A real CDIO mechanical engineering project in 4th semester

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ABSTRACT

In the past 6 years at the mechanical engineering study at the Engineering College of Aarhus we have been practicing project work on 4th Semester in the design of energy technology systems. In my presentation, I will give a description of the project, and the thoughts behind; pedagogic-didactic as well as technical and professional considerations. The project is presently a permanent part of the 4th semester and counts as one third of the semester. The semester's theme is Energy-and System Design. Content on 4th semester is organized in light of which skills an engineer must possess in the field of energy technology. Here, it is vitally important, that the engineer is able to develop energy technology systems, thus being able to design systems, and not just individual components. It is not sufficient, that the engineer is able to calculate eg. a heat exchanger; the engineer must be able to consider the components as parts of a complex system. The semester project design is developed on basis of these considerations.

The semester consists of 4 theory courses in: thermodynamics, control- and simulation of dynamic systems, electronics and hydraulic systems. The project work is performed in groups of 4-6 students, and will partly support the general theory being taught in the courses, but will also provide students with skills in teamwork, project work and system building. The pedagogical considerations behind the development of the project are quite simply that students learn best through active work and experiments, after which they can analyze and reflect on the results obtained. It was therefore natural to enable the students to implement projects based on the ideas in the CDIO concept.

KEYWORDS

Energy and system design, prototypes, project work, thermodynamic, control-and simulation of dynamic systems.

INTRODUCTION

In the following, my intention is, to describe the practical implementation of several key CDIO elements through a 4th semester project at the mechanical department at Engineering College of Aarhus. The semester's theme is Energy-and System Design. Content on 4th semester is organized in light of what skills an engineer must possess in the field of energy technology.
The most important key CDIO elements implemented in the project are:

- ***Standard 2, CDIO Syllabus Outcomes, section 2, 3 and 4***
    - Section 2 (*Personal* learning outcomes). The current project focuses specifically on problem solving, experimentation and knowledge discovery,

system thinking and creative thinking. The project is specifically working with the development of energy technology systems based on real problems.

- Section 3 (*Interpersonal* learning outcomes). The current project focuses on individual and group interactions, as the works is done in groups of 4 - 6 students.
- Section 4 (*Product and system building* skills). This element fits exactly with the current project, as most of the projects are done in cooperation with companies near Aarhus.

- ***Standard 3, Integrated Curriculum***

  This standard is descriped in the following manner; *A CDIO curriculum includes learning experiences that lead to the acquisition of* personal, interpersonal, and product and system building skills *integrated with the learning of disciplinary content…*

  This standard is incooperated in the project, as the project work is done parallel to 4 theory courses in: thermodynamics, control- and simulation of dynamic systems, electronics and hydraulic systems, and will partly support the general theory being taught in these courses, but will also provide students with skills in teamwork, project work and system building.

- ***Standard 8, Active Learning***

  Active Learning Teaching and learning based on active experimental learning methods is the pedagogical thinking behind the design of the course.

PEDAGOGICAL AND DIDACTIC CONSIDERATIONS

The pedagogical considerations behind the development of the project are quite simply, that students learn best through active work and experiments, after which they can analyze and reflect on the results obtained. Three basic elements have to be present to ensure that learning takes place, 1) the student must work, 2) work engaged and 3) and the work must be within his/her possible bandwidth [1]. This I think we have fulfilled here! The students work both practically and theoretically with important issues, they work engaged, because they have chosen relevant and motivating topics and they work within their capable bandwidth because they more or less decide themselves how deep they dive into the theory.

Based on this it was therefore natural to us, to enable the students to implement projects based on the ideas in the CDIO concept.

The whole way through the design of the project course we were aware, that the students to as far extent as possible have to work the same way in the project work as they will do when they have graduated with an bachelor degree in engineering. Therefore we try as much as possible to encourage the students to find real problems to solve together with a company, even though this is sometimes in conflicts with the content, we also want the students to learn during the course.

The students are to find and describe the project problem by themselves and afterwards to have the description approved by their supervisor. With the approval procedure we want to ensure that the project has the right focus namely, to design an energy technical system and to do all relevant calculations needed (specific thermodynamic and simulation considerations).

To ensure the integrated curriculum, we have designed a scheme for the entire semester, where courses are planned parallel to the project course. It is done parallel to 4 theory courses in: thermodynamics, control- and simulation of dynamic systems, electronics and hydraulic systems, and will partly support the general theory being taught in these courses, but will also provide students with skills in teamwork, project work and system building.

Thermodynamic, 7½ ECTS
Control- and simulation of dynamic systems, 5 ECTS
Electronics, 5 ECTS
Hydraulic systems, 2½ ECTS
Project work course, 10 ECTS

Figure 1. Scheme for 4th semester in mechanical engineering

LEARNING OBJECTIVES OF THE PROJECT COURSE

The learning objective of this fourth semester project reads:

When the semester project is completed, the student will be able to:
- Design, analyze and calculate an energy technical system, specifically in terms of thermodynamic calculation.
- Select and explain the choice of instrumentation
- Analyze the structure of the system in order to be able to simulate the system function and select the appropriate regulating components
- Develop a prototype and test it in the laboratorium
- Write a technical report incl. references and experimental report

Project work has to include an experimental part, ie. test of a prototype, and it is important that the measurements are compared with the calculation model or the base calculations and that conclusions are made according to this.

CONTENTS AND IDEAS OF THE PROJECT DESIGN

Based on the above mentioned considerations, we designed a project work, as follows.

- There will be a short start-up meeting where:
    - Groups are formed by students of 4 to 6 people. The groups are formed based on the students' own preferences, although we encourage them to form groups based on which skills are needed in this specific project work.
    - Project ideas are presented. We have a project catalogue with ideas to inspire the groups to find a motivating project and we also have a list of relevant companies to contact, but as earlier mentioned, they are free to find a project and a partner company on their own.
    - Learning objectives, level of implementation, guidance form and evaluation form are presented.

- A main idea behind the project work is, that students must develop an energy-technical system, buy parts and components and build them together into a prototype. Students thereby gain experience with putting the related courses in perspective and they learn actively by using the theory on "real" issues.

- The projects are open, i.e. the task text is not fixed. The students are required to work seriously with the problem formulation and specification. The phases of the project implement elements that the students have worked with at the previous semesters. The students are allowed to present their own project ideas, they can find a project from a company or they can choose a project from the project catalogue. In all cases, they must have the project formulation approved by the teachers.

As a part of the project work the groups must hand in a project specification which has to be continuously and regularly updated and at all times in the the project period has to be available. It is important that the project specification is so detailed a technical description of the project, that the supervisors on this basis can decide whether the project meets the learning objectives and professional themes on fourth semester.
The idea behind this demand is, that this also is how engineers often works with projects in real life and that it is important for the students to develop professional communication skills.
The project specification has to contain:

- A cover page with title of project, version number and date
- A section titled "Project". This section includes text, figures, etc. This has to be a detailed description of what the project is all about. It should enable an outsider to get a fairly overview, and it should enable the supervisor to assess, whether the project can meet the learning objectives.
- A section entitled "Timetable". Here one should be able to see the timetable for the project, i.e., applicable to the already time already spent and a plan for the remaining time.
- A section with information on project staff, i.e., names, initials, telephone numbers etc.
- Optionally also a section on with project group cooperation and other issues.

- Examples of projects that have been implemented:
  - Dehumidifier
  - Soft ice machine
  - Milk Shake machine
  - Desalination plant
  - Climatic chamber
  - Heat pump
  - Water Cooler

PHASES OF THE PROJECT WORK

When designing the project course, we have tried to fulfil the CDIO-phases as much as possible, not only to fill out a kind of form or table but because it makes sense since this is how engineers work.

The course design is a result of some years of development. The challenges in this development process have been many. To mention some:

- Being able to build the many prototypes (normally 5- 8 per semester) it requires good machine shop with sufficient workers, tools and last but not least a stock with the relevant goods and articles

- It is resource consuming to build the prototypes, in terms of salary to the workers and purchasing of all the components
- it requires the availability of many group rooms for the students to work without being interrupted and for the students to be able to lock their rooms, so that they can use them as a place where small experiments can be made
- it has required some development of skills among the staff to be able to give the appropriate supervision
- it is important, that the supervisors have broad competences in the field of thermodynamic systems and simulation of dynamic systems etc., since the students come up with very different and creative ideas. Since we have a limited staff in this area and often have to hire some supervisors on hourly basis, it is a challenge to find supervisors who are competent in this field

Below, description of the phases as the structure is just now:

1. First phase of the project is to establish project formulation, and from a brainstorming session to come up with possible solutions. This is the conceptual clarification phase, the **conceiving phase**. In this phase the students use the project work tools that they have required in the previous semesters, such as tools for brainstorming and problem solving.

2. Second phase is the **design phase**, which most of the time takes place in the group rooms, complemented by small experiments in laboratories, group room and the machine shop.

3. The third phase is the construction of prototypes, the **implementation phase**. Here, the students work in groups in the machine shop, with help from the technical staff.

4. The fourth phase is the testing phase, where students perform function tests and measurements on the prototype, the **operating phase**. This phase should, according to the CDIO standards, take place in real-life situations. This has in most projects not been possible to fulfill, because of time resources etc.

5. The final phase is the **documentation phase**, where a technical report is produced, that describes all four phases and explain the group's calculations, the design process, analysis and comparisons between test results and calculations. The report shall also include reflections on the group's work process.

The students will at the examination present their results and the project is evaluated in the light of the report and an individual examination.

REFLECTIONS AND CHALLENGES

We have now been working with this project design in more than 6 years and have constantly been developing the design. Still there are a lot of things to do, things to improve and challenges to meet.
Hereby I have listed some of the challenges, I see, and some reflections on how the design works:

- When the students work in groups, they develop some important skills, such as interpersonal, teamwork, leadership, and communication skills, but in their future career they in many cases will have to work partly alone. Although they work in teams they partly will have to work out individual problems in the role of an expert. These competences are not developed sufficiently in the project work.

- Testing of the prototype has to evaluate specific calculations and assumptions. This work is not done in a sufficiently sciencetific and systematic way. It does not give validated and reliable results.
- The reflections on the project work are not satisfactory. The students do not sufficiently reflect and compare the calculations and the test results. Here they maybe miss some tools.
- When building the prototype, the students do a lot of ordinary handwork, because they think it is fun and because of lack in workers in the machine shop. Handwork is not a learning objective. Although it also is motivating and fun, we have to be aware of the balance here.
- The process of forming the groups is not optimal. Here we have to look at other solutions. Maybe forming the groups according to the competences represented in the groups or similar.

CONCLUSIONS

When asking, is this project design a success? I have to say; yes. I think so.
Let me justify this in the following.

What was the goal and did we reach it?
The reason, why we chose this design, can be read from the learning objectives. This is what we want the students to learn. So, let us take a look at those:

- *Design, analyze and calculate an energy technical system, in terms of thermodynamic calculation specifically.* We have not comparable data that shows if the students learn more from this than from other possible designs. But we observe that the students are working actively and hard on the projects an with designing, analyzing and calculating so we strongly believe that the students learn through the projects.
- *Select and explain the choice of instrumentation.* The project work force the students to chose proper instruments, and if they fail, they will have inappropriate results.
- *Analyze the structure of the system to be able to simulate the system function and select the appropriate regulating components.* Here we see the need of some improvements. The students have problems with making proper mathimatical models as basis for the simulations.
- *Develop a prototype and test it in the laboratorium.* We see a lot of amazing prototypes and think that it is incredable what the groups reach in relatively short time. In terms of the test, as mentioned above, here we see some improvement needed.
- *Writing technical report incl. references and experimental report.* The students do write proper reports, but again here we see some improvement needed.

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Biographical Information

Aage Birkkjær Lauritsen is an associate professor at the Engineering College of Aarhus. In half of his work time, he teaches mechanical engineering-students in the field of thermodynamics, fluid mechanics, and centrifugal pumps etc. He has a nearly 30 years of experience in teaching.

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