate the workload was. The distributions of scores in the five groups in per cent are shown in Fig. 2. The statistics for the groups are presented in Table 2, where *n* is the amount of questions of the certain topic multiplied with the number of student answers. Highest scores were given for questions related to organization and group working.

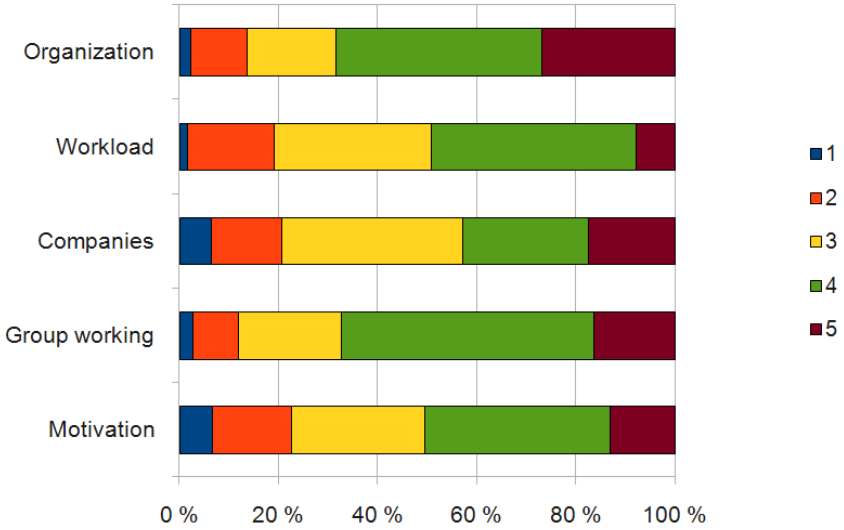

Figure 2. Distribution of scores in per cent.

Table 2. Statistics for different groups of questions (n=number of answers).

	n	*Mean*	*Standard deviation*	*Median*	*Mode*
Organization	*219*	*3.8*	*1.0*	*4*	*4*
Workload	*63*	*3.4*	*0.9*	*3*	*4*
Companies	*63*	*3.3*	*1.1*	*3*	*3*
Group working	*110*	*3.7*	*0.9*	*4*	*4*
Motivation	*242*	*3.3*	*1.1*	*4*	*4*

The organization of the course was mostly estimated very positive. The questions were related to the instructions, timetable, structure, amount and quality of guidance in the exercise.

The workload was considered appropriate, and the groups had found quite easily the time to meet and work on the exercise. This is probably partly due to the detailed timetable (Table 1), which was recommended to be followed during the seven weeks period. The time of optional weekly meeting was selected according to the study schedule of the students, in order to make it accessible for most of the participants.

The companies involved in the exercise were considered as a good source of motivation. The groups of students were treated well and welcomed to the company. However, the communication between the students and the company people seemed to be a bit passive. The students visited the company preferably two times during the exercise. In addition to that, no

greater communication about the innovation ideas between students and company existed, excluding few exceptions.

The students used several different working methods during the exercise, such as the group conversation, excursions, individual work, and brainstorming. Most of the students also felt that they worked well as a group. The division of tasks was equal and it was easy to agree about the future meeting times.

The motivation is an important part of a meaningful study work, and this was also asked in the feedback form. A large amount of the students felt that the interest and motivation to study photogrammetry grew during the exercise at least a bit. Also this kind of a larger exercise was considered a better option compared to the smaller individual exercises during the course. One big reason for the high motivation was the hosting company. In this way the students felt the work meaningful, as it was done for a real case and for a real company.

Most of the students felt that the innovation development was interesting, but at the same time challenging. Problem based learning was quite new for the majority, and they were not used to student-based teaching. The exercise was considered to give enough freedom for the students, but for many of the participants the amount of freedom was even too much. In addition, the real company brought extra pressure to the work, and many students felt that the innovation should be a high-quality and useful one. In some cases, this led to the state, where high expectations blocked creativity and therefore also new innovative ideas. However, the lectures on the course gave ideas for many of the groups. Additionally, the influence of the staff was noticeable, as the research areas of the institute were involved in the innovations in many cases.

The resulting reports were surprisingly good and of high quality. The students had significantly taken effort in developing new ideas, which acquired lots of data retrieval from the issues previously unknown for them. Some of the students were motivated even to search information outside the course subjects to improve the innovation. Further on, many students felt that the resulting innovation could actually be useful for the company.

In addition to the Finnish students, also two exchange students accomplished the course. The target company was a bit disappointment for the foreign students, because the company presentations and other communication were in Finnish. Fortunately, the Finnish members of the group were active with the foreign members, and made them feel as an important part of the exercise. In the future, when foreign students will attend the exercise, the willingness of the hosting company to communicate in English should be confirmed beforehand.

The innovation exercise gave students a great opportunity to visit and get familiar with a company in their own field. They were able to see the real working environment, how photogrammetry is utilized in practice and what are the methods used in the applications. In addition, at least one student was employed for a summer job.

For the companies, the main benefits were to meet students and create contacts with them. This was also a good possibility for companies to make themselves known among students, who may be the future employees. No financial investments were needed from the company, only the time to present their activities. The feedback was asked from all of the companies involved, and five answers out of seven were received. Generally, the companies experienced the exercise as a good idea and worth of keeping in the course program. They may not directly have benefit from the student ideas, but after some further development, they might have something useful.

6. DISCUSSION

In this case, the innovation-oriented exercise was executed in the course "Fundamentals of Photogrammetry", which is aimed for the second year students in Geomatics. The amount of students attending the course is suitable for organizing such an exercise, contrary to the first year course, in which there are approximately 80 participants every year. When the exercise was planned, there was a long discussion whether the exercise should be organized for the students that were at the Masters level and not any more at the Bachelor's level. At the Masters level, the knowledge of the students on the subject is more mature, and the quality and feasibility of the innovation could be better. On the other hand, students at the early stage could create totally new ideas, since they don't have such a strong knowledge of the photogrammetric techniques and how things are usually done. It was also assumed that if this kind of exercise would increase the motivation of students at an early stage, it would benefit and give more focus on their studies in the future.

From the companies' point of view, more suitable place for the innovation-oriented exercise would be on the later stage of the studies. The students would have more knowledge of photogrammetry and therefore also the companies would probably benefit more on students' ideas. Nevertheless, it was surprisingly easy to get companies involved in the exercise. One company also suggested, if the ideas created during this course could be used as a starting point for another, more advanced exercise later on in the students' course programme.

In practice, due to the early stage of the implementation, the students' knowledge of the field is rather small. This is one reason for the fact that some students felt the exercise to be a bit difficult. In addition, according to the PBL method, no actual problems to solve were directly given to the study groups. Instead, the group familiarized oneself with the company, and tried to find out how to use photogrammetry to improve processes of the companies. Some students felt a bit confused at first, because the task was very open. At this point, the role of the tutor was essential in order to guide the group forward. Also, some students felt that the workload was more than average. PBL requires very keen participation from each student and the involvement of a real company gave clearly extrinsic motivation to the exercise. Our experience was that PBL was a very fruitful teaching method in addition to lectures and more traditional exercises.

The PBL method requires some training both from the students and from the teachers before it will be fully understood and one can realize the possibilities it has to offer. In this case, the course staff paid lots of effort to give students a positive feeling of the method, because for the most of the students this was the first experience with PBL. It required a careful planning, extensive instructions and possibility for assistance whenever needed. Also, the companies were aware of the procedure in the exercise.

7. CONCLUSION

The problem based learning method was utilized in a photogrammetric innovation exercise. The exercise took place in a course of photogrammetry for the second year students of Geomatics. The aim of the exercise was to familiarize student groups with a selected company in the field of photogrammetry and to create new ideas for the company.

During the exercise, the students were able to see real working environment while visiting the company. Contacts between the students and companies were also created, which may be

beneficial in the future in the need of job or employees. The amount of motivation was increased among the students, as the work was done for a real company. Also, the companies were mostly satisfied with the student works.

The PBL method appeared to be a rather new method for the students, and therefore, they needed guidance to get a clear picture of the method. In addition, the lack of clear problems to be given in advance for solving caused confusion. The students got a lot of freedom to create an innovation, and for some of them, it was almost too much and made it therefore harder to decide what to do. In this kind of an exercise, the students may feel the overload of information. They also have to be able to recognize relevant and useful data for the specific task.

It was a challenge for both the students and teachers to adopt the PBL method in the course program. However, when succeeding with such an educational situation, it will be very useful for the students. In addition to the contents, the students will learn other important skills, like searching information, evaluating the importance of various sources of information, working within a group and thinking of the case from several different aspects. The final reports from the innovation-oriented exercise were of surprisingly high quality and practically all of them could have been implemented as a true innovation that would bring additional value for the hosting companies. From the questionnaire, especially satisfactory was the fact that half of the students expressed that their motivation increased. The positive feedback from the students, staff and companies encourage the Institute staff to continue organizing the innovation-oriented exercise for the students that are at the early stage in their study programme.

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