

Enhancing Student Engagement – A CDIO Approach in an Engineering Physics Master Program

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Abstract

This paper describes a project for first year students at the Master program in Engineering Physics at Linköping University (LiU) in Sweden. The project follows the approach of CDIO (Conceive, Design, Implement and Operate), and introduces a project model that has been developed at Linköping University. During the course, the students apply the project model to a CDIO project. The idea to use this approach is to enhance student engagement, one of the key aspects for achieving a deep-level approach to learning. According to the course and project evaluation, the students are become very engaged in the projects, finding it stimulating, interesting and relevant, which highly contributes to student engagement and a deep-level approach to learning. It is also noted that the students appear to learn more effectively and with an improved conceptual understanding than students attending a course with similar content but with a classical course approach.

Keywords: CDIO, student engagement, active learning, engineering project, LIPS, project model.

1 Introduction

CDIO, Conceive, Design, Implement and Operate, was developed as an international initiative for engineering education, characterized by a formalized platform for projects in an engineering education context (Young, et al., 2005). This approach is used in several courses at the Master program in Engineering Physics at Linköping University (LiU) in Sweden. The particular project presented here “Heat loss from the human body” is designed for the first course, in which the students are introduced to among others a project model invented for engineering education projects at LiU, project management, group dynamics and written and oral communication.

One of the basic ideas of the CDIO concept is to get the students involved and engaged in their work – an active learning, which has been shown to significantly improve student learning (Bonwell and Eison, 1991; Johnson, Johnson & Smith, 1991). The idea is to get the students involved in their learning, and has been described as "When using active learning students are engaged in more activities than just listening. They are involved in dialog, debate, writing, and problem solving, as well as higher-order thinking, e.g., analysis, synthesis and evaluation." (Bonwell and Eison, 1991).

The aim of the project is to determine (i.e. estimate) how much heat the human body loses to the surroundings under various circumstances. The project is designed to be quite “wide” in order to facilitate the student’s creative thinking, and to let them learn project work/management and the CDIO concept without distinctive boundaries that limit their activities. The project includes several engineering aspects – from own manufacturing, evaluation and use of temperature sensors to experimental design, applying simplifying assumptions in order to carry out the necessary calculations. According to the course and project evaluation, the students are become very engaged in the projects, finding it stimulating, interesting and relevant, which highly contributes to student engagement and a deep-level approach to learning (Tebbe, 2007).

2 Context of the Study

The students of interest in this study had just started a 5 year Master’s program in Engineering physics and electronics at Linköping University, Sweden. About 160 students start the program each year. The program is considered to be quite theoretical, with the majority of courses in mathematics, engineering physics and electronics.

In parallel with the course “Engineering project using a CDIO approach” of interest in this study, the students took courses in Mathematics (calculus and linear algebra) and digital technology.

Education in the programme are mainly carried out as lectures, lessons and laboratory sessions (when appropriate), although in some courses some of the lectures and/or lessons are replaced by seminars. In a typical engineering course, 40-50 % of the education is carried out as lectures, 40-50 % as lessons and 5-10 % as laboratory experiments. The traditional seminar at Linköping University can be seen as a mix of lecture and lesson.

The lectures are normally dominated by one-way communication from teacher to students as the students are supposed to listen and take notes. Asking questions is not at all prohibited, but not very common, thus this educational design makes the students' relatively passive. During a typical lesson, 25% of the time is taken up by a summary during which the teacher briefly discusses theory and solves a few standard problems. The students then work with problems on their own, discussing problems with each other and with the teacher.

The laboratory sessions can be based upon "hardware" or be "computer labs". Labs normally last 2-4 hours and consist of assignments solved in groups of 3-5 students. There are often some preparatory tasks for the students to work with before the lab, and they often write a report describing how they solved the tasks assigned and answer the preparatory questions etc. following the lab.

3 The Course "Engineering project using a CDIO approach"

3.1 Overview of the Course

The course starts at the beginning of the first semester, and runs during the first two semesters. The course makes up about 20% of the workload for the students during this period.

The course is intended to give the students an introduction of working in "real" engineering projects using the CDIO approach which is described below (CDIO: Conceive, Design, Implement, Operate). The objective of CDIO is to teach the basic concepts and disciplines of engineering in the context of hands-on exercises where students have the opportunity to manipulate concrete objects and ground abstract thought in experience, see e.g. Miller et al. (2002). For more information about the CDIO™ please see (CDIO, 2011).

Theory and practice of leading and working in projects are presented at a few lectures at the beginning of the course, which for example cover topics as project work, project management models, written and oral communication, seeking and evaluation of information and group dynamics. The students work in groups with engineering projects that are introduced at the beginning of the course. The project follows the LIPS project model (Svensson, T. & Krysanter, C., 2003) described below (LIPS: "Easy Interactive Project Model" (translated from Swedish)). A road map of the course is found in Figure 1.

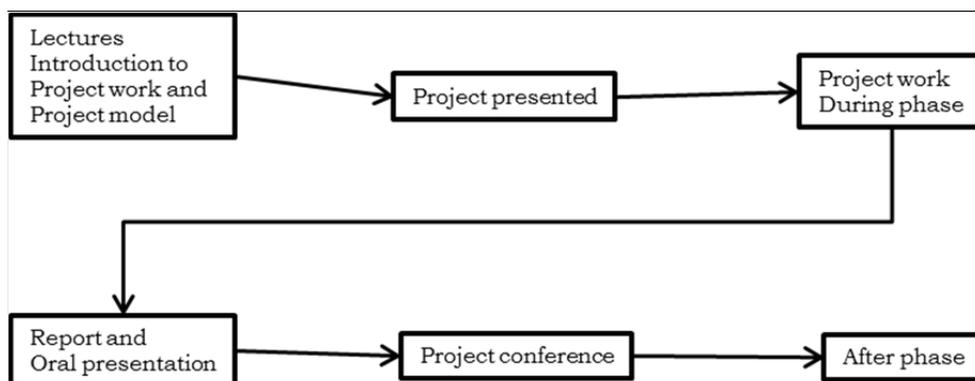


Figure 6: Overview of the moments in the course. The course starts with lectures describing projects as a way of organizing work, and work and management of projects including project management models. This is followed by a presentation of the projects, forming of the project teams and project plans. The groups then work under supervision for about 10 weeks before the results are presented in a written report as well as orally. Before the project is ended, the project is evaluated.

To manage the projects in an industrial-like way, but also follow the educational demands, the roles customer, supervisor and project group are used. Different teachers are assigned the roles as customer and supervisor, in this case the authors of this work. Each project group consists of 5-6 students who carry out the project work.

The customer is responsible for the demands on the project and its deliverables, and is also examiner of the students. The students work on the project following the LIPS model described above. The supervisor is a discussion partner for the students, but also serves as a spokesman for the communication of information

between the customer and students. The supervisor guides the students through the writing of project documents, helps in interpreting the demands stipulated by the customer, and supervises the various parts of the project work and finally serves as “control station” of the final product before delivery to the customer. The supervisor meeting time is generally short about 30 minutes per week for each project group and each group is responsible to book these meetings when needed.

Twelve different projects with very different focus run in parallel during the course. Each project is carried out by 2-3 student groups that do not cooperate between the groups. The project of interest in this study is named “Heat loss during breathing”, and is described below. Other projects regard for example the development of a weather station, communication over the internet, a system for simulating the dose for radiation treatment for cancer patients, and development of an optical system for measurement of gas contents in industrial processes.

3.2 The LIPS Project Model

LIPS, “Easy Interactive Project Model” (translated from Swedish) is a project template developed at Linköping University. The aim of the template is to mimic an industrial way of working and managing projects, but at the same time be adapted to the learning environment at a university.

LIPS was created in order to formulate and describe how to pursue a project. It can be scaled to fit projects on different complexity levels:

- Level 1: Short straight-forward projects, suitable for learning a project model.
- Level 2: Design projects with about 5-6 group members with clear roles, project and time plans, and milestones.
- Level 3: Large projects including e.g. quality assessment and formulated evaluation.

The project model has three distinguished phases, before, during and after, which all are included in the present course/projects (see also Figure 2).

1. The Before phase. Initiated by the customer in form of a project demand document, the requirement specification, where the aims, demands and deliverables are described and split up in smaller measurable units together with a priority setting. The requirement specification is the main input to the project group and this is used by the group to prepare a project plan including a time plan. During this phase, the students also formulate and sign a group contract, which can be described as a set of rules for the project work.
2. The During Phase. The main work of the project is carried out in this phase. The work aims at fulfilling the project requirements in the stipulated time with the resources at hand. It also includes deliverables (reports and/or a product). Milestones that represents a significant and measurable occurrence in the project are used for quality assurance. A positive side-effect is that the students get a feeling for the progress of the project. The milestones also serve as gates/decision points where the customer decides whether the requirements are met or not. At the time of each decision point, there is a communication between the customer and the project group to secure a correct valuation of the milestones.
3. The After phase. This phase closes the project. The project is evaluated, and students give and take feedback on the project.

The LIPS project model includes a more or less complete set of template documents for the project and its management, for example requirement specification, project plan, time plan, status reports and final report. Depending on the complexity level of the project, some of the project documents can be omitted.

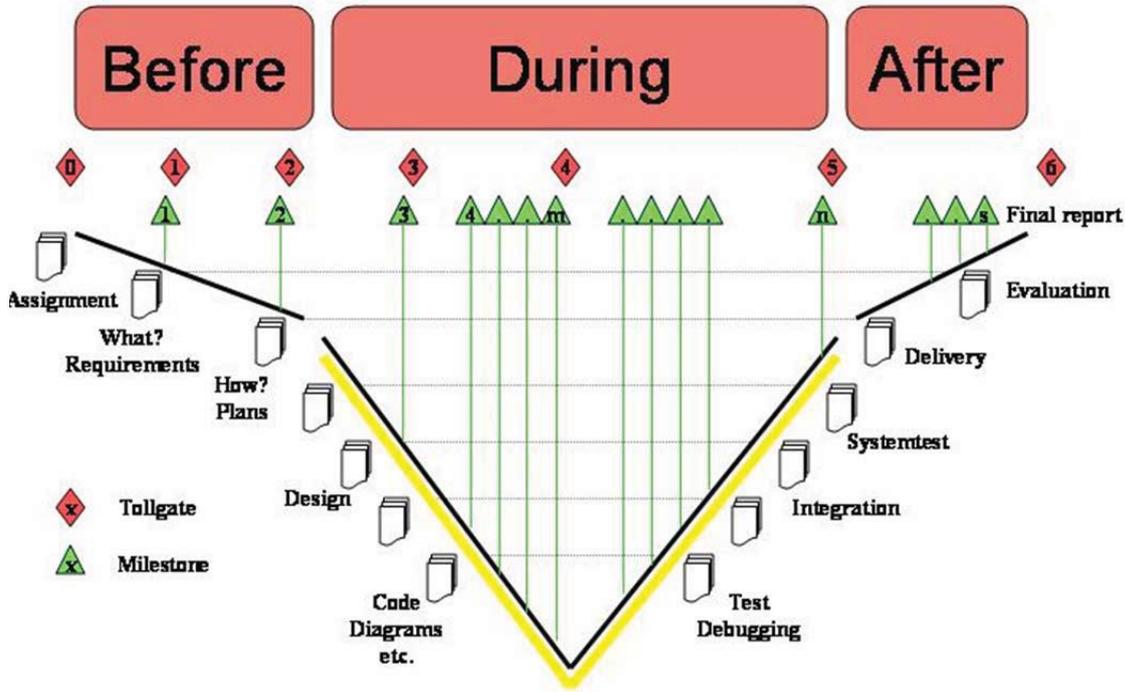


Figure 2: The LIPS project model and its phases *Before*, *During* and *After*. See further description in the text.

3.3 The Project – Heat loss during breathing

The project aims at an analysis and estimation of the heat loss of the human body, particularly due to respiration. To achieve this, the students should also design, build and evaluate a simple system for measurement of breathing temperature and volume. The project is divided into work packages and milestones as described by the requirement specification.

The project starts with the before phase by an introduction of the project and the requirement specification by the customer for 2 student groups with 6 students in each group. The background and aims of the project is presented, and the content of the project is discussed. Each group decides which student that should be responsible for the various roles in the project; project leader, responsible for customer contacts, documentation, system testing and heat loss estimation. The time spent on these roles is maximized to 25% of the total working time for each student. The group must also prepare and sign a group contract, which can be described as a set of rules for the project work. The next step is to prepare a project plan including a time plan. All major parts of the work should be included, and it should also be specified how much time each student is planned to spend on different tasks. The group continuously reports the time spent on various activities, and updates the previously created time plan if necessary.

When the project plan, time plan and group contract is finished, the During phase starts. Due to the multidisciplinary nature of the project in combination with the students' sparse knowledge about its areas, the students should first gain knowledge about the areas of the project, e.g. basic heat transfer, heat transfer interaction between the human body and the surroundings, and temperature measurement systems and their evaluation. Since the course is focused on projects and not heat transfer or medical aspects, the students are provided with literature and other support, and a relatively large amount of supervision during the initial part of the During phase of the project.

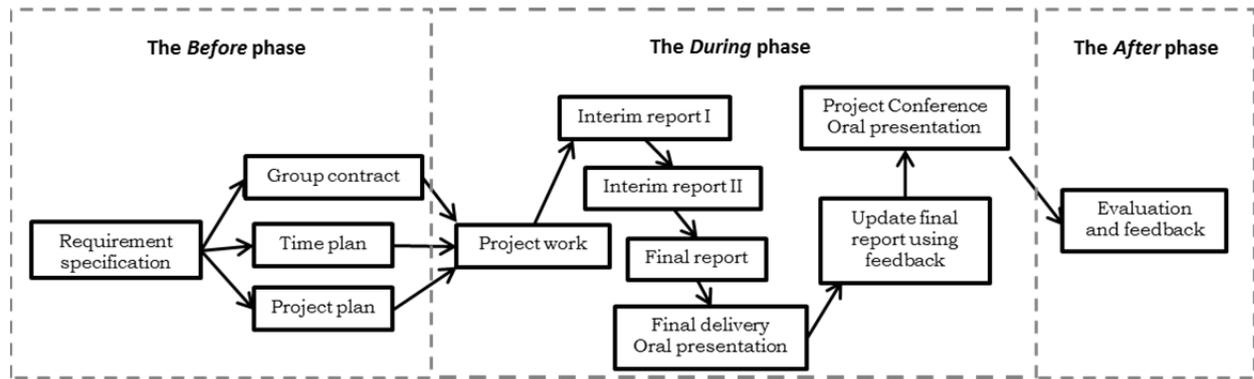


Figure 3: The LIPS project model and its phases *Before*, *During* and *After* and their respective content applied to the present project. Please see further description in the text.

The students then start to build, test and evaluate temperature sensors that later should be used in the system for respiration heat loss analysis. In the requirements is stated that focus should be on stability, response time and accuracy. The sensors are then to be combined with a simple device for measurement of respiration volume. This device is developed and manufactured by the students. One group for example fitted a pipe to a deflated plastic bag, and then let the respiration fill the bag while the temperature of the inspired, expired and bag air was measured and subsequently used for the heat loss estimations. Three reports should be prepared under the *During* phase:

1. Interim report 1. This includes a description of the heat transfer, breathing and temperature measurement aspects of the projects. A plan for testing of the temperature sensors should also be included.
2. Interim report 2. Include the result of the testing and evaluation of the sensors, and a plan for the design of the simple measurement system including an analysis of the aspects that affects the heat loss estimation.
3. Final report. The final report contains the most important parts of the 2 part deliveries, and also a description of the measurement system and its use. Calculation of the heat loss due to respiration should be included, together with an analysis of the validity of the results.

The supervisor meets the groups each week for supervision, and helps solving both theoretical and practical matters. Supervision covers both work strategies and contents of the project. The customer, supervisor and other teachers can be consulted as “experts” during the project. The main role of the customer is to give feedback on the reports, and make sure the groups follow the requirements of the project. The supervisor and customer also discuss the work of the groups along the project, so that the supervision etcetera can be adapted to the specific needs of each group.

The *During* phase is finished by 2 oral presentations (see Figure 2). The first is at the delivery to the customer. At this occasion, the customer is present together with a teacher specialized in communication. The students get feed-back on both the oral presentation and the written final report, and should update the report based on the feed-back. The other oral presentation is held at the project conference. At this conference, all students in the course present their project to other students in the course (students that have carried out other projects). All students must present their project, and listen to a few other projects.

In the *After* phase, the projects are evaluated. The students carry out a self-evaluation considering their work, plans documents etcetera in retrospect. The students also evaluate the project and the project teachers (customer and supervisor) as well as the course as a whole.

4 Evaluation

An important part of the evaluation process is the project evaluation carried at the end of the course. This document is available as one of the project templates, and consists of about 15 open questions that the students answer on a group basis by writing a short evaluation report. The questions are divided into 4 groups:

1. Time and Project plan
2. Analysis of work and task
3. Target achievement
4. Summary

Analysis of work and task together with target achievements are the two groups that are evaluated most thoroughly, and are made up of about 10 questions, for example “What happened during the project phases (good/bad/reason)?”, “How was the project model used?”, “How was the relation between project group and supervisor, and project group and customer?” and “What was the major learning outcomes?”

The project evaluation template is quite focused on the project, project work and management, project model etc. To also investigate the project from a learning perspective, both the supervisor and the customer discussed this issue with the students at several occasions during the project, both with the individual students and with the respective groups.

Finally, the teachers (customer and supervisor) evaluated the project work from a teacher perspective. This evaluation focused both on the process (project as a form of work) and the knowledge and skills in e.g. heat transfer that the students got during the project. The outcome of the latter is carried out with reference to the results of courses regarding heat transfer and measurement technology with more traditional design.

5 Results

From a student perspective, the main opinion of the course is positive. The project together with e.g. lectures and project conference give a thorough introduction to projects as a work form, project models and documents as well as project management.

One of the first things the students carry out in the project is the time plan. They think this is tricky, in part since this is the first time they encounter a project time plan, and in part since they have only limited knowledge of the specific subjects included in the project. It is found that most groups overestimate the time required for specific tasks in the project by about 10-20%, but at the same time they under-estimate the time for “unspecified activities” e.g. “slack” and in-productive time.

Another aspect that the students highlight as a key to success is the communication, both within the group, and between the group and supervisor and customer. The students express the importance of focused and well documented meetings in order to be overall efficient in the project work.

All groups stress the importance of real hands-on projects to learn about how to work in projects using project models etc in an efficient way. The project should be sufficiently complex and stimulating to “force” the groups into using a project model, project documents etc. as well as teamwork. It is also believed that the use of different roles in the project makes the work more focused and efficient.

The students also express their increased knowledge regarding heat transfer and measurement technology, and analysis and evaluation of measurement methods and results. The general opinion was that the group had reached the goals of the project, both regarding project work in a general sense and the aims of the specific project. The following quotation from one of the groups illustrates the learning situation:

“In the project, we were responsible for how the project aims were met. This was demanding, but also stimulating. Since we worked in a group with different responsibilities, we constantly needed to communicate and discuss what we had learnt and what we needed to learn more about, both within the group and with the supervisor. “

From a teacher perspective, it is clear that the students appear to learn heat transfer, thermodynamics and measurement technology more effectively than students attending a course with similar content but with a classical course approach. It also appears to be an improved conceptual understanding using the project approach.

6 Discussion and Conclusion

The learning during a CDIO project during a first year Master program in engineering physics has been studied. The main objective of the course was to introduce project work and management using a project model, together with providing supporting skills such as project management, group dynamics and written and oral communication. To achieve this, the students worked in groups with industrial-like projects – the project of interest in this study was about development and evaluation of a system for estimation of heat loss due to breathing.

There are several reasons to use projects in engineering education. One reason is that the future engineers need training in an environment that mirrors that of a future working place. One reason is that most engineering subjects are either closely related to other subjects (e.g. Solid mechanics to Engineering materials), and/or multi-faceted in themselves (e.g. Machine design); in such cases, complex tasks are

needed to be realistic. Regardless of the reason for using projects, it is important to recognize the strengths and weaknesses of this form of education. One benefit with projects in engineering education is that a deep-level approach to learning is facilitated. According to Karlsson (1991), the deep-level approach to learning is all about gaining understanding, seeing the phenomenon in a holistic manner and relating things to each other, whereas a surface approach might be described by an atomistic view of learning focused on, for instance, reproducing facts seen as separate parts. A deep-level approach to learning is stimulated if the student for example experiences clear goals regarding the aims of the course and what is expected of the student, and time for individual studies and exchange with other students (Karlsson, 1991).

These are examples of learning situations present in the investigated project. It is interesting to note that the students seem to agree on this in the discussions with the teachers. Even if the project requirements are predefined by the customer, the student groups need to interpret the demands gives a high degree of ownership of the problem which enhances motivation for solving problems (Silén, 2000). This is in line with the teachers' experience that the students learn more effectively and with an improved conceptual understanding than students attending a course with similar content but with a classical course approach. One reason to this can be related to the frequent presenting and discussion of the project on a relatively advanced level, activities known to facilitate an active and deep-level approach to learning. It would have been interesting to investigate these aspects in detail, but this is beyond the scope of the present study.

The project evaluation using the evaluation template is the same for all groups in the course. The evaluation template has a clear project perspective, as most important aspects of the project work and management in the present situation is evaluated. Since the project evaluation using the template was carried out on a group by group basis, the answer of each groups tend to show the main consensus of the group. If there is a large diversity between the individual opinions in the group, this is not catch by the evaluation. The teachers' opinion based on many discussions with the groups, however, is that the diversity of the opinions is small in most cases.

In conclusion, it has been found that the students become very engaged in the projects, finding it stimulating, interesting and relevant, which highly contributes to student engagement and a deep-level approach to learning (Tebbe, 2007). It is also noted that the students appear to learn more effectively and with an improved conceptual understanding than students attending a course with similar content but with a classical course approach.

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