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USING A PROJECT MODEL FOR ASSESSMENT OF CDIO SKILLS

T. Svensson, and S. Gunnarsson
Department of Electrical Engineering, Linköping University, SE-58183 Linköping, Sweden

ABSTRACT

It is discussed how a project model can be used for assessment of CDIO skills in Design-Build-Test courses. A project model offers a structured method for carrying out projects and gives the students experience of project work under industry like conditions. The different phases, activities, and documents in the project model enable assessment of a large number of topics in the CDIO Syllabus.

INTRODUCTION

The Applied Physics and Electrical Engineering (Y) program at Linköping university, Sweden has been participating in the CDIO Initiative since the second half of 2000. One result of the participation is the LIPS model (Linköping project management) model, which has been designed to support the CDIO concept and to introduce a professional project management approach in the academic environment.

A primary reason for using a project model in engineering education is that the students shall be exposed to work methods used in industry. A secondary reason is that a project model provides a useful tool for assessment of the skills of the students. This paper will show that a project model contains a number of tools and components that can be used for assessment of CDIO skills in Design-Build-Test courses.

The paper starts by a brief discussion about the desired knowledge and skills as specified by the CDIO Syllabus. In the following section the LIPS model is presented briefly, and this is followed by a discussion about how a project model supports the assessment of CDIO skills. In the following sections the three phases of a project are discussed with emphasis on how various topics in the CDIO Syllabus relate to the activities in each phase. The paper ends by some concluding remarks.

The discussion in this paper implicitly has a Design-Build-Test course within electrical engineering as background, and this influences some of the topics in the CDIO Syllabus that are addressed. In other types of projects other topics will be relevant.

THE CDIO SKILLS

One of the fundamental documents within the CDIO Initiative is the CDIO Syllabus [1], which is a specification of the desired knowledge and skills of an engineer. The expression "CDIO skills" is often used as a short form for "personal, interpersonal and product and system building skills", and this is the expression used in the CDIO Standards [2]. The CDIO skills correspond to sections 2 (Personal and professional skills and attributes), 3 (Interpersonal skills: Teamwork and communication), and 4 (Conceiving, designing, implementing, and operating systems in the enterprise and societal context) of the CDIO Syllabus.

A key idea in the CDIO Initiative is to aim for integrated learning, which means learning experiences where disciplinary knowledge and CDIO skills are obtained simultaneously. See #3 in the CDIO Standards. For team based Design-Build-Test courses this means that all sections of the CDIO Syllabus are relevant and need to be assessed, but in this paper the main interest will be on Sections 3 and 4 of the Syllabus. The paper will discuss how these topics can be assessed using a project model. In particular the LIPS model [3] will be discussed, but the discussion is not restricted to this particular choice of project model.

THE LIPS PROJECT MODEL

The LIPS model [3] is designed according to modern industrial project models and adapted for use in education or in small industry projects. It can be used for any type of project, independent of the project outcome. The tasks described in the model are used for steering the work towards the predefined goals and for facilitating control of the work. The model introduces the phases, definitions and decision flow needed for running a project in an efficient way. The three steps of the model describe the project preparation and planning, the project execution and the project delivery and evaluation phase. The model also includes descriptions of activities, roles and communication flows in a project.

The project model has been developed as a result of the participation in the CDIO Initiative. Originally it was introduced in a sequence of project courses within the Applied Physics and Electrical Engineering program at Linköping University, see [4]. The model has also been introduced in courses in, for example, the Computer Science and Engineering program and the Engineering Biology program.

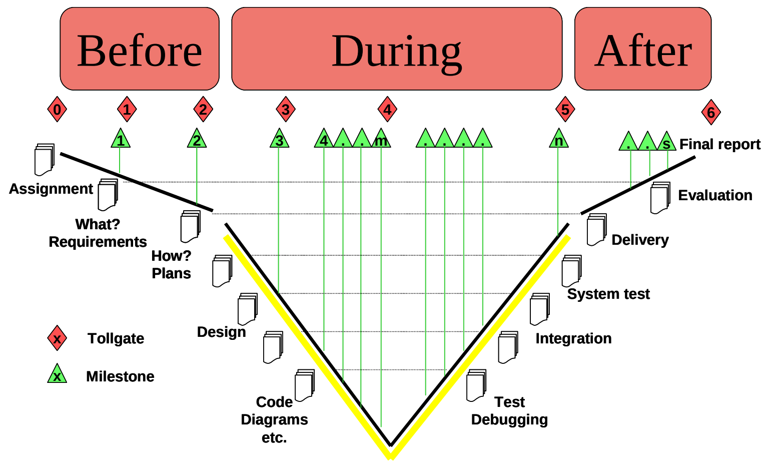

Figure 1: Structure of the LIPS model.

The different project documents are described and exemplified by electronic templates. The templates also include instructions and example of headlines. The aim is to decrease the time to produce and review the documents. Examples of documents are requirement specification, project plan, time plan, status report, meeting minutes and project reflection document. The use of milestones and tollgates is introduced. The dynamics in a project is trained by the use of a sponsor- executor relation. At defined tollgates the students are required to deliver documents etc. to get approval for entering the next phase in the project. The model is scalable and can be applied to project courses with differing levels of complexity. It is particularly suitable for final year projects, although it can equally well be applied from first year undergraduate to small industrial projects.

Using the project model one can clearly differ between the assessment of the process and the assessment of the practical result of the project. There are a large number of aspects of team-based project courses that can be assessed. The list below shows some of the aspects that can be assessed using the project model.

Planning:

- How is the planning done?
- Is there enough time planned for the different steps?
- Has the planning been checked lately?
- Are there planned test activities?

Design process:

- Is there a good system design before going into details?
- Is the design innovative?
- Does the process include several design generations?

Resource management:

- Has the planning been changed due to new conditions?
- Is the workload spread out in the group?
- Has the group and the individuals spent the planned time on the activities?
- Does the time reports match the planning?
- How did the group adapt to detected problems?

Communication:

- How did the communication between the project members take place?
- How was the communication between the group and the sponsor?

Documentation:

- Are project documents delivered on schedule?
- What is the quality of the documents?
- Has the group reviewed the documents?
- How many versions are there before an accepted version is available?
- Is there a good documentation of the project outcome?
- Are there test protocols?

Technical result:

- Is the project outcome accepted and checked against the requirement specification?

Reflection:

- Have the students analysed the process in a reflection document?
- What is the quality of the discussion in this document?

ASSESSING CDIO SKILLS USING A PROJECT MODEL

A primary reason for using a project model in engineering education is that the students shall be exposed to work methods used in industry. A secondary reason is that a project model provides a useful tool for assessment of the skills of the students. We will here discuss how a number of elements in the project model can be used for assessment of CDIO skills in Design-Build-Test courses. The section will deal with general topics, and in the following sections the different phases of the project model will be discussed in some more detail. Assessment of knowledge and skills in project based courses is an issue that has received considerable interest, and some recent contributions are presented in [5] and [6].

Section 3 of the CDIO Syllabus is closely connected to the process objectives in a Design-Build-Test course, and the issues 3.1 (Teamwork) and 3.2 (Communication) are central throughout the entire course. The assessment of the teamwork is supported by the project model both directly and indirectly.

The direct assessment of 3.1 (Teamwork), and its subsections, is supported by the clear definitions of the roles in the project group. A well functioning team requires clearly specified roles for each team member 3.1.1 (Forming effective teams). This is one of the first steps when using a project model. The roles within the team and with respect to the customer, technical experts, etc, are defined. In connection to the formation of the group the members can agree upon a group contract which specifies the rules in the group, responsibilities and how to handle conflicts. The project process requires several types of leaderships. There are of course a project manager but there are also often team leaders for sub tasks.

The team operation can also be assessed using weekly time and status reports to the customer on the progress in the project and difficulties that have been encountered. Such reports can easily be generated using one of the document templates in the project model. The reports enable early discovery of conflicts, problems with leadership or other problems within the team 3.1.2 (Team operation) and 3.1.4 (Leadership). The project model also contains a reflection document as a mandatory part. This document is written as the last step in the project and contributes to the evaluation of the teamwork 3.1.3 (Team growth and evolution). A project model specifies several tollgates, at which the customer evaluates the results of the project. The use of tollgates hence enables a continuous assessment of the work.

The communication is essential in the project, both within the project group and with the customer. The project model contains a large number of documents, supported by templates, which are relevant for a project. Depending on the complexity of the project task the customer determines which documents that are required. A minimum level is to use requirement specification, project and time plan and reflection document. All documents have to be approved by the sponsor. The approval depends on both the technical contents and the quality of the language. The production and review procedure of these hence give a thorough assessment of several of the issues in Subsection 3.2 (Communications) of the Syllabus.

ASSESSMENT IN THE BEFORE PHASE

The before phase is described in some detail in the Figure 2. The project is initiated by an idea defined in a *project directive*, which is the first document in the before phase. The aim of the before phase is to investigate what you are going to do, and how you are going to do it. During the pre-study, the prerequisites for running the project are evaluated, and the project directive is translated into more concrete demands for **what** should be done; this is known as the *requirement specification.* The requirement specification includes functional requirements as well as requirements of performance, economy, delivery, documentation etc. Completion of this process brings the project to milestone 1 (MS1). The result of the pre-study is delivered to the sponsor, who will decide if the project is allowed to continue (TG1).

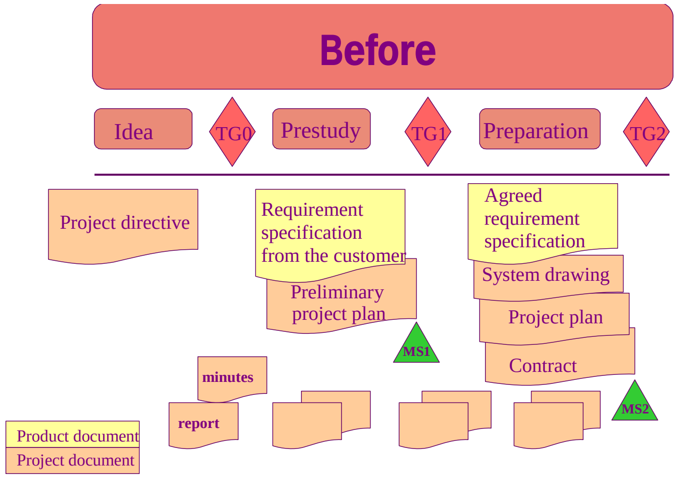

Figure 2: The Before phase .

During the preparation process, the requirements are studied and a description of **how** to execute the project task is documented in a *system drawing*. The next task is the preparation of a detailed *project plan*. Within the plan, the project organization and phases are described and all *activities* are identified and their duration estimated. The project plan will define how often meetings are to be held, and how often status reports are to be given to the sponsor. It must include a *resource plan* and a *time plan*, and in some cases a *quality plan* and a *test plan* are also included. The resource plan shows the available resources, and when they are available. The time plan is a detailed description of when each activity is to be executed. It shows dependencies between activities as well as the duration of each activity.The project has now reached milestone 2 (MS2). The specifications and plans are delivered to the sponsor, who will decide if the execution phase of the project can proceed (TG2).

The before phase is closely connected to the Syllabus Section 4.3 (Conceiving and engineering systems), and several topics in the project model support the assessment. Setting system goals and requirements (Topic 4.3.1) can, using e.g. the LIPS model, be done on three different levels. One level is the Project directive where the task is specified in general terms. The second level is the Requirement specification, in which the technical requirements are specified in detail. The third level is in the Project plan where the global project goals are defined in relation to the functional requirements. The alternative levels give the examiner of a Design-Build-Test course possibility to select a suitable start level. Letting the student group start from a project directive and develop the requirement specification gives a direct assessment of several issues in Section 4.3.

As mentioned, the before phase includes writing a System drawing and a Project plan, which has to be approved by the sponsor at a tollgate. The system drawing is a preliminary design, made to identify how the system is to be built and the included work blocks. This includes technical collaboration with team members, 3.1.5 (Technical teaming), and the first steps in the design process, 4.3.2 (Defining function, concept and architecture). The project plan includes topics from 4.3.1 (Setting system goals and requirements), 4.3.4 (Development project management) and 4.4.2 (The design process phasing and approaches). In addition to that, the definition of activities and assignment of people for the activities in the project plan provides an assessment of 3.1.2 (Team operation).

This phase also includes negotiation with the sposor about requirements, resources, delivery times etc. This is done both orally and in written form and these activities are related to the topics 3.2.1 (Communication strategy), 3.2.2 (Communication structure) and 3.2.3 (Written communication).

ASSESSMENT IN THE DURING PHASE

Figure 3 shows the different steps and documents in the During phase.

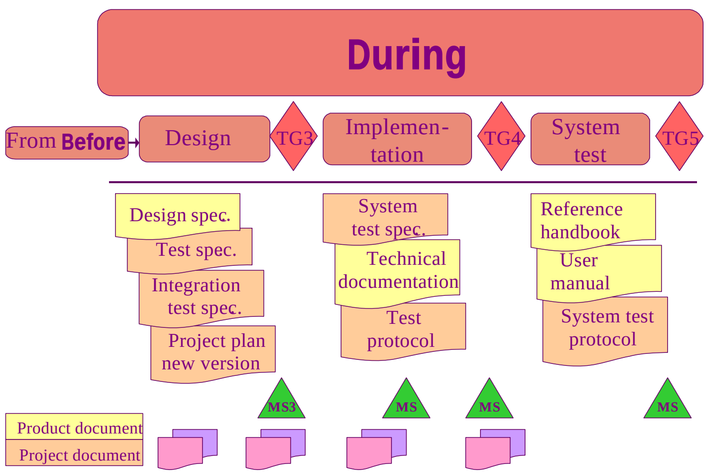

Figure 3: The During phase.

Activities performed within the during phase lead to the project results. Depending on the work model in use, different documents and activities will be executed. A number of milestones are required during the execution phase, since this phase often has a significant duration. Sub-goals will be required to effectively execute and assess the project. Unforeseen problems will almost certainly arise during the execution phase and the ability to rapidly handle deviations is of the utmost importance to the success of the project. The execution phase is completed with a tollgate, TG5, at which a decision is made on the suitability of the results and if the final phase of the project can commence.

To a large extent this phase corresponds to the Design and Implement steps, represented by Sections 4.4 and 4.5 in the Syllabus. The topics in these sections can be assessed using the documents and activities in this phase. The design specification can for instance be used to assess the initial design, 4.4.1 (The design process). Since the design specification continuously develops, it can also be used to track the evolution of the design, 4.4.2 (The design process phasing and approaches), creative thinking, 4.4.3 (Utilisation of knowledge in design) and analytical refinement of the design, 4.4.4 (Disciplinary design).

A more detailed planning of the implementation phase, 4.5.1 (Designing the implementation process), can be assessed at tollgate 3. The implementation of the system in hardware and software (4.5.3 and 4.5.4) can be assessed at the milestones and by the technical documentation. The technical documentation, user manuals, etc., can also be used to assess written communication (3.2.3) Test, verification and validation (4.5.5) can be assessed by the test specifications and the test protocols. Also here the tollgates and the time and status reports enable continuous assessment of the project work.

ASSESSMENT IN THE AFTER PHASE

The after phase is depicted in Figure 4 below.

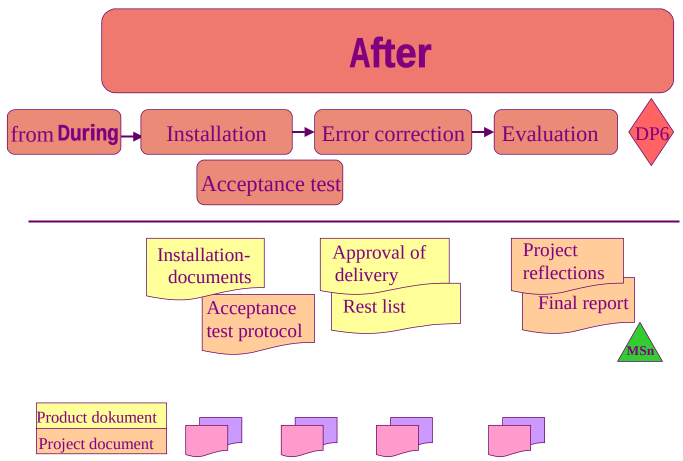

Figure 4: The After phase.

During the after phase, the project outcome is transferred to the sponsor, and the project is closed. The functionality of the project outcome has been tested in the during-phase. The after phase may include installation at the customer site of the finished product. After installation the customer will conduct an acceptance test, in which the results are evaluated against the requirement. Other tasks to be conducted in this phase include education of the customer's staff and project evaluation. The project evaluation is documented in a reflection document. In an industrial project, there is also a final report, where the suitability of the goals and economics are evaluated.

The transfer or the project result to the sponsor often includes a presentation, which can be used to assess electronic/Multimedia communication and oral presentation (3.2.4 and 3.2.6). The after phase is also, to some extent, connected to Section 4.6 (Operation) of the Syllabus, e.g. concerning education of the customer. An important document in this phase is the reflection document, which supports the issue of Team growth and evolution (3.1.3).

CONCLUSIONS

It has been discussed how the use of a project model supports the assessment of CDIO skills, i.e. personal, interpersonal and product and system building skills, in Design-Build-Test courses. The project model is useful for assessing the process and the technical contents. The different elements, activities and documents are particularly well suited for assessment of sections 3 and 4.3 - 4.6 in the CDIO Syllabus.

Even though the outcomes from a Design-Build-Test course are results from a team effort they rely on the contributions from each individual team member. From the definition of activities in the before phase and the allocation of persons to the activities there is a clear connection between the outcome from a particular activity and a team member. This enables assessment of topics in Section 2 (Personal skills and attitudes), like e.g. 2.4.1 (Initiative and willingness to take risks), 2.4.3 (Creative thinking), 2.4.5 (Awareness of ones personal knowledge, skills and attitudes), and 2.4.7 (Time and resource management).

It is also obvious that the quality of the technical result rely on the technical knowledge of the team members, and the fulfillment of the requirement specification will be an assessment of the topics 1.2 (Core engineering fundamental knowledge) and 1.3 (Advanced engineering fundamental knowledge).

ACKNOWLEDGEMENTS

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REFERENCES

[1] Crawley, E.F, "The CDIO Syllabus: A statement of goals for undergraduate engineering education", Technical report, MIT CDIO Report no. 1. MIT, Cambridge, MA, USA, 2001.
[2] The CDIO Standards. http://www.cdio.org
[3] Svensson, T. and Krysander, C, "The LIPS Project Model", Linköping University, Sweden, 2004.
[4] Berggren, K.F, Gunnarsson S., Svensson, T. and Wiklund, I, " Development of the Applied Physics and Electrical Engineering (Y) program at Linköping University through the participation in the CDIO Initiative", 8th UICEE Annual Conference on Engineering Education, Kingston, Jamaica, 7-11 February 2005
[5] Powell, P.C, "Assessment of team-based projects in project-led education." European Journal of Engineering Education, 29(2), 221-230, 2004.
[6] Hansen, S, "The supervisor in the project-organized group should participate in developing the students' project competencies", European Journal of Engineering Education, 29(3), 451-459, 2004.