REFLECTIONS ABOUT REFLECTIONS

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ABSTRACT

A case study of the use of reflections within the Applied physics and electrical engineering program at Linköping University is presented. Reflections have been used for several years and they are done at four stages in the program, in terms of reflections at the end of the Introductory course in year one, design-implement experiences in year three and five, and a reflection document that is the last component of the Master's thesis. In the first three stages a project model is used to support the planning and execution of the project, and in the project model the project work ends with a reflection. In the reflection document connected to the Master's thesis the student reflects upon both the thesis work itself and the entire education program, according to the sections and subsections of the CDIO Syllabus. The paper describes how the reflections are integrated in the program. Experiences from student perspective are collected in a small-scale study via interviews with students from year one and year five.

KEYWORDS

Reflection, learning, project model, CDIO Syllabus, Standards: 2, 4, 5, 11

INTRODUCTION AND AIM

Reflections for learning is a wide field, and the literature in the field is comprehensive. The aim of this paper is not to give a complete overview of the area, but to present a case study of how reflection is a natural part in project-based learning. In the literature the work in Kolb (1984) about experiential learning and Kolb's learning cycle as a key reference. The learning cycle consists of the stages (i) Concrete experience, (ii) Reflective Observation, (iii) Abstract Conceptualization, and (iv) Active Experimentation. See also Gibbs and Habeshaw (1989). Within the CDIO community there are several references where reflections in different forms have been studied, where Junaid et al. (2018) and Cosgrove and O'Reilly (2019) are two examples. In addition, Cheah (2022) presents an excellent overview of the field with an extensive list of references related to reflections. Also, in project-based activities reflection at the end of the project is a standard last step. See, for example, Andersen and Schwenke (1998) and Lööw (1999).

The aim of the paper is to present a case study of the use reflections throughout the engineering education program Applied physics and electrical engineering at Linköping University. Reflections have been used for several years in four stages of the program. The

first reflection is done at the end of the Introductory course (see CDIO Standard 4) that is given during the fall semester of the first year of the program. Reflections two and three are included in the design-build experiences (see CDIO Standard 5) in year three and year five. In these three cases the reflection is based on the reflection document that is part of the LIPS (Swe: Lätt Interaktiv ProjektStyrningsmodell) project model. Finally, the fourth stage is the reflection document that is a mandatory part of the Master's thesis at the end of the education program. The reflections are mainly done in connection with project-based learning activities, which can be seen as a limitation, but, on the other hand, it comes in very naturally in such a learning activity. In addition to presenting the case study, the aim is also to present a small-scale study of how the reflections are seen by the students.

The paper starts with a background section including a short overview of the CDIO framework The following section focuses on how the framework has been implemented within Linköping University and the Applied physics and electrical engineering program, with emphasis on how reflections are used at several stages in the program. In the next section some outcomes of interviews and surveys with students in year one and year five are presented, and the next section contains summary and some conclusions.

BACKGROUND

The CDIO framework

The fundamental aim of the CDIO framework is to educate students who are "ready to engineer" and to raise the quality of engineering programs. See Crawley et al. (2014) and the web site CDIO Initiative (2023). The framework relies on four key components:

- A "definition" of the role of an engineer.
- Goals for the desired knowledge and skills of an engineer listed in the document the CDIO Syllabus (2023), which serves as a specification of learning outcomes.
- Goals for the properties of the engineering education program collected in the document CDIO Standards (2023), which work as guidelines of how to design a well-functioning engineering education.
- Methods for systematic development and management of education programs.

According to the CDIO framework, see Crawley et. al. (2014) page 50, the goal of engineering education is that every graduating engineer should be able to *Conceive-Design-Implement-Operate complex value-added engineering products, processes, and systems in a modern, team-based environment.* This formulation can serve as a definition providing the basis for the entire CDIO framework. Adopting the definition, it is natural to design and run an engineering education program with this in focus. The CDIO Syllabus is a list of the desired knowledge and skills of a graduated engineer. Via the sub-sections and sub-sub-sections, the document offers an extensive list of knowledge and skills, which can be used to specify learning outcomes of individual courses or education programs. The CDIO Standards (2023) is a set of twelve components that are necessary for designing and running an engineering program that enables the students to reach the desired knowledge and skills. The CDIO framework offers a variety of tools for development and management of education programs, including for example the so-called Black-box exercise and the CDIO Syllabus survey. These tools are described in some detail in Crawley et al. (2014).

CDIO WITHIN THE APPLIED PHYSICS AND ELECTRICAL ENGINEERING PROGRAM

Background

Linköping University was one of the four original participants in the CDIO Initiative, and during the first years the efforts were concentrated to the Applied physics and electrical engineering program. Gradually the framework was applied within other areas, such as Engineering biology and Mechanical engineering. See for example Hallberg (2018). The framework has been disseminated outside the engineering field, and it has been applied successfully in the re-design of the Bachelor's program in biomedicine, as reported in Fahlgren et al. (2019). Another example of the widespread use of the CDIO framework within Linköping University is that the CDIO Syllabus has been extended and adapted to enable for programs in, e.g., natural sciences to be included. The adapted version, the LiTH Syllabus, is a key component in the quality system, via the use of course and program matrices, as reported in Gunnarsson et al. (2019).

An important outcome of the re-design of the Applied physics and electrical engineering program was that a sequence of project-based courses was introduced in the program, in terms of an Introduction to engineering (see Standard 4) and design-implement experiences in year three and year four (see Standard 5). More detailed descriptions of the re-design are given in Gunnarsson et al. (2005). With the big emphasis on project-based design-implement experiences it was found motivated to develop a common project model, and this effort resulted in the LIPS model, which is a project model adapted for educational use. See the website LIPS (2023) and Svensson and Krysander (2011). In the LIPS model the project work is split into the three phases *Before*, *During*, and *After* with tollgates between the phases. The Before phase starts from a project directive with a, rather vague, description of what the customer wants to have developed. The main tasks for the student team during the Before phase is to interpret the project directive and formulate a requirement specification and to write a project plan and a time plan. After approval, at the decision point two, the team enters the During phase and the actual design and implement work starts. The work, which often includes several iterations, leads to the decision point five, which leads to the After phase in which the team is allowed to deliver the results. The reflection is a built-in evaluation step after the delivery of the project result at the end of the After phase. The main sections in the reflection document are *Time report*, *Fulfillment of the goal*, and *Summary of the three most important experiences*, where the last section contains the subsection *The three most important experiences* and *Good advice to those who are going to perform a similar project*. A template for the document is found via LIPS (2023), and the table of contents of the document is given in Appendix B.

Introductory Course

The development of the introductory course *Engineering project* (Swe: Ingenjörsprojekt) started almost immediately after that the CDIO Initiative had been launched, and the course was given for the first time during the fall semester 2002. The structure and organization of the course is described in some detail in Box 4.3 in Chapter 4 of Crawley et al. (2014). The course encompasses 6 ECTS credits, and it consists of the three main parts *lectures and seminars*, *project work*, and *project conference* respectively. The project work is carried out using a subset of the steps and documents in the LIPS project model, and the key documents are the requirement specification, the project and time plan, the technical documentation, and the reflection document. The student teams, normally six students, are put together by the course management, while other approaches for forming the teams are used in courses later in the program.

Student interviews
During fall semester of 2022 the Engineering project course had 133 participating students. The students came from the Applied physics and electrical engineering (Y) and the Biomedical engineering (MED) program. The course is constructed around 13 different projects and the students are split into 23 groups, consisting of 5-7 students/group. Three students from the different classes participating in three different projects where interviewed. The interview was carried out by email using a questionnaire, and the answers are summarized below:

Process for writing the document (corresponding to questions 1 – 3 in Appendix A)
For some students this was the first time they met a reflection document, but one student had worked with a similar document in high school. All groups wrote the document together, with some delegation among the group members. Thoughts and comments from all students in all three groups were added in the document where they together wrote the reflection document. The groups spend between 2-6 hours in writing the document.

Benefit in writing the reflection document (see questions 4 -5 in Appendix A)
All students appreciated writing the reflection document. It gave them the chance to reflect over new experiences. It was clear for some that their view of the project differed from how other students in the same group experienced it, and this helped them understand that group dynamic is a very complex process and very important for a successful outcome. The writing of the document also made a very defined ending of the project course, it “closed the bag” as one student said.

Use of the LIPS reflection template (see question 6 - 7 in Appendix A)
Writing the reflection document comes with some challenges. It can be noted that students find it difficult to correlate the time spent in the project with the estimated time. This is understandable since logging of working hours is mostly new for most first year students. One group thought it was difficult to remember early challenges when the document was written since several months had passed in the project. One group thought it was difficult in writing on how to use the LIPS model since they felt “they didn´t use it”. This can partly be explained that among the 26 teachers involved in the different projects, the use and emphasize in implementing the LIPS model differs. Some are very accurate whereas some are more “relaxed”, and this highlights a problem managing a course with more than 30 teachers involved.

Individual reflection and feedback (see questions 8 – 9 in Appendix A)
All students, except one group, thought it also could be good to write an individual reflection document as well. One aspect of this that was mentioned was that thoughts and ideas could be ventilated without any influence from other group members. This could be valuable especially if the group didn´t work in an efficient way. The group that didn´t see a benefit with an individual reflection document had a very good group dynamic and they were very much in agreement with each other. Most students also saw the benefit of writing a reflection document earlier in the course, midway through. It was considered to increase motivation within the group but also give the possibility to perform changes while the project was running.

Continuous group-based reflection and feedback (see question 10 - 11 in Appendix A)
When asked if they in a “structural way” had reflected over the groups’ work they said that during their weekly meetings, where notes were written, they usually reflected over what had been accomplished during the last week as well as how the last meeting had been. Although one group mentioned that they “didn’t work in a structured way” they still had meetings with notes, so in this sense they did work accordingly without really reflecting over it.

Future benefit from writing a reflection document (see question 12 in Appendix A)
When asked if they thought the reflection document would improve their work in future courses, they all agreed. They all reflected over problems and errors they did during the project, and they all saw the benefit of reflecting over this and use this know-how in their future work. To spend time so everybody agrees and knows what to do as well as to move the project forward, although they got stuck in specific details was an important lesson for one group. As one student wrote "The consequence of not doing your job is that it later on will come and hit you."

Reflection document versus course evaluation (see question 13 in Appendix A)
The students write one common reflection document and one individual course evaluation (arranged separately by Linköping University). They all thought the reflection document was more detailed and gave better feedback to them, both as individuals and as a group. The general course evaluation was considered more general and more focused on how the course is structured (seminars, working environment, equality etc.) whereas the reflection document penetrated their work in their dedicated project.

Advice for next year students, corresponding (see question 14 in Appendix A)
When the students are asked what their most important advice for next year's students is, there are a few common thoughts that are mentioned. Make the group work efficiently (group dynamic) and divide the work within the group, start work early in the project and use the skill and know-how from the supervisor (LiU teacher). Let it take time for everybody to find their role and listen to what all group members have to say.

Bachelor's Project

The origin of this design-implement experience is the project course in electronics that was developed and launched during the first years of the CDIO Initiative. A thorough presentation of the course is given in Svensson and Gunnarsson (2012), and, as can be seen in the paper, the course has been very appreciated by the students ever since the start. During the first years the course comprised 8 ECTS credits, and because of the Bologna process to course was at a later stage extended to a 16 ECTS Bachelor's project. In the expansion a module with engineering ethics was introduced. Also, a pre-study of a sub-topic of the project (communication, control, or sensors) was added as a preparation step before the actual project. Also, the complexity of the project task was increased. At the same time a Bachelor's project in physics was developed and introduced, to a large extent following the structure of the one in electronics. Also, in these projects the reflection document is used extensively, but since this project runs over the spring semester it is not included in this study.

Design-Implement Experiences in Year Five

One more result of the CDIO Initiative was that a set of design-implement courses were introduced in the program, and there are now eight different courses for the students to choose from depending on which specialization they have chosen. Some early descriptions of courses and project outcomes are given in Enqvist et al. (2005) and Karlsson et al. (2006). A more recent example is presented in Larsson et al. (2017) where Massive MIMO technique for mobile telecommunication was tested in practice using sound waves. At the time of the Bologna process the courses expanded in size, and at the same time entrepreneurship was introduced into the courses, as described in Gunnarsson et al. (2010). The courses give 12 ECTS credits, where 9 ECTS correspond to the technical contents and 3 ECTS are given for the entrepreneurship part. This paper focuses on the Automatic control project course, which

is the largest in terms of number of students with approximately 60 students each year. It is taken by the students in year five as the last course before the Master's thesis project. This increases the practical importance of the reflection document since the conclusions can be of use in the coming Master's thesis. Most of the projects in this course are carried out in collaboration with an external stakeholder, i.e., a company or research institute.

Student interview
In this case an interview was carried out on-site with one of the project teams. The team was selected as one of those consisting of students from different programs. The different programs represented in the group were Mechanical engineering, Applied physics and electrical engineering, and Computer science and engineering. The discussion was based on the questions in Appendix A, and the answers and discussions are summarized as follows:

Process for writing the document (corresponding to questions 1 – 3 in Appendix A)
The experience was somewhat different depending on which program the students follow, and whether the LIPS template or some other template has been used. In one program the reflection after the Bachelor's project was performed as an individual reflection. Since the writing has been straightforward in the fifth year's course the previous experience has not been that important. Approximately 4 – 5 hours were spent on writing the reflection document and it was performed sequentially among the students. The writing was to some extent distributed according to the sub-projects. Finally, the entire group came together and finalized the document.

Benefit by writing the reflection document (see questions 4 -5 in Appendix A)
It has been an opportunity to exchange and compare experiences and reflections and to structure the thoughts and to remember.

Use of the LIPS reflection template (see question 6 - 7 in Appendix A)
Some, partly overlapping, parts were merged, and some part was removed. The most difficult part was to describe the achievements since, for this group, the main goal of the project wasn't reached, and to balance the disappointment over this with descriptions of the sub-goals that were achieved.

Individual reflection and feedback (see questions 8 - 9 in Appendix A)
The benefit of an individual document would probably not have been that much in our case. The collaboration in the team worked very well, and the team members had similar levels of ambition. Maybe in case there had been problems in the team and if it would have been constructive.

Continuous group-based reflection and feedback (see question 10 - 11 in Appendix A)
The weekly project meetings have served this purpose, even though the reflections and items haven't been written down. The discussions during the weekly meetings have, for example, led to decisions about contacts with the supervisor or customer concerning revised requirements. Since there is already a substantial amount of documentation in the project and reflections are done via the weekly meetings, it is hard to motivate one additional document.

Future benefit from writing a reflection document (see question 12 in Appendix A)
Difficult to say, but one important experience documented in the reflection document is the difficulty in setting up goals and the importance of formulating sub-goals. Also, the importance of writing down experiences and reflections.

Reflection document versus course evaluation (see question 13 in Appendix A)

The course evaluation is entirely for the course management, but the reflection document is primarily for the team and team members. Maybe 60 – 40. Good to have it as a mandatory activity.

Survey

In addition to the interviews, a questionnaire was sent out to all students in the course, and 13 replies were received and those are summarized below.

Process for writing the document (see questions 1 – 3 in Appendix A)
All students that replied have previously written a reflection document. The benefit of this prior experience was mainly indicated as neutral, apart from two positive and two negative answers.

Individual reflection and feedback (see questions 8 - 9 in Appendix A)
Regarding individual reflections, the opinion among the students is divided, with half of the group positive and half of the group negative. Among those who are negative, the majority are strongly negative. When it comes to obtaining individual feedback, the students are leaning in the positive direction, with three neutral and five weakly positive. One is strongly positive and two strongly negative.

Continuous group-based reflection and feedback (see question 10 - 11 in Appendix A)
The majority, i.e., eight students agree to that there has already previously been performed structured reflection about the work of the group, while five do not recognize this. Nine students believe that it would have been beneficial to perform a reflection already halfway through the course, one is neutral, and three are negative to this suggestion.

Future benefit from writing a reflection document (see question 12 in Appendix A)
Only three students disagree to that writing the reflection documents in this and previous courses will help to improve the work in future courses/projects. The majority, seven, students are weakly positive and three are neutral.

Overall, the students are positive to writing reflection documents and many would also appreciate it earlier. The LIPS project model is known to require many documents, so it is expected that suggesting writing additional documents will not be popular. Individual feedback is considered somewhat positive, but we also expect that this can be somewhat sensitive both to give and receive. Only three out of thirteen students disagree to that they will perform a better work because of the reflections they have performed during their studies.

Master's Thesis

The reflection document at the end of the Master's and Bachelor's thesis was introduced around 2011 as a mandatory last step of the thesis work in all engineering education programs within the Faculty of Science and Engineering at Linköping University. One purpose is to make the student reflect upon the execution of the final major task before graduation, and a second purpose is to give feedback to the program management concerning how well the education program has prepared the student for the intended role as engineer. Initial observations about the outcomes and values of the reflection documents were presented in Kindgren et al. (2012). The instructions for the document have been revised, and the current version can be found via Reflection document (2023). The third generation, which is a web-based system, was launched

early 2023. The structure of the document follows the sections of the CDIO Syllabus, which means that the students are expected to reflect upon their work based on the following items:

- The significance of knowledge of the subject for the execution of the degree project.
- The significance of your personal and professional skills and the approach you have taken for the execution of the degree project.
- The significance of working in a group and communication during the degree project.
- The degree project from an engineer's perspective – planning, development, realisation, and operation of technical systems, taking into account commercial and societal needs and demands.

For each of these items the students are supported by a set of questions. Finally, the students are asked to reflect upon the work process and the interaction with examiner, supervisor, and the external partner.

SUMMARY AND CONCLUSIONS

The use of reflection as a support for the learning process within the Applied physics and electrical engineering program at Linköping University has been presented and evaluated in a case study. Reflections are used in design-implement experiences in year one, three, and five and as the last component of the Master's thesis. The paper has described in some detail how the reflections are integrated in the program, and experiences from student perspective are collected via interviews with students from year one and year five have been presented. The most important observations from the interviews are the following:

- All students found it useful to write the document, with somewhat stronger emphasis among the students in year one. The writing gives an opportunity to compare each other's impressions and opinions, and the document also marks the end of the project.
- The weekly team meeting with agenda and notes gives one type of continuous reflection since the team discusses the outcome of the last week's work and discusses progress as well as difficulties.
- The opinions concerning using also individual reflection documents were somewhat mixed, but the students point out the potential value of such a document in situations when there are problems in the team.
- The quite large difference in opinion in using reflection document among year five students was a bit highlighting. The reason for this could be due to that they participate in different education programs, hence different study plan that emphasize differently, but it could also be something else. This could be evaluated further but was not in the scope of this case study.

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APPENDIX A – QUESTIONS IN THE STUDENT INTERVIEWS

1. Have you written a reflection document or any similar document before. If yes, in what situations(s) and has that been of any help in this case?
2. How much time have you spent on the writing of the reflection document?
3. How did you organize the work to write the document?
4. What benefit have you had from discussing and writing the document together
5. What do you see as the main use of the document?

6. Have you used all parts of the template?
7. Which parts were most difficult to write, and which were easiest?
8. Would it have been useful to also write an individual reflection document?
9. What benefit would you have had from giving individual feedback to the team members during the project? Would you have appreciated getting individual feedback from the team members?
10. Have you, in any structured way, reflected over the activities of the team during the execution of the project, and in such a case how?
11. Would it have been useful to write a reflection document also halfway through the course
12. Do you think you will do an even better job in future courses/projects by having written the reflection document?
13. How do you view the difference between the reflection document and the regular course evaluation?

APPENDIX B – TABLE OF CONTENTS OF THE REFLECTION DOCUMENT IN LIPS

1 Time report

- Time report over spent time
- Comparison between planned and spent time
- Distribution of the work between the project participants
- Evaluation of work distribution
- Collaboration in the group
- Collaboration with tutor and customer
- Theoretical problems
- Technical problems
- The project model Lips – use, comments

2 Fulfillment of the goal

- Summary of achievements
- How the delivery worked out
- How the study situation influenced upon the project

3 Summary of the three most important experiences

BIOGRAPHICAL INFORMATION

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