Practical elements in Danish engineering education including EPS

Jørgen Hansen

European Project Semester (EPS)
Centre of Business & Innovation
Copenhagen University College of Engineering
Lautrupvang 15, 2750 Ballerup, Denmark
(jha@ihk.dk)

Abstract: In Denmark, all engineering education has practical elements. On the bachelor level, an internship is an integrated part of the education. Further, Denmark has a long tradition for problem based and project organized learning. A big part of the students' projects, including the final projects, are done in cooperating with industry. The interaction with industry is important because the students learn about the culture of the companies, and it is usually very motivating for students to see that companies can benefit from their work. It is also an important link between universities and industry. There will always be a difference between the theoretical teaching at a university and the practical work in a company, and especially the internship helps students to combine practice and theory

Many big projects are done in teams. This can cause problems, so it is important that students are guided well. Usually, students learn well from projects done in teams, and many improve their interpersonal skills. An added value is that students learn to learn, which is important today because much knowledge is outdated after a few years.

Today, engineers must be able to work in an international context. In consequence, a "European Project Semester", EPS, was introduced in 1995. EPS is based on the experience from problem based learning and put into an international context with exchange students in international teams. There is focus on international teamwork and intercultural communication, and the students not only acquire technical skills. They also improve their communication skills and their international competencies. With 1280 students so far in Denmark, EPS has been very successful, and today it is offered at 11 universities in 10 countries.

Keywords: *Practical learning, projects, working in teams, international competencies*

1. INTRODUCTION

Denmark has a long tradition for practical elements in all engineering education. Furthermore, Denmark has a very long tradition for problem based learning, project organized learning and cooperation between universities and industry. Very often, students work/study in teams.

2. ENGINEERING EDUCATION IN DENMARK

Like most other countries, Denmark has a long tradition for a long, theoretical engineering education and shorter, practical educations.

2.1. "CIVILINGENIØR"

Danish engineering education started in 1829. The famous Danish physicist, H.C. Ørsted, who discovered electromagnetism, founded together with various other people an institution for higher technical education [1], [2]. Later, this institution was called "Polyteknisk Læreanstalt" and from 1933 it also had the name "Danmarks Tekniske Højskole" or DTH. Since 1994 it has been known as "Danmarks Tekniske Universitet", DTU or "Technical University of Denmark". Since 1933, the title of the candidates from this institution has been "civilingeniør", which (apart from doctor and PhD) is the longest and most theoretical engineering education in Denmark. (It can cause some confusion that the title "civilingeniør" not is applied in the international way, i.e.construction or building engineer.)

2.2. "TEKNIKUMINGENIØR"

In 1881, an institution for a practical engineering education was founded in Copenhagen [3], [1]. Later, similar institutions were founded in several other towns, e.g. in Odense in 1905. The students were people who already had a practical education such as mechanics, electricians, carpenters, bricklayers etc. A candidate from those institutions was known as a "Teknikumingeniør" Such an institution was known as a "Teknikum" and later on as an "Ingeniørhøjskole" (Engineering College). Later on, fewer people with a practical education continued in engineering, but there was still a need of practical engineers, so students from high schools without a practical education were accepted. However, they had to do a trainee period before they started their engineering education, and later it became a part of the education.

2.3. "AKADEMIINGENIØR

After the Second World War, the number of people who went to high school and after that took a long, theoretical education increased rapidly. In consequence, the number of people with a practical education who wanted to continue in engineering (or had the skills) decreased. There was a lack of practical engineers, and in 1957 "Danmarks Ingeniørakademi", DIA, was founded [1]. At DIA, students who had finished high school with maths, physics and chemistry could get a short, practical engineering education. Their title was "Akademiingniør", and a trainee period has always been part of this education.

2.4 "DIPLOMINGENIØR"

Step by step, the two practical engineering educations became more similar, so it made good sense that they were united in 1993. The candidates got a new title, "Diplomingeniør".

2.5 "EXPORTINGENIØR"

In the eighties, there was a lack of engineers. Few girls went into engineering, and at high school most girls preferred language instead of maths, chemistry and physics. So, it would make sense to create an engineering education for young people who had learnt language at high school. In reality, many engineers didn't make use of all the theory they had learnt, but needed knowledge of marketing and communication and language skills because they were working as sales engineers, often abroad. In consequence, a new engineering education for "Export Engineering" was founded in 1985. The title of the candidates became "Exportingeniør", and the aim was to get more engineering students via an education that was more appealing to those who had learnt language and to girls. Another aim was to get engineers with language and business skills and international competences. Problem based learning and interdisciplinary projects have been part of this education from the very beginning.

3. PRACTICAL ASPECTS OF DANISH ENGINEERIN EDUCATION

3.1 INTERNSHIPS

Initially, the practical engineers, "teknikumingeniører" were people who had a practical education [1], [3] and who had worked before they studied engineering. They were appreciated for their practical skills and they had a valuable experience from their practical work. Gradually, more students without a practical background were accepted. Those students had to achieve practical skills, partly in workshops, partly as trainees in companies, before they could attend engineering schools. Later on, when few students came with a practical background, the internship became part of the education.

Similarly, an internship has always been part of the other short, practical engineering education, "Akademiingeniør". In consequence, the two short educations became similar, and it made good sense to unite them. Since the amalgamation in 1993, a placement has always been part of this education (Diplomingeniør).

An internship has always been part of the "Export Engineering Education", and it has even been part of some lines of the long, theoretical education (civilingeniør).

In general, the internship is appreciated by students and companies. Usually, it is motivating for students to see that their skills can be utilized in a real life work situation, and when they return to their engineering school, they have a better understanding of why they learn what they learn. Very often, it is also a nice change. For many, it could be boring with too many theoretical semesters without a break. .

For companies, there is an added value of the internships. It is (of course) very important to employ the right people and the internship certainly helps companies to know whom they would like to employ and whom they don't want. In the same way it can help students to find out if they want to work in a company. Another important outcome is that many students find good ideas for their final projects during the internship.

Both for students and for industry, it is also an important benefit that students come to know the culture of the companies; it can be rather different from the culture of the students at universities or engineering schools!

The cooperation between universities, engineering schools and companies is important, and internships are a valuable link. All partners benefit from this cooperation, and even at the most theoretical and advanced level, there have been many examples of fruitful cooperation in Denmark.

The cooperation on internships gives the educational institutions a better feeling of what is going on in industry and can make the teaching more relevant and realistic.

Anyway, it is important that an industrial placement to a certain extend is controlled by the universities and engineering schools to secure a good learning outcome, and the internship should be assessed in a proper way. One by one the Danish engineering schools have been assessed to get the title "University College of Engineering" (University of Applied Science), and the assessment procedure revealed that the control and assessment of industrial placements not always was properly done. In consequence, all Danish engineering schools now have procedures to secure a good learning outcome of internship periods.

3.2 LABORATORIES

In spite of a lack of money in 1829 when "Polyteknisk Læreanstalt" was founded, H.C. Ørsted knew the importance of well-equipped laboratories [1], and there have always been good laboratories at Polyteknisk Læreanstalt and other Danish engineering schools. Those laboratories have covered all levels from practical engineering to very advances research.

3.3 PROBLEM BASED LERNING (PBL)/PROJECT ORGANIZED LEARNING (POL)

Those learning methods have been applied in Denmark since the 1960's. In consequence, there is much experience of it, and today it is applied at all levels of teaching or learning in Denmark. A few examples will be mentioned:

In 1972, a new university, Roskilde Universitetscenter (RUC), now Roskilde Universitet, was founded [4]. At RUC all learning was by projects, and all projects were done by students in teams. Further, all projects were interdisciplinary. In 1972 many perceived it as a provocation and were sceptical. In the beginning, RUC only had bachelor students, but the number of study lines and students has constantly been growing. Today, the name is "Roskilde Universitet" and it offers several studies at bachelor, master and PhD level. However, there is no engineering education at RUC.

In 1974, several higher educational institutions in Jutland merged, and Aalborg Universitetscenter (AUC), later Aalborg Universitet (AAU) was founded [5]. The learning methods were similar to RUC's with PBL/POL and focus on teamwork and interdisciplinary projects. AAU has educations on bachelor, master and PhD levels and many subject areas including engineering.

Many didn't like PBL and POL because they were afraid that some students would benefit from the work of the other students without contributing and without learning much from the projects. Probably, it has to a certain extend been the case, at least during the first years. However, this problem is well-know today, and much effort has been put into assessment systems securing that all students learn from the project work or fail in case they haven't learnt enough.

Others were afraid that students wouldn't learn the various subjects in depth because of the interdisciplinary approach. Other concerns were if students would learn what they were supposed to learn from PBL. In real life, it is difficult to find problems that include all the elements students should learn, but with careful selection of problems and awareness of what students should learn when problem statements are made, it is usually possible to find good, relevant problems. Anyway, a part of PBL is that students take ownership for their projects. Sometimes, they could misuse this ownership and define the projects in such a way that the difficult parts they could learn from are excluded. In those cases, the guidance from the supervisor becomes important, and so does the assessment. Anyway, although students don't learn exactly what they were supposed to learn in traditional teaching, it is not necessarily a problem. Much knowledge can be outdated after a few years, so maybe it is more important that students learn to learn which one of the outcomes of PBLPOL is.

In project organized learning, the projects are chosen and defined in such a way that there is more control of the learning outcome. However, it can be a problem year after year to find new projects meeting this demand, and often the projects become similar to earlier projects.

When PBL and POL were implemented in Denmark, many professors were skeptical. Others were very enthusiastic, and in a period it almost was like a religious war. Much research has been done about the outcome of traditional teaching compared with the "new" learning methods, but conclusions are difficult because students are assessed differently in the two systems. The learning outcome is also different which also makes very absolute conclusions difficult. A general conclusion could be that the more well-skilled and mature students learn more from the "new" learning methods, and less mature students learn better from traditional teaching. However, students acquire interpersonal skills and to a higher extend learn to learn from PBL/POL.

Today, most professors agree that there should be a balance between traditional teaching and PBL/POL and so it is e.g. at RUC, AAU and many other higher educational institutions where

approximately half of the teaching/learning is more or less traditional, and the other half is by PBL/POL.

At Copenhagen University College of Engineering (IHK), there is also a long tradition for PBL and POL. It started at the department of electronics and the department of civil engineering and in 1985 an "Export Engineering" education was initiated. Export Engineering is a mixture of technology, language, business and international culture, and a big part of the learning was from the very beginning done by interdisciplinary projects in order of integrating the different fields well in the learning process.

Two interesting example of PBL were done at Elsinore Engineering College. In 1994, Professor Arvid Andersen made a project semester at the department of mechanical engineering. One of the challenges in mechanical engineering is to teach the students thermodynamics which can be very difficult and theoretical. In this project semester the students learned thermodynamics from some extensive, real-life projects and it worked very well. One of the advantages of PBL is that students can learn more in depth when they combine theory with real-life, and thanks to the teamwork and the discussions in the teams, they were motivated and got a deeper understanding of the subject.

One of the challenges in PBL and POL is the teamwork. Do all students work well together? Do all students contribute? Are there conflicts, maybe caused by a lazy student? In the thermodynamic project semester there was focus on the team process which was carefully assessed and counted as part of the marks. It certainly helped the students to cooperate and to keep all students active.

Based on this project semester, Arvid Andersen added internationalization to the project semester, and in 1995 he created a "European Project Semester". The semester became international and integrated more fields of engineering.

4. EUROPEAN PROJECT SEMESTER, EPS

4.1 THE BACKGROUND OF EPS

The aim of EPS is to make students active, motivated and creative, to give them team competences and to enhance their communication skills and interpersonal skills. However, the most important aspect of EPS is that students study in international teams and acquire teamwork and communication skills in an international context. In short, students get international competences which are very important today.

EPS started at Elsinore Engineering College in 1995 with 6 students, and when this college closed down, it made good sense that it in 1997 was transferred to Copenhagen University College of Engineering (IHK) to the Department of Export Engineering. At this department there is a very international ambience, and project based learning with interdisciplinary projects and students in teams have been the order of the day for many years. EPS became a great success, and in the autumn semester 2011, EPS-student number 1355 will be received at IHK.

4.2 WHAT IS EPS?

EPS is a semester for international students who have completed at least four semesters. It is not only for engineering students, but also for other students who can contribute to an engineering project. Like in real life, e.g. marketing people often have to cooperate with engineers, and in some projects civil engineering students have cooperated with architect students.

EPS consists of a formally taught course programme (9 ECTS) and a large, interdisciplinary project, (21 ECTS). All project groups are put together according to the students' fields of study, the demands of the projects, the students' preferences, the group size (usually 4 or 5), and the international mix: all teams should be international.

The overall aim of the courses is to help students to work in international teams and to carry out the project work. The courses given are Team Building, Communication, Project Management and Systematic Innovation. Other courses are Environmental subjects, European Law and language, i.e. English and basic Danish.

The projects are the major part of EPS. Most of them are interdisciplinary, but a few of them are narrower and go more into depth. A big part of them are real-life projects done in cooperation with industry, but some projects are academic projects without a company, although it is very motivating for the students to do a "real" project for a company waiting for their findings. Most companies are Danish, but some projects have been done in cooperation with companies or institutions in Spain.

4.3 WHEN AND WHERE?

Thanks to its great success, EPS has spread from Denmark to many other countries, and today it is also offered at Avans Hogeschool in 's-Hertogenbosch in Netherlands, Høgskolen i Oslo in Norway, The Technical University of Lodz in Poland, La Universidad Politécnica de Valencia in Spain, Universitat Politècnica de Catalunya in Vilanova i la Geltrù in Spain, Fachhochschule Kiel in Germany, Novia University of Applied Sciences in Vasa in Finland, École Nationale d'Ingénieurs de Tarbes, ENIT, in France, Artesis Hegeschool Antwerpen in Belgium and Instituto Superior de Engenharia do Porto in Portugal. Some EPS-providers offer an EPS in spring semesters, some in autumn semesters, and others in both. There is more information on www.europeanprojectsemester.eu

4.4 GETTING OFF TO A GOOD START

In reality, a semester is short compared with the time that can be lost in the beginning for exchange students who come to a new place, new habits and a new accommodation. It can especially be a problem for students who not are used to PBL and POL because they can waste much time in the initial phase of a project period when the students have to find out what is important, what is not and define the project. In consequence, it is important that the projects start so efficiently as possible. Therefore, all the students receive descriptions of the projects they can choose at least two months before the semester starts. Students send back a prioritised list of three preferred projects, and the project groups are formed on the basis of this. It is motivating for the students if their first priority can be respected, but other things are also important: The skills of the students should meet the demands of the projects. The group size should be 4 or 5 students, and all teams should be international. After the semester, students tell us again and again that the international experience was the most motivating part of it all.

Once the groups have been formed, each student receives an e-mail informing him/her about his/her project and the names and e-mail addresses of the other team members. Students are asked to discuss with a professor or supervisor from their home university how they can and shall contribute to the project work. This is important for many students to secure them credits for the semester when they return to their home universities, and it helps them to define and start the project work when they meet the other team members. Those initial discussions about the projects are done on the second day of EPS when the teams meet their supervisors from IHK and from the companies.

When the projects shall be defined, many students are reluctant to make decisions and prefer to be told what they shall do. However, it is important that students take ownership of the

projects and responsibility for their learning. Of course, companies will contribute with their expectations to the projects, and supervisors from IHK will help students to make realistic problem statements at a sufficiently high level.

Courses like teambuilding, communication, systematic innovation and project management will hopefully also help the students to start their projects work well.

4.5 THE BELBIN TEST

EPS-students have different fields of study, different nationalities and different cultures, but they have also different personalities! In consequence, they are required to do a Belbin test on-line before they start on EPS. The result of this test is important because different personalities with different qualities and skills are needed in teamwork. It is always nice to work with people like yourself because you feel you are on the same wavelength, but in the long term the outcome of the teamwork will be better with different personalities. The Belbin test and theory throws light on this [6], and hopefully the students will learn to appreciate diversity, although diversity can cause difficulties and maybe even conflicts.

4.6 PROJECT WORK AND SUPERVISION

Often, when people are working in teams, the cooperation is not efficient and much time can be wasted. It can be caused by people who don't contribute effectively, maybe because they are not motivated, or people who don't organize their work well.

In the beginning of the semester, there is a course about project management, and during the semester supervisors help students to work well-structured and well-planned and to make use of what they learnt in project management.

A team cannot work effectively without meetings. On the other hand, many people have wasted much time on meetings! So, students have to learn to prepare meetings, to write agendas, to chair meeting and to write minutes of the meetings. All EPS-teams have meetings at least once a week with their supervisors, The students are responsible for the meetings and all team members must try to write agendas, chair meetings and write minutes.

Supervisors should – of course – be able to help with technical questions from the students and give them good advice about the projects. However, they must also help students with the team process and follow the teamwork and the group performance closely. Sometimes students feel that the project work is fine and everything is OK. Sometimes they are frustrated and inclined to lose confidence and need to be cheered up. Sometimes there are hidden conflicts. Sometimes there are open conflicts. Misunderstandings due to different cultural backgrounds can generate many conflicts. When 60 – 70 students of maybe 15 nationalities are working together in teams, many things can go wrong and misunderstandings can cause many problems and conflicts. Communication is not only a matter of language; the cultural background and the context are also important factors. Different people with different backgrounds interpret the same words differently. Different working habits, monochronic or polychronic culture, formal or informal culture, direct or indirect communication, expressive or reserved culture, relation-focus or deal-focus and many other differences can cause misunderstandings and conflicts. Of course, some conflicts are not caused by misunderstandings, but by different opinions. This is legal; students are not clones of each other and can have different opinions about how the projects should be. In consequence, an important part of teamwork is to learn to negotiate.

Finally, although there is a need of different characters in well-functioning teams, too big personal differences can also cause problems. In consequence, supervisors must be aware of conflicts and other problems and have to be able to and willing to help the students deal with them. Students must learn how to treat conflicts. Some students tend to hide conflicts because

they find them embarrassing, but hidden conflicts will usually get worse till they explode, so it is important that supervisors can detect hidden conflicts.

In short, supervisors have several important tasks in EPS: technical teacher, advisor for the team process and as a person who can facilitate and nurture the team process. E.g. if a student loses motivation, it is important to find out what the reason is. In some cases, a change of the problem statement can be the solution.

Many things can go wrong, but the majority of students who choose EPS are aware of the importance of the international experience and well-motivated. They usually have a positive attitude and they learn to appreciate diversity in spite of the problems caused by diversity.

An important part of the EPS-concept is that students are responsible for their project work. They are treated as adult students, not as children. It would be too time-consuming for supervisors to monitor the students continually, and it would also be very boring for the students as well as for the supervisors! The idea is that students will behave in a mature and responsible way if they are treated like grown-ups. For some students, however, this freedom can lead to temptations! There will always – at all universities and colleges – be students that try to get their education with a minimum of effort or even try to cheat. Such students – especially if they are used to more traditional teaching – can believe that EPS is an opportunity for leaning back and enjoying life instead of studying. It is important to be realistic and face this problem.

If all students in a team agree to be lazy, the supervisor must be able to detect it and explain the students that it won't work. However, some teams can put much effort into concealing their indolence and try to make it look as if their poor results are simply due to bad luck. Supervisors must be aware of this situation, and after many years of experience with 1280 international students, I dare to maintain that we have learnt to deal with this situation.

However, it rarely happens that a whole group agrees to be lazy. More often, one or maybe two students in a team can be lazy. In those cases, the overall performance will be poor, conflicts can occur, and the good students can lose motivation. To overcome such problems and to secure that lazy students don't pass the exam thanks to the work of other team members, EPS has a special assessment system.

4.7 ASSESSMENT AT EPS

Twice during the semester, the students have to do a "self and peer assessment". Their opinion about their own and the other team members' performance are compared. They are required to assess the quantity and quality of the technical contribution and the contribution to the team process. For some students, it can be a very instructive experience to see that the other team members have assessed them differently than they did themselves. It cannot be part of the marking system because we need honest answers, but it is very instructive for the students, and it can help to detect and solve problems before it is too late. It is also a very good tool for supervisors to detect problems and appraise the conditions of the team.

At the exam, students are assessed individually. After a common presentation, where all are contributing and assessed individually, they are examined individually. However, the team process is very important, and based on the supervisors opinion each team receives an average mark for the teamwork. The students must distribute this part of the marks (35 %) individually according to their individual performance. Some students don't like it, but when they are explained why, they tend to understand and accept it. They may divide the marks equally, but groups who have had teamwork problems caused by lazy team members know how to make use of the system!

It is to be hoped that this assessment system ensures that all students get correct and individual marks. It dissuades some students from leaning back, because they know in advance that if they don't contribute effectively, they'll get bad marks or won't pass the

exam. Another important outcome is that many conflicts about who is lazy and who is not are avoided.

It is of course a challenge to give marks for the teamwork in a well-defined way. Many different elements are assessed such as quality and quantity of the work, how well-organized the work was, how well the students cooperated, how well they solved problems and conflicts etc. It is difficult to give precise marks for all those elements, and it should not be based upon how nice people they are! To a certain extent, the teamwork marks are based upon intuition, but many years of experience have told me that intuition is more correct than people usually believe.

4.8 BENEFITS OF EUROPEAN PROJECT SEMESTER

After 1280 students from 36 countries, the experience with EPS is very positive. Many of the benefits known from PBL and POL are seen, and thanks to the international context, they are reinforced. When the teamwork is good – which is usually the case – synergy takes effect, i.e. the whole is greater than the sum of the parts. It becomes more "we" and less "you and I". Students become motivated, active and creative. Students mature and assume responsibility for their project work and for their learning.

There is no doubt that the international experience is the most important part of EPS. Student diversity is a source of strength, but it can also cause problems and conflicts. The majority of students learn to appreciate diversity and tell us that the international experience was the aspect they liked best. From various social networks and many emails we see that they keep in touch and that EPS starts their international network.

After EPS, many have written to me that they got a job thanks to the international experience from EPS.

Many EPS-students and professors who know EPS well have given us very positive statements.

5. CONCLUSION

My conclusion is that PBL and POL work well when properly applied, especially in an international context like EPS. However, students have different learning styles, professors have different teaching styles, subjects are different, and all learning/teaching will become boring if it always is done in the same way. Learning is nutrition for the brain, and like all other nutrition it should be a good mixture of good components.

An important aspect of group work is that students (hopefully) improve their communication skills and interpersonal competences. The international competences will also be reinforced when the teams are international like in EPS, and so will the motivation thanks to the international experience.

Assessment is an important aspect. Assessment should always be in harmony with the learning process, and when teams are learning by PBL/POL, especially by interdisciplinary projects, things become complex. It is important that the assessment system is able to cope with this challenge and so does the assessment system of EPS.

6. Acknowledgement

I would like to thank Professor Arvid Andersen whose good idea it was and who started the first EPS in 1995.

4. REFERENCES

[1]. www.denstoredanske.dk
[2]. www.dtu.dk
[3]. M Fasting, D. Dynnesen, M. Holbøll, J. Hvidtfeldt Rasmussen, ”KØBENHAVNS TEKNIKUM 100 ÅR Danmarks Industrialisering” (1980).
[4]. www.ruc.dk
[5]. www.aau.dk
[6]. Meridith Belbin, ”Managing Teams – Why They Succeed or Fail” (1981).