INTEGRATION OF WORK BASED LEARNING IN ENGINEERING EDUCATION

Flemming K. Fink[1]

Abstract - *Developing a new engineering educational set-up, which integrates formal education and productive work is a new challenge. The best way to learn and understand a theory is trying to see whether you can apply the theory in engineering problem solving. Therefore it is obvious to try to combine the academic learning process and engineering problem solving. This has been one of the fundamental reasons for the existing Problem Based Learning concept (PBL). In the light of the experiences from this PBL concept some further development makes it possible to integrate work based learning in academic engineering education. This presentation will give some examples on how this is being implemented now and discuss further improvements by combining engineering education, Continuing Professional Development and productive engineering.*

Index Terms - *Problem Based Learning, Work Based Learning, Continuing Professional Learning.*

INTRODUCTION

The pedagogical concept of Problem Based Learning (PBL) has been implemented since 1974 at Aalborg University (AAU) in Denmark [1][2]. In the light of the experiences from this concept some further development will make it possible to integrate productive engineering into engineering education. The basic elements will be described shortly. The pedagogical model centred on problem based, project organized teamwork is evaluated to be an absolute strength of the educational system. The PBL concept allows the students to develop excellent analytical skills and they add up with good experiences in coping with and attacking complex engineering problems. This presentation will deal with the three issues: formal education, life long learning, and industrial production – do we have to keep these separated or can they be integrated?

PROBLEM BASED LEARNING

An excellent way to learn and understand a theory is trying to see whether you can apply the theory. Engineering is problem solving – by applying results from engineering research. Therefore it is obvious to try to combine the fundamental learning process and engineering problem solving.

The curriculum is organised in semesters. One semester is a 20 weeks program at the University. Each semester has its own theme such as Analogue and Digital Electronics (3rd semester), Microprocessor Systems (4th semester), Real-Time Communications Systems (5th semester) etc. The project work – approximately 500 hours of workload for each student - must be within the theme, and some project-related courses are offered to the students. In addition, the students must take some mandatory courses such as mathematics, computer science, and circuit theory. The load for coursework will normally be another 400 hours each semester. This organisation of the curriculum implies that students learn to apply the theoretical courses from the very beginning and on the other hand that mathematics and other fundamental courses are spread over several semesters – in due time before the theories are needed, but at a time where students are motivated to improve their theoretical skills in that field.

Real life problems are not defined in engineering terms. Therefore *problem analysis, definition and formulation in engineering terms* are very important before starting with the problem solving. The *problem solving* part of the project is by far the most demanding part, but it is also very important that the students learn how to document and communicate the process and the results to other engineers. At the end of each semester the students must pass an oral examination based on a report of up to 150 pages plus HW and SW documenting their project. This examination normally takes up to six hours on group basis resulting in individual marks. In addition to this the students must pass individual examinations in the mandatory courses.

The *Problem Based Learning* concept allows the students to develop excellent analytical skills and they add up with good experiences in coping with and attacking complex engineering problems. In addition to a thorough theoretical insight the students become experienced in applying the theoretical elements from the lecturing in practical engineering problem solving.

A great variety of projects at all professional levels must always be accessible, and co-operation between university (students, researchers) and industry is a necessity to find enough relevant real life problems. On the other hand this co-operation will increase the contact and mutual understanding between industrial development centres, students and university professors with benefit to all partners. In the light of the experiences from this concept

[1] Flemming K. Fink, Electronics and IT, Aalborg University, Fredrik Bajers Vej 7A, 9220 Aalborg, Denmark fkf@kom.auc.dk

some further development would make it possible to integrate productive engineering and engineering education.

WORK BASED PBL

In some countries many engineering students never finish their engineering education. Because of the deficiency of educated engineering staff, still more 2nd or 3rd year engineering students are engaged in local industry – initially on part time basis. At first this is very positive for the students, as they earn their living costs and for the local industry, as they are supported with dynamic and inexpensive staff members willing to work whenever needed. Some companies even invest in these young staff members by giving them additional company-internal education.

But there are also severe drawbacks with this trend for the students, companies, universities and polytechnics and for the society as such. For the students it can be difficult to foresee the consequences, but far to many drop out and never graduate. Major companies invest in educating these students to be good staff members, but small and medium sized enterprises (SME's) do not have the resources to do that, and they might be the losers. Universities and Polytechnics invest a lot of resources on those students. Improving the content of the engineering programs can reduce this waste of resources. In the long run this situation may result in more company-based education resulting in less flexibility of the engineering profession, less usable staff for SME's and survival problems for some polytechnic and university educational programmes.

We learned from the implementation of Problem Based Learning in full time educational programmes that learning by applying the theoretical material in engineering problem solving (development) is a strong way of learning. This is inspired from the every day learning process in industry – without doing it "on purpose". Carrying out the engineering task the engineer might seek information in his textbook, in scientific papers etc. and applying the information from here to his development task. The purpose here is not to learn, but to solve the problem, and the increase in competence level is an attractive side effect.

In the PBL concept, the main goal is to learn – learning by combining courses and engineering problem solving. Problem solving is a tool for learning in the PBL concept – solving the problem is not the primary goal.

Combining these two ways of thinking is obvious. The challenge will be to use a modified PBL concept to combine productive engineering and academic learning, to combine industrial tasks for students with their tasks in studying:

- Substitute university based projects with company-based projects
- Substitute teams of students with company based teams
- Re-arrange the curriculum into fewer courses and include work based learning
- Achieve acceptance among staff and management at the university
- Achieve support and commitment in industry for the students learning process in the teams
- Obtain co-operation between industry and university about projects that guarantee the learning context for the students beneficial for both student, company and university.

TEAM WORKING

It is also important to face that engineers are not working in isolation – real life engineering problems are solved in teams of well skilled individuals integrating their capabilities into solving huge and complex problems. Therefore teamwork has also always been part of the PBL concept at AAU [1][2].

The pedagogical model centred on problem based, project organised teamwork is evaluated to be an absolute strength of the educational system [3]. The *group based project organised teamwork* is a very important element in the learning process. It increases the students' skills in professional argumentation, presentation of own proposals for solutions, and critical evaluation of proposals from the other students. Preparation of documentation in form of reports, scientific papers, and posters together with oral presentation is exercising the students for future production of written material and preparation and performance of oral presentations.

Being part of a team the students learn how to co-operate in solving major engineering problems. They learn how to deal with professional discussions in situations like problem definition and argumentation for their choice of solution. They learn how to sort information in what is needed now and what is nice to know later. Students learn how to argue about and explain in scientific terms what they believe is the right solution – it is not enough to claim you are right, you must be able to convince other group members. *Argumentation is a god way of learning.*

They learn how to organise teamwork, learn that a team does not work if not everybody is doing their part of the job. In this way the students assimilate an attitude to work different from what is possible for students doing traditional university study on their own. In return to this the students will get the feeling of safe social surroundings, the other students expect them to show up every morning, and if they do not, they will probably be contacted to find out what is wrong.

The teamwork also has the effect that students push each other. Of course the students go for solving the problem - engineering is problem solving, and they define some sub-tasks for each member of the group. To succeed with your task, you have to read the book, seek out some extra information, read some scientific papers, search the Internet, and do some programming or whatever is needed. And as no student want to end up with a bad solution they work very hard with their project. The project is the key element in the curriculum; students apply the theoretical courses in problem solving, students can via the project reflect on their professional work.

At the end of the semester the supervisor is responsible for the final examination of the project together with external examiners appointed by the minister of education.

EDUCATIONAL DEGREE UPGRADING AS WORK BASED LEARNING

Teamwork often involves people with very different educational backgrounds. In many companies engineering teams often include staff with non-engineering background such as technicians. Technicians with years of work-based experience are often very difficult to tell from the group of engineers. Bright and experienced technicians often come up with good experience-based solutions; they can solve the problem without understanding the theoretical background of what they are doing. On the other hand – if these technicians want to evolve with their tasks and be able to work with the inspiring engineering problems in the future they must have some formal academic knowledge in addition to their work-based skills.

For people engaged in working life and having established a family and financial involvement etc. it is not attractive to leave their job and salary to study at the university, they might even soon get bored and quit again. Therefore part-time educational programmes might be a solution for an educational upgrading from technician to B.Sc.E. level. A formal part-time continuing education between these two levels without any overlap between study and work will take several years and is therefore not attractive – to both the technician and his company.

Therefore the curriculum for this programme must be organised in modules, making it possible to identify professional fields, and composing a personal educational programme from these modules, for two reasons:

- The individual technician can make the choice of studying a narrow field to reach a certain academic level (B.Sc.E.) within this field only
- The individual technician can go for a formal test within his strongest areas without spending to much time following lectures.

It is very important not to underestimate the skills obtained from years of experience. Universities must therefore develop ways to evaluate and compare work-based skills to academic skills within these fields [4]. Compared to the PBL concept it is identified that there is a strong similarity between projects carried out by students in an ordinary PBL curriculum and projects carried out by students in a continuing education programme. One major difference is that full-time students in a university-based team are rather homogeneous with respect to academic level, age, social activities, etc. whereas this is not the case for company-based teams. We consequently have to

- Learn to evaluate projects and test students who are part of a very inhomogeneous team with respect to formal educational background, practical experience and goals to achieve.
- Learn to evaluate students in a teamwork composed of people involved in a formal learning process and people just doing their job, people on engineering level and people trying to reach that level.

CONTINUING PROFESSIONAL DEVELOPMENT AS COOPERATIVE PROGRAMMES

Continuing Professional Development (CPD) for engineers within the fields of electronics and information technology has become increasingly vital. CPD includes the development of professional theoretical skills in addition to the practical work functions i.e. a combination of continuing engineering education along with productive engineering. The extremely engineering-intensive field of mobile communications, which is subject to very rapid innovation processes in which the development of new products and services accounts for the majority of the costs, provides an excellent example of an environment in which engineering CPD is especially valuable. Thus, there is a new focus on the importance of human resources as a significant resource for the industrial development.

Until now mostly private professional organisations offer courses for engineering professionals to update their skills, organised as in-plant courses, five days intensive courses in nice locations or major international cities etc. This kind of upgrading, re-education or just follow-up courses takes time.

Most innovative companies are aware of the importance of improvement of professional competence. From research on trying to describe the context of CPD [5] it is known that even though professional development is identified as vital for the future of the company, the individual engineering staff member often tells that he must find the time for such courses himself – they are not integrated in the time-plan for the project. Money for financing the course is normally no problem – but *time* is.

Another parameter that must be considered is the recognition of the course as being part of the personal curriculum – which means that some kind of standardised approval is desirable. This means that CPD-programmes must be developed to meet the expectations of both the managers as well as the engineers, programmes that integrates new academic knowledge into the productive daily process of the engineer or vice versa.

Part-time Master programmes

At AAU we have implemented this in some specific “Master – programmes” as research based PBL – like the ordinary programmes described above but adjusted to the daily situation of the new “students”. These “Master-programmes” are 1-1½ year programmes on half-time basis, which means that it takes 2-3 years to succeed. The programme consists of courses and project work. As in the ordinary daytime studies the project must cover at least 50% of the time and some of the courses must be applied in the project. The programme is also organised in themes and for the engineers attending the programme it should be possible via the project to integrate his job tasks into his study – or to integrate the application of the courses into his job tasks. In this way the workload from following the study will nominally be reduced. Until now we have only urged the engineer to do this integration of study and work. We have however realised that this is not always easy. In the future we will consider new ways of more direct cooperation between university and company on management level to define the framework of the educational process.

In these master-programmes IT-based distance education is very important [6][7]. In the courses as well as the dialog between students, the dialog between students and teachers, development in the project work etc. distance education tools are being used. This means for example that even though an engineer for a period is posted to work from another country he can still be an active student. Face-to-face seminars though are still important if possible. We tend to schedule 7-8 two-day seminars a year at the university (or where ever optimal for the group or the content). Here the students and teachers can meet, hands-on laboratory exercises can be carried out, etc.

The mentioned concept for CPD-programmes has been implemented at AAU for several years. By now the acceptance of this concept of combining PBL, IT-based distance education and face-to-face seminars is so outspoken that we have been requested to apply it to other programmes with less content.

COMPANY COMMITMENT TO STAFF DEVELOPMENT

The awareness of the importance of professional development of engineering staff differs from company to company. As more and more consumer products, industrial equipment, etc. includes an increasing amount of advanced functionalities and features the demands for skilled engineering staff increases as well. Different strategies for meeting these requirements can be identified from company to company. Based on several years of dialog with industry concerning engineering staff development these strategies can be divided into different idealised categories.

Decentralised strategy

We can still find even very large companies with old traditions without any company strategy for engineering competence development. The decision about competence development is decentralised to as low a level in the organization as possible. The result from such a strategy will often be that the individual engineer may apply for a CPD activity if he believes he needs it. Organising courses for staff members with similar professional profiles across department boarders will normally not take place, and there will probably be no correlation between individual ideas of professional profile development and management decisions on future company development. The individual engineer may risk finding himself on a wrong track of competence development without correlation to decisions made on department or company level.

Competence import

Many companies still do not have a policy for competence development for their development staff and for the company as such. So far the individual engineer has managed to improve his skills on individual basis. The manager of the company is quite aware of the limitations in professional capacity in the company, and if new competence is needed for new products he will try to engage a skilled person. Participation in external seminars, courses etc. are only on individual and ad hoc basis. The only way for engineering staff in such a company to improve his academic skills is to follow a course on individual basis in his leisure time or find another job.

Internal staff development

Companies with theoretically well skilled engineering staff members with a thorough knowledge of what is needed for the development tasks in the near future may want to use their capacity as a basis for internal professional development of the engineering staff. This is seen to be the situation in companies with fast innovative processes: They engage new engineering staff, perhaps young graduates with fresh theoretical competence from the university every month. Mixing these new colleagues with elder staff members in project teams and in organised seminars the common professional level will improve for both groups. If new knowledge is needed ad hoc courses will be organised or bought. As there is no CPD strategy for each individual engineer, a busy development engineer might be too busy to realise new opportunities, theories or tools.

Buying courses

There are a large number of enterprises, schools etc. trying to sell courses on all professional levels for every kind of staff. Courses like intensive 3-5 day seminars with world wide well known experts, video taped courses, streamed web-based courses, self-study courses etc. are available. Buying such courses is an easy way to try to catch up with the fast innovation in new technology.

Future opportunities

The implemented strategy for CPD will in many cases be a mix of the above listed categories. CPD will in the coming years be more and more a competing parameter – in two ways: 1) you need to have the best skilled engineering staff in your company to compete your rival firms, 2) young engineers are seeking companies with good opportunities for developing their skills and carrier i.e. the CPD-strategy will influence the possibility to attract new staff member.

To keep up the professional level of the individual engineer and the total development staff is a time consuming task using traditional means such as courses whether they are in-plant, external, web-based etc. New steps must be taken to improve CPD and in parallel to this reduce the time consumption.

IDENTIFYING LEARNING GOALS

First step is to introduce procedures and tools to identify the professional capacity of the company as such and compare this with the capacity needed to fulfil the goals for the company in whatever terms they are formulated (share of market, annual turnover, specific products within a given timeframe etc.) This must be based on a thorough analysis of what is needed to carry out each task in the company compared to the profile of the team and team-members responsible for the result.

The result of this analysis can be identifications of some competence deficiency – minor or major for individuals and for departments. The identified deficiencies, present or future, are the prerequisites for the definition of the learning goals that must be reached. Learning goals will be defined for individuals and for teams, departments and the company as such. Depending on the character of the learning goal different means may be taken into consideration to reach the content and level of the goal within the defined timeframe.

The easy way is to search the market and identify the best course to meet the requirements. But as mentioned above this might not be the best way. We learned from the implementation of Problem Based Learning in full time educational programmes that learning by applying the theoretical material in engineering problem solving (development) is a strong way of learning.

Individual learning goals

Competence Development by following face-to-face courses is only possible if a course is accessible – either for individual enrolment or as in plant courses. These courses must be taken in a given speed at a given time without any possible consideration for individual needs. Streamed or videotaped courses are flexible, but normally there will be no dialog between participants or between participants and a teacher.

Following individual learning goals by work based learning the learning process will be integrated into the daily engineering productive work. The learning speed as well as the professional content and goals are defined individually.

The transformation of identified competence deficiencies into learning goals will be a new task for competence providers such as university professors. This transformation must be carried out in cooperation between the competence provider, the competence receiver and the company represented by the human resource manger or the team leader. The result will be a CPD programme consisting of

- A description of defined learning goals in terms of professional content, time schedule and exams
- Planning of which pedagogical means should be involved
- Defining the tasks for the professor
- Defining the company commitment to involve the engineer in relevant projects and teams and give him/her support from senior staff members.

ORGANISATIONAL LEARNING

Individual oriented competence development like courses with individual enrolment includes the risk of being a waste of money and time for the organisation. The course might not be 100% relevant for the participant and the timing of the relevant issues to his/her needs might not be optimal. Bad timing means knowledge input too late or too early, i.e. the engineer is not going to use the new knowledge with the risk that his/her competence is not consolidated.

To get the optimal benefit from investment in new competences the single element of competence development must be pre-defined in the CPD plan for the individual and for the team or the company. Each learning element must include a definition of the purpose with this activity. The correlation between the content of the learning element and the overall learning strategy must be identified, and the outcome of carrying out the task must be evaluated.

Too many participants in CPD-courses are never faced with the demand of justifying the relevance of the course afterwards – only on beforehand. It is perhaps even more relevant to go through the course in a very condensed form for a group of colleagues and highlight the most important issues in the course. In this way the learning process of the course participant will be improved and the organisation as such will also benefit.

In work based learning the benefit for the organisation is more obvious. The learning process, goals, content, form, and timing is planned to optimise the situation for the participant and for his team. The content, form, or timing can be revised based on the context, and transformation of knowledge into the organisation can be an integral part of the strategy.

CONCLUSION

The pedagogical model centred on problem based, project organised teamwork is evaluated to be an absolute strength of the educational system. The problem based part – the *Problem Based Learning (PBL)* concept allows the students to develop excellent analytical skills and they add up with good experiences in coping with and attacking complex engineering problems.

Compared to the PBL concept it is identified that there is a strong similarity between projects carried out by students in an ordinary PBL curriculum and projects carried out by students in a continuing education programme. As the demand for continuing professional development programmes, formal or informal, short or long, is growing and the time for following these programmes are very limited, it is an obvious task to further develop and implement the PBL concept from full time programmes.

The challenge will be to use a modified PBL concept to combine productive engineering and academic learning, to combine the industrial tasks with tasks in studying: substitute university based projects with company-based projects, substitute teams of students with company based teams, re-arrange the curriculum into fewer courses and include work based learning, obtain commitment from industry on projects that guarantee the learning context beneficial for both student, company and university.

If we do that, the answer to the introductory question will be "yes" – formal education, industrial productivity and life long learning can be integrated.

Such re-engineering of the PBL curriculum can be seen as a way for the modern university to change from being a closed academic world to be an open an integral part of the community.

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