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Experiences from a Pedagogical Shift in Engineering Education

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The electronic and electrical engineering programmes at the Engineering College of Odense (Ingeniørhøjskolen Odense Teknikum) (IOT), Odense, Denmark, were transformed from programmes based upon traditional ways of teaching and a traditional curriculum into project organised and problem-based programmes. This transformation was a response to the new challenges in engineering education; the need for life-long learning and new personal competences, programme overload and competition for the students' time. The new programmes have been well received among the students and in industry. This article focuses on some of the experiences gained in Odense during this transformation of programmes, taking both the points of view of teachers and students. Finally, a few words of advice are passed on to others who may be facing similar challenges. The IOT is presently discussing what the key competences of its students and graduates should be and, furthermore, how the different course elements in the curriculum and the choice of pedagogical methods support the creation of these competences. It is the impression of the IOT that a lot could be gained if all teachers were more aware of the exact role of each course in relation to the support of different competences. Thus, the next issue to be focused on is the improvement of the quality of IOT syllabi by being able to clearly state the relationship between the learning goals of each subject and the competences gained.

INTRODUCTION

This article describes the pedagogical transformation of the undergraduate programmes in electronic and electrical engineering at the Engineering College of Odense (Ingeniørhøjskolen Odense Teknikum) (IOT), Odense, Denmark.

The transformation that took place during the period from 1996 to 1999 incorporates a major pedagogical shift from traditional subject- and classroom-based teaching to project organised and problem-based learning.

This article aims to describe the purpose of the transformation, how it was carried out, as well as the impact the transformation of the pedagogical method has had on both the students and the teaching staff a few years later.

The article concludes with some recommendations to others who may face similar challenges to those that the Engineering College of Odense encountered six to seven years ago.

WHY TRANSFORM GOOD PROGRAMMES?

The engineering BSc programmes in Denmark are organised as a 3½-year programme, which incorporates half a year of industrial placement.

Until 1996, the BSc in Electronic Engineering and the BSc in Electrical Engineering programmes at the IOT were based upon this very traditional curriculum and a very traditional way of teaching. In short, the curriculum consisted of a number of subjects (eg mathmatics, physics, circuit theory, electrophysics, etc) – normally six or seven per semester. Almost all of these were taught using traditional classroom teaching methods; some subjects were taught in combination with laboratory experiments.

Each subject was planned as per normal, taught by a single teacher and with an examination for each subject at the end of the semester for assessment. The examinations were normally either oral or, as in most cases, written 2- or 4-hour exams.

It should also be stated that the graduates from the IOT were (and still are) very much appreciated in industry, the unemployment rate among young engineering graduates is extremely low and the general reputation of IOT programmes remains rather good.

So why go through a drastic transformation of the programmes? The answer is that the IOT was (and to some extent still is) facing some new challenges of which the following four are of special importance in relation to the transformation of the programmes:

1. Now, more than ever, we have to deal with the need for life-long learning. Universities should take this aspect into consideration when planning educational programmes. Every programme should prepare the graduates to function in a world where life-long learning is essential. This is especially seen as true within engineering.
2. Engineering programmes are very much under time pressure as new subjects arise and must be addressed in the programmes at a pace that far exceeds the possibility of removing topics from the curriculum, at least when using more traditional pedagogical approaches. This issue of programme overload seems to be a well-known reality within engineering education.
3. New programmes should do more to increase emphasis on the increasing importance of certain personal competences in future engineering jobs. These competences include the ability to cooperate and to work in groups, as well as improved written and verbal communication skills.
4. Furthermore, IOT students are increasingly spending time on activities related to social lives, eg part-time jobs, sports, etc. This means that the time used for studies may decrease unless the studies are so involving that the students choose to spend more time studying. We are, in other words, competing for the students' time.

Transforming curricula and creating new ones should therefore adress all the four major challenges stated above.

HOW DID THIS GET STARTED?

In the early 1990s, the common idea began to evolve among many of the teachers at the IOT's Department of Electronic and Electrical Engineering that a pedagogical shift was needed. They wanted to make better programmes by placing the students closer to the center of the whole learning process, while also creating more satisfactory and creative jobs for the teachers at the same time. This job involved more time spent on developing new knowledge and interacting with students and less time spent standing lecturing in front of a blackboard.

During this period, a number of teachers, as well as management personnel, participated in conferences and seminars concerning Problem-Based Learning (PBL), etc, in order to gain inspiration for potential IOT programmes. Furthermore, guest speakers were invited to come to the IOT to give input about how things were done elsewhere at institutions already running programmes that incorporate project organised teaching methods. A number of institutions were quite inspiring in this regard; firstly Aalborg University, Aalborg, Denmark, but also intriguing was how things were done at Linkøping University, Linkøping, Sweden and at University of Twente, Twente, the Netherlands.

After a while, the motivation for change grew very strong among the teachers and it was felt that it would be beneficial to create a pedagogical model at the IOT for teaching engineering students. Therefore, in 1995, the management of the Department of Electronic and Electrical Engineering decided that teaching based on new curricula should be implemented in all their programmes starting in September 1996. More than 90% of the teaching staff affiliated to these programmes supported the decision. The decision was thus not a standalone managerial decision but was heavily supported from the people who had to undertake the actual task of transforming the programmes.

This initial support was considered very important because of the massive workload involved in the transformation, the tight time schedule applied (one year from decision to implementation) and because of the problems that inevitably arose during the process but were dealt with a lot easier because the decision was a joint one.

THE NEW PROGRAMME

The new programme was developed using several overall principles, as follows:

- All of the first four semesters are to have an overall theme.
- Within a semester, preferably all subjects are to be linked together and coordinated under the overall theme.
- All semesters are to be planned and taught by a group of teachers of which one is appointed semester coordinator.

- Project work is, on average, to constitute about 50% of the scheduled time.
- Each semester should involve one major project with students working in groups of five to six students.
- The project is to be linked to the subjects in the same semester.
- Subjects are to be assessed in relation to the project work and there are to be few (possibly one) examinations each semester.

These overall principles were developed through an intense process of discussion involving most of the teachers and a number of students. The discussions focused upon what would work at the IOT and why, partly based upon all the collected experience and evidence from other institutions as mentioned above and partly based upon IOT's experiences from minor pedagogical experiments within the existing curriculum.

The resulting new structure of the IOT curriculum is shown in Table 1, using electronic engineering as an example. The table shows the division of the semesters into project-time and theory-time; the overall theme for the first four semesters is stated also.

EXPERIENCES GAINED

After five years of experience with the new project organised and problem-based programmes, it is now possible to come up with some points that may be of general interest as to the IOT's experiences in the change process.

This section is divided into two major areas: experiences mainly related to the teaching staff and experiences mainly related to the students.

The Teachers

The whole change process has been driven by teachers from day one. It has been the IOT's experience that it was, and still is, important to reinforce motivation by constantly focusing on different aspects of the curriculum, eg processes within groups or the effect of different forms of assessment on student learning, thereby keeping alive interesting pedagogical discussion among the teachers.

The IOT has observed that one of the best ways to do this is to invite experts from other institutions to come to Odense for discussions. Teachers from Aalborg University have been of assistance and the pedagogical network among engineering institutions in Denmark (IPN) has also been utilised to give input on pedagogical aspects related to teaching in project organised programmes.

Constant pedagogical awareness and continuing education of the teaching staff is thus very important. But it is also important to be mindful of the fact that this is an internal project. The group of teachers must maintain a feeling of ownership of the project, meaning that the teachers should always be allowed to *translate* external input into relevant use at the IOT or to reject the relevance of the input.

As all semesters were planned by groups of teachers, it turned out to be very important that there was enough time scheduled for the teachers to meet during the semester in order to plan (and adjust) both the lectures and the projects. If sufficient time is given for the teachers to work together, this will definitely increase the feeling that this is a joint project, and the motivation to work even harder will be there.

Table 1: Schematic representation of the new project organised and problem-based programme in electronic engineering at the IOT.

7th semester	Final project Specialisation/elective courses
6th semester	Theory/project
5th semester	Industrial placement
4th semester	Theory / Project *Semester theme: Control System – Analysis, Design and Application*
3rd semester	Theory / Project *Semester theme: Generation and measurement of electromagnetic fields combined with analogue electronic signal processing*
2nd semester	Theory / Project *Semester theme: Microcontroller-based measurement/analysis/control of mechanical/physical system*
1st semester	Theory / Project *Semester theme: Project-based work; methods and organisation*

On the other hand, it was also found that some teachers were having difficulties finding the right level of cooperation. This was due to the fact that most teachers were used to traditional and individualistic teaching. In this sense, it could be said that the process of switching to project organised methods was in many ways harder and more demanding for the teachers than for the students.

It was also found to be essential to stick to the overall rule that all subjects in a semester should align with the overall theme and with the project. It turned out that the few exceptions made in order to handle difficulties (eg lack of teacher motivation, too many restraints to project topics, etc) led to unsatisfactory results.

If the students are taught to view things from a holistic perspective, it will be difficult to convince them that subjects should not be an integral part of the overall semester's theme. Furthermore, there seems to be a tendency by students not to give a single subject sufficient priority because most of their focus will be on the project itself.

The conclusion that can be reached is to stick to the rule: every subject in the semester should be an integral part of the overall semester theme and relate to the project work.

In relation to the teachers' workload, it turned out that the actual time needed for teachers to plan in advance for the coming semester was heavily increased. This came as a little surprise, but was related to the fact that it turned out to be quite important to take different possible developments of the projects into consideration. Compared to traditional teaching, a teacher is less behind the *steering wheel* when using the PBL method because the method implies a higher scale of student involvement. However, many teachers also see this as one of the most exciting elements of this new method of teaching.

The possibility of the teachers gaining new knowledge through the role as advisor to the students' projects is now considered to be much greater than using traditional teaching methods and more or less teaching the same subject over and over again.

Thus, the IOT has generally encountered that the switch to new teaching methods did not save time, not even after the transition took place. But the time used for planning or meeting with the students as a consultant, advisor or coach is generally considered by the teachers to be used in a more satisfactory manner compared to the former traditional lectures. Moreover, it is the teachers' impression that the students now put more work into their studies.

The Students

Generally it is clear from various evaluations (internal as well as external) that the students are very happy with the project organised problem-based curriculum, and that the shift has not created problems in this respect.

The IOT's experience has shown that it is important to start the new way of teaching from semester one when the students come to the University. It was found that students starting at semester one in the new curriculum understood very quickly the concepts and put them into action. However, with some difficulties, attempts were made to implement some of the project organised elements in the higher semesters for students who had been taught in the traditional curriculum. There seems to be a certain amount of conservatism involved in this regard from the students' point of view, but starting the new type of curriculum from semester one, when students begin new studies and expect change anyway, should minimise or eliminate these kinds of problems.

As stated earlier, it is the teachers' impression that students tend to be more dedicated and spend more working hours studying in the new curriculum. According to the IOT's evaluations, this view is also shared by students. Furthermore, it is the impression of both students and teachers that this effect is primarily related to the large project work involved and due to the group organisation of the students. Several different aspects seem to play a role here.

Firstly, and probably most importantly, the students tend to become more involved in the studies of the single subjects because every subject is of relevance to the project in every semester.

Secondly, the students are mutually interdependent in groups of five to six students. They all seek a good result because a part of their final assessment is given on the basis of their common project (report and process/project assessment). In this sense, the students mutually commit themselves to put in more work in a way that could not have been achieved by the teachers.

However, this can also be described as a sort of group pressure and is also considered to be the main reason why the group formation process at the beginning of each semester can be a harsh process for the students to get through.

At the IOT, the students are generally allowed to form their own groups. The only requirement is that everybody gets to be member of a group. Obviously, students who did not perform well the previous semester might have difficulties finding a group the following semester. The students who encounter

major problems here are those who did not put in sufficient time the previous semester. So, like it or not, in this sense the system works as a means to motivate students to work harder.

Thirdly, it also turned out, as hoped, that the synergy effects coming from students working closely together, learning and getting inspired from each other is also a quite substantial benefit.

Fourthly, the physical facilities are good and accessible to students around the clock, which is also considered by the students to be quite important.

When it was decided to transform the IOT curriculum, some of the teaching facilities were also accordingly rebuilt. Thus, each group has their own group room at their disposal 24 hours a day throughout the whole semester. The room is equipped with working tables, blackboard, noticeboard and computer with printer and Internet connection. The students can also bring their own computers into the project group rooms.

Different types of group rooms were experimented with in order to find out what students liked the best. This included trialling several groups in larger rooms with sound reducing movable walls, etc, but the resulting evaluations were quite clear: one enclosed room per group is considered by the students to be the best solution. Consequently, almost all IOT project rooms have been rebuilt like that now.

The students (as well as the teachers) judge it essential that the necessary facilities are at hand in order to successfully implement a project organised curriculum.

It has been learned that it is extremely important to choose the appropriate forms of assessment to be used through the whole curriculum. It is well known that the assessment form has a decisive impact on how students behave during the semester. For example, if the final examination is an individual written exam solving certain types of exercises, then the students will study in a manner that makes them good at doing just that. However, if the goal is to have students be proficient at addressing problems from a holistic perspective and to come up with overall well balanced solutions by going through a development process within project work, then the form of assessment chosen should reflect just that; process assessment and various continous assesment methods should be utilised. In general the choice of assessment should be balanced with the learning goals desired.

At this point, it should also be mentioned that industry feedback, after having employed the first batch of engineers from the new programme for a couple of years now, clearly indicates that they welcome our new engineers and that the grduates' new competences are highly appreciated. Therefore, it is the IOT's impression that the reputation of IOT graduates has progressed from good to even better after the introduction of the new programmes.

WHERE DO WE GO FROM HERE?

Based on the experiences gained from transforming the traditional curriculum in electronic and electrical engineering into a new curriculum based on project organised and Problem-Based Learning (PBL) methods and from actually running these programmes for more than five years, the IOT is presently in the process of transforming all of its programmes using the same model (with minor alterations).

Apart from the overall work to carry out this pedagogical shift in all of our programmes, the focus of the curriculum development work at the IOT is currently directed towards two issues: assessment methods and describing the key competences of an IOT graudate.

In relation to assessment the IOT is elaborating on the issue of choosing and developing appropriate assessment methods as mentioned above. It is the IOT's impression that habit and more traditional ways of looking at assessment should not restrict development. It is the author's expectation that the choice of assessment will change dramatically within the coming years and it is still an issue that leaves the IOT and elsewhere plenty of room for improvement.

The IOT is presently discussing what key competences should characterise IOT students and what role the various course elements should have in creating these competences. The impression is that much could be gained if all teachers were more aware of those course elements and pedagogical methods that can support and strengthen such competences.

The next issue to be focused on is to clearly state these relationships between the subjects' learning goals and competences in the syllabi.

WORDS OF ADVICE

In summing up the issues in this article, the author endeavours to give a few brief words of advice that may be of use to others who are considering major changes in their curricula based on new project organised and problem-based teaching methods.

- First of all, if a lively debate about new pedagogical methods is not present among the teaching staff, then put in a lot of effort to get it started and

to keep it going. This debate is the basis for creating the motivation to change programmes.

- Once the readiness for change is there amongst the majority of the teaching staff (and this may take a while), management should decide what the overall guiding principles of the changes and the new programmes are to be.
- Make sure that the facillities needed to support both teachers and students in the new programmes are present (eg project rooms, pedagogical support, etc).
- Make sure that most (if not all) teachers and all subjects are involved in the process of changing the curriculum and the pedagogical methods.
- It is important to make intensive use of student feedback to make adjustments during the change process.
- Once decided, stick to the overall guiding principles for the change. Do not let the traditionalists stop progress, but have confidence in personal judgements and do not be afraid to trial new methods of teaching and assessment.

BIOGRAPHY

Henning Andersen has been the Rector of the Engineering College of Odense (Ingeniørhøjskolen Odense Teknikum - IOT) since 2000. Prof. Andersen previously held the position of Head of the Department of Electronic and Electrical Engineering at the IOT for a period of six years. Apart from this, he has been involved in engineering education since 1987, both as a teacher in electronic and electrical engineering programmes at the IOT and as a member of various working groups concerned with the development of engineering education. Prof. Andersen graduated with a Bachelor of Science in Electronic Engineering and has worked in Danish industry for a number of years in the field of research and development prior to coming to the IOT.