INVOLVING STAKEHOLDERS IN CDIO PROJECTS

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ABSTRACT

The Technical University of Denmark has implemented the CDIO standards and principles in all of its B.Eng. courses since 2008. In order to increase innovative skills and to educate engineers who are capable of directly fulfilling the needs of Danish industry, the curricula of the B.Eng. Software Technology (SWT) and B.Eng. IT and Economics (ITOE) have recently been revised (Nyborg et. al. 2015). This revision has focused upon combing the best of the existing educations which are rooted in a practice oriented development environment and by strengthening the involvement of stakeholders in general. The involvement of stakeholders is a central tenet in the implementation of the CDIO framework and can be challenging to accomplish. This is even more pronounced when considering external stakeholders.
We present a roadmap that shows how external stakeholders can be successfully involved in undergraduate courses. Already from the beginning of the 2nd year studies, students and stakeholders are engaged in significant collaboration on real world projects. The project ideas are proposed by external stakeholders and come from the field of mobile application development.
The product development process has been designed and developed to closely reflect the processes and challenges that the students will meet when employed in industry after graduation. This process includes the challenges and uncertainties that occur in real life with real customers and stakeholders. The courses involved are compulsory courses which are offered annually on the third semester. The courses have now been held three times and after each completion the process and content have been evaluated and refined in accordance with the feedback received from the students and stakeholders involved.

The involvement of stakeholders from the very beginning of the projects provides an environment for real world development processes including requirements elicitation and design build experiences utilizing industry standard tools and cutting-edge technologies. This approach achieves the involvement of external stakeholders within the full CDIO framework, clearly establishing CDIO as the context for engineering education (CDIO Standard 1). We encourage engineering educational institutions to implement the roadmap as a way of involving stakeholders within the CDIO framework. This article will present details and important considerations on each step of the roadmap as well as findings and insights gained.

KEYWORDS

CDIO-based study programs, Stakeholder involvement, Innovation, Standards: 1, 2, 3, 5, 7, 8, 11

INTRODUCTION – THE STAKEHOLDERS

In a software development project undertaken in industry there are a variety of stakeholders. According to Pressman (Pressman et al, 2015) stakeholders can be grouped as follows: "senior managers who define business issues, project/technical managers who organize and control the practitioners, the practitioners who engineer the system, customers who specify the requirements for the software, and end-users who will interact with the delivered system". These groups can be classified at a higher level as those which are found within the development organization and those which are external. A significant challenge for academic institutions when running project based courses is to ensure an appropriate level of commitment of time and resources from external stakeholders. By external stakeholders we refer primarily to external project providers who initially specify the project vision and scope and also the end users of the product. The process and methodology which we describe below have met the challenge of involving stakeholders and in such a way that the software development process utilized by the students reflects the processes used and favored by industry, namely iterative, lean user experience design and agile software development.

In the context of the courses described in this paper the product is a mobile application and unless otherwise stated, the term stakeholders refers to the external providers of the mobile applications' vision and scope. The stakeholders who provide the projects and are involved throughout the entire development process are wide and varied in terms of the problem domains they represent and also experience in project participation. Initially, there are also widely varying expectations amongst stakeholders towards the finished project and their involvement. Establishing common expectations for stakeholders and project groups is a very important initial activity.

METHODOLOGY

Both the theoretical and practical knowledge required for the projects is provided by two courses: a course in user experience and mobile application development (DTU course 62550) and a course in modelling and software development processes (DTU course 02368). The user experience and mobile application development course provides a thorough foundation in how the desired user experience is achieved and follows a lean UX process with extensive prototyping involving stakeholders in each iteration. Implementation is done in the Android environment. The second course focuses on requirements gathering, software development processes and issue tracking using industry standard software.

At the very beginning of the semester, a seminar is held where the external stakeholders present their project ideas to all the participating students. The students subsequently form project groups themselves based upon their choice of project and start working on the project. Throughout the project period, close collaboration with stakeholders is achieved through a lean UX process with prototypes and a scrum process which delivers increments of the final product in sprints.

We have developed and refined a roadmap which enables 2nd year B.Eng. students to experience "the full CDIO framework" involving external stakeholders:

1. Before the semester start, a call for external project providers / stakeholders is made.
2. At the semester start, the selected stakeholders pitch their projects.
3. Within the following week, the students form project groups.
4. During the remaining semester, an iterative process in close collaboration with the stakeholders is followed.

At the end of the 13 week semester, the students work fulltime on completing the project during a 3 week sprint period.

The individual projects are undertaken in groups with typically five students in each project group. In order to prevent the stakeholders from being overburdened and thereby unable to provide the required level of involvement, usually only one or two student groups is assigned to each project providing stakeholder. Typically, there are around fifteen to twenty stakeholders and a corresponding number of different projects each year. The task of finding project providers has been successfully addressed by project pitching seminars which are held during the second week of term.

PROJECT PITCHING SEMINAR

A project pitching seminar is held where companies and individuals are invited to the university to present their ideas for their mobile application projects to the students on the course and the associated staff. Two project pitching seminars are arranged during the second week of term with different projects being presented at each seminar. Two seminars are held in order to obtain a sufficiently large number of projects such that each project has a maximum of two student groups. It is also a goal that each project presented is chosen by at least one group.

Two to three weeks before the start of the course, advertisements for and invitations to the project pitching seminars are sent out. The project pitching seminar is advertised via numerous channels such as professional groups and networks to a wide range including entrepreneurs and professionals from public and private enterprises. Included in the invitation is a clear description of what is expected from the stakeholders. This includes:

Meeting with the students, physically or virtually at least every three weeks, replying to mails within two working days, providing/discussing project requirements and providing constructive criticism after each iteration and delivery.

The project ideas of companies and individuals who express an interest in presenting at the seminars are assessed and evaluated and those deemed suitable in terms of scope and technical level are selected for presentation. Each stakeholder is given ten minutes to present their ideas followed by five minutes of questions from the audience. After the last presentation, an informal discussion and networking takes place between all participants. The entire seminar typically lasts for approximately two hours. Photographs taken during the pitching seminars can be seen in Figure 1 and Figure 2 below.

Figure 1. Stakeholder presentation sessions

Figure 2. Stakeholder - student networking

The students then use the next week to form project groups themselves according to which projects they find the most interesting. By choosing their own project from those available, the students are more motivated. When also combined with a stakeholder who is very enthusiastic about their project, it provides an ideal starting point for the subsequent process. The majority of stakeholders can often be characterized as being very enthusiastic and passionate about their ideas but generally lacking in technical expertise. This is not considered to be a disadvantage as it reflects the conditions often occurring in developer-customer relations in industry. Occasionally, stakeholders are very technically knowledgeable but do not have the time to undertake the project themselves. Examples of previous projects undertaken have included mobile apps for: reading training, Parkinson's disease patients, weather data for agriculture, patients in respirators, educational games etc. Despite many differing problem domains, the learning outcomes are common and aligned with institutional vision and mission (CDIO Standard 3) of DTU. The mission of DTU today is the same as when founded by Hans Christen Ørsted in 1829, namely "creating value for the benefit of society".

ITERATIONS AND DELIVERABLES

The objective of the User Experience and Mobile Application Development course is to enable the students to identify user needs, conceptualize and validate prototype interfaces based on a lean customer-driven agile iterative design process and subsequently implement the design on a mobile device. As such the course includes of a series of lectures about user experience, interaction design and user interface design. The prototype designs are implemented on the Android platform and a series of lecturers and exercises are given to support this.

A lean process is followed in order to establish the desired user experience. The build - measure - learn cycle is iterated over and over again, validating or invalidating hypotheses, as shown in Figure 3. In some projects, a design thinking process is adopted, following the empathize - define - ideate - prototype - test cycle. For example, the design thinking approach was chosen by a group of students who chose to design and implement an application for type 2 diabetes patients. In the empathize stage, the students themselves established contact to newly diagnosed diabetes patients in the local area, attending meetings in patient organizations and conducting interviews and embodying the "get out of the building" philosophy. Stakeholders representing the end users were thus identified and were subsequently involved for the duration of the entire remaining development process. Having developed an understanding of the users' problems and needs, prototypes were developed and user research conducted involving the stakeholders. The design thinking approach actively engages the students directly in thinking and problem-solving activities as outlined by CDIO standard 8 (Active Learning). Similarly, the problem domain and close involvement of the end-user requires the students reflect upon their social responsibility as well as the technical analysis and design (CDIO standard 7, Integrated Learning Experiences).
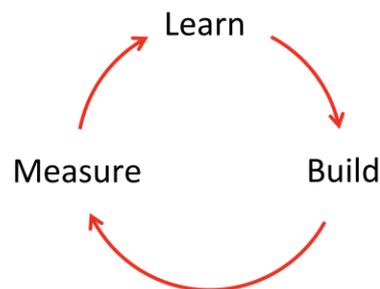

Figure 3. Lean UX Cycle

At the end of each iteration the student groups delivered a series of artefacts to the external stakeholders for review. The feedback and comments received from these meetings were subsequently incorporated in the following iteration. The artefacts delivered to the stakeholders varied as the project progressed from low fidelity wireframes, to high fidelity prototypes and ultimately versioned Android apps, thereby reflecting the CDIO progression. This range of engineering activities is central to the process of developing new products as defined in CDIO standard 5 (Design-Implement Experiences).

Professional tools have been used throughout, with Justinmind (https://www.justinmind.com) being used as the prototyping tool. Using such tools is essential when conducting user research by involving the stakeholders. An overview of the iterations can be seen in Figure 4.

13 week semester (4 timetable hours/week)

Project pitching seminar

1st iteration (prototype) delivered to stakeholder

3rd iteration (app) delivered to stakeholder

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |

Invite external project proposers

Students choose projects and form groups

2nd iteration (prototype and app) delivered to stakeholder
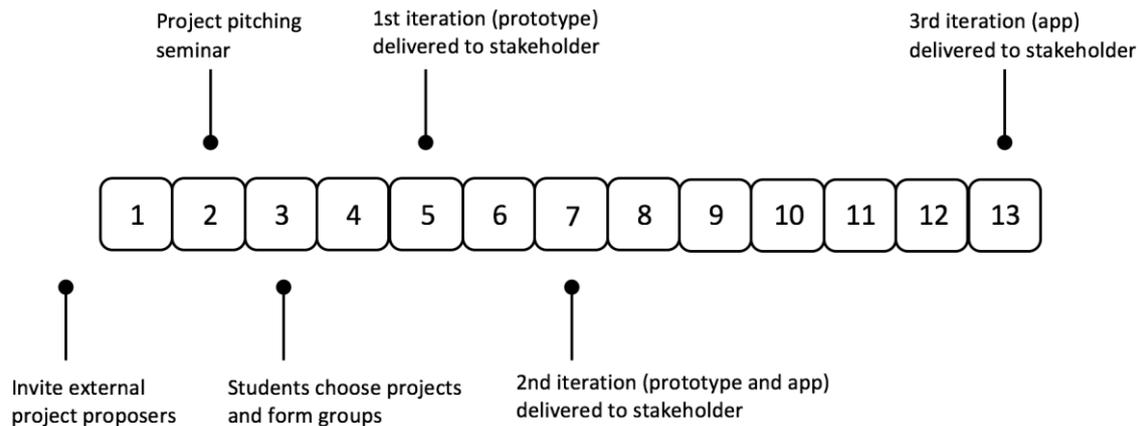
3 week period following 13 week semester (fulltime)

4th iteration (app) delivered to stakeholder

| 1 | 2 | 3 |

Final app release
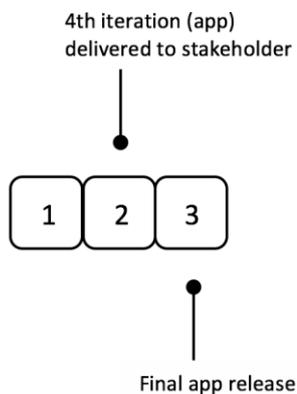
Figure 4. Iteration plan

THE SOFTWARE DEVELOPMENT PROCESS

The development process was supported by a course in software development processes. This implements CDIO Standard 3 (Integrated Curriculum) with the mutually supporting courses having explicit connections with related supporting content, learning outcomes and co-curricular activities.

An agile approach using Scrum was chosen as the overall organizational method combined with selected techniques from Extreme programming (Andrew Stellman et al., 2014). Initially, the students divided themselves into teams of approximately five to six persons, according on the mobile app they chose to work on.

User stories and product backlog

The work begins with each group establishing a preferred method of communication with their stakeholders. In most cases, emails or a digital workspace like Slack (https://slack.com) combined with physical meetings were chosen.

The product requirements were identified through conversations with stakeholders and described by user stories, which are easily understood and provide a value to the stakeholder. Together they form the product backlog.

Prioritizing the Product backlog

After user stories have been identified and added to the product backlog, teams together with stakeholders spend time on prioritizing items. The team assigned story points to each user story, using relative estimation techniques. Since both the domain and the technology were new to most of the teams this was a challenging task. Most teams started allocating a story point value to a simple user story, e.g. login and then estimating the other stories relative to this value. This provided an initial guess of the complexity of each story.

The value of each user story was discussed with the stakeholder. A value point system was agreed on and for each user story, the BFTB ("bang for the buck") ratio was calculated by dividing the value point by the story point.

Releases and sprints

The BFTB values were used in the planning of releases and sprints. Most teams decided to work on one release in the autumn period and one release in the following 3-week period in January. The first release contained the basic functionality of the app and the development phase was divided into two to three sprints of approximately four weeks.

Each user story was broken down into tasks that were developed using selected techniques from Extreme programming. The most common techniques used were: simple design, refactoring and collective ownership, pair programming and test driven development.

A scrum master was appointed who was responsible for setting up daily meetings in the team and setting up the review meeting with stakeholders upon completion of a sprint.

Tool

It was decided that all teams should use the issue tracking tool, Axosoft (https://www.axosoft.com), to control and monitor the development process.

Each user story is entered along with the break down in tasks. As time goes by work effort is registered for each team member.

Axosoft offers a number of valuable visualization tools, e.g. scrum board and a number of gadgets e.g. the burn-down chart for measuring progress, which provide the team with a good overview of the process (see Figure 5 and 6).
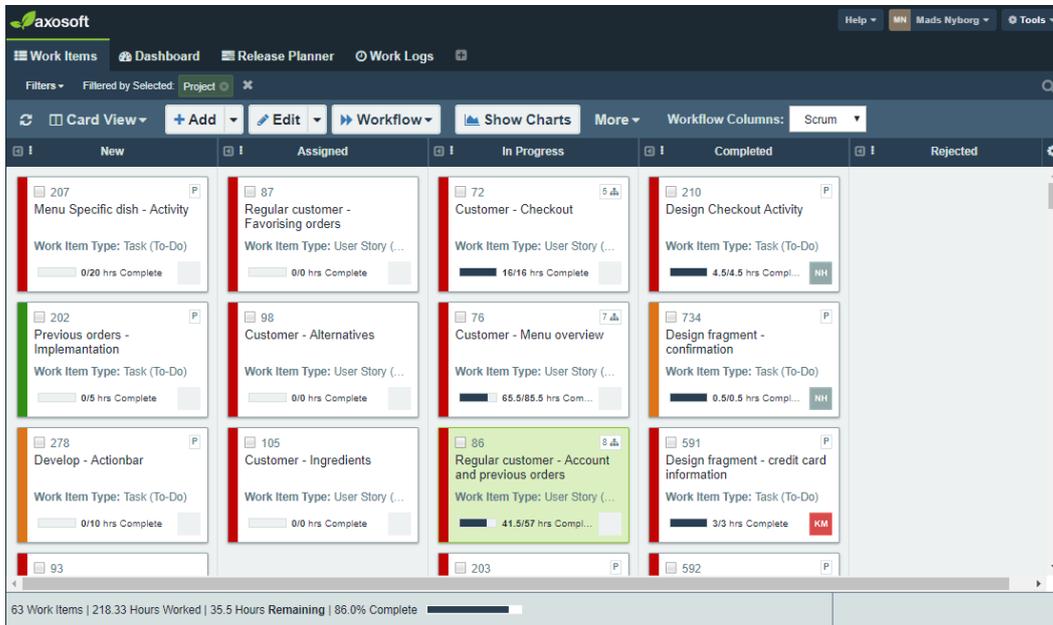
Figure 5. Scrum board for team 23, developing the app:
"The digital restaurant experience" for a Sushi restaurant chain
The task can be dragged and dropped into different states, e.g., New, Approved, In progress,
Ready for testing, Completed or Rejected
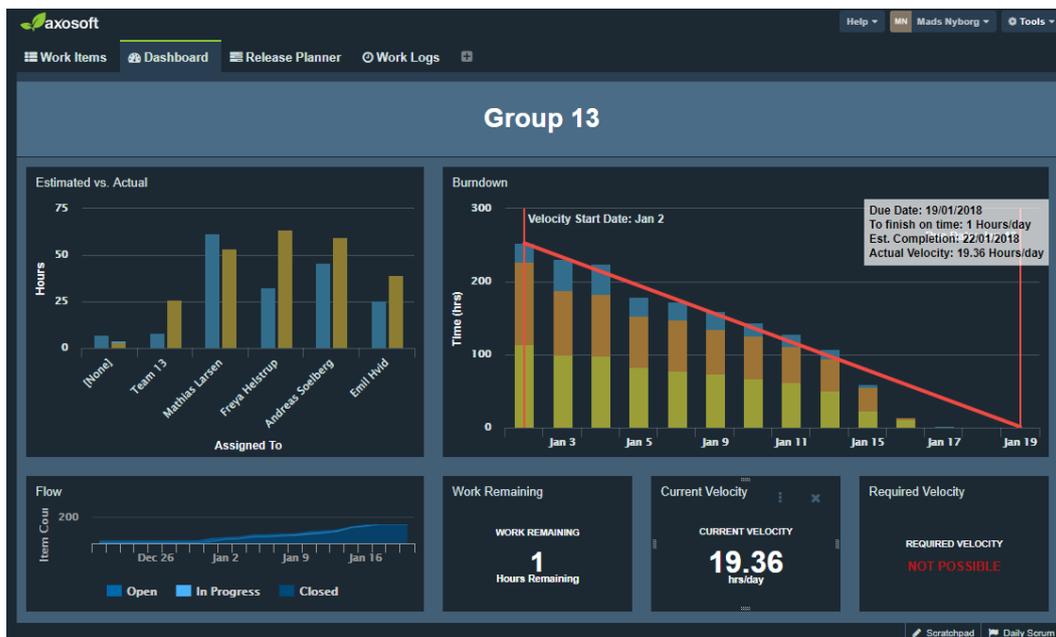
Figure 6. Dashboard for team 13, developing an app where voting citizens can vote on the parliament's bill. The dashboard shows assigned task for the team and individual members together with the burn-down chart

All teams including their members are set up at course start by the responsible course staff member and hence it is possible to get and overview of e.g. the velocity of all teams.

LEARNING ASSESSMENT

Learning assessment is done both formally and informally using a variety of methods during and at the end of the semester (CDIO standard 11, Learning Assessment). When using an iterative development process in a learning environment, the students are able to compare the artefacts produced at the end of each iteration with previous ones to reflect on the progress in their learning. Quizzes undertaken in a relaxed environment using e.g. a Kahoot quiz (DTU UX Design Kahoot Quiz, 2017) are used as informal status checks. Formal peer reviews are also held along with compulsory assignments which contribute to the final grade are given. At the end of the entire period a final report and poster are delivered. An example of a poster is shown in Figure 7.
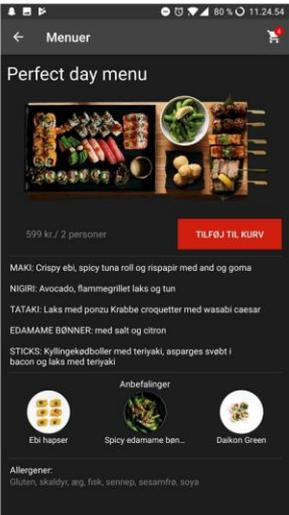

Figure 7. Poster showing the final app for team 23

CONCLUSION AND FINAL REMARKS

A procedure has been described which facilitates the involvement of external stakeholders in project based courses which are compulsory courses in the B.Eng. Software Technology (SWT) and B.Eng. IT and Economics (ITOE) degrees. The involvement of external stakeholders is in fact an essential part of the lean UX process and agile software development process that has been used in the courses. From a CDIO perspective, involving project customers and end users provides the inputs and dimensions required to implement the CDIO standards referred to a greater extent than would otherwise be possible.

The roadmap used to involve external stakeholders is not without challenges though. It requires a good deal of effort to recruit a large number of suitable project providers and who are also able to provide the continuing involvement and commitment required. Aligning expectations and obligations between external stakeholders and the project groups is a task which is essential for the successful involvement of stakeholders and one which must be addressed by the academic staff responsible for the course right from the beginning.

Throughout the course, not unrealistic problems are experienced by groups such as stakeholders failing to provide material and system interfaces, delayed correspondence etc. While the students find this frustrating, the advantages far outweigh the disadvantages. The anonymous evaluations completed by the students at the end of each semester, consistently mention the external stakeholder involvement as a very motivating and rewarding experience.

The following comment was made by a student in the anonymous, end of course online survey:

"*I think this course is exceptionally good because you get the opportunity to work with a real customer. The project pitching seminar is an excellent initiative and works excellently. It is really good to be allowed to make a project that is so close to the real world.*"

The benefits for external stakeholders is expressed by the following comment from project proposer Mie Haraldsted from the company rarebird.design:

"Joining the students on a journey to produce a useful app has proved very beneficial for us as a company. The motivation to produce something that we would be pleased about and would use has pushed through a series of questions that has forced us to re-evaluate decisions and correct product specifications. Specifically going through the user journey has created a lot of value thinking of when and in which scenario the app would be used. The students have shared our company vision and have managed to graphically show this to make it a significant part of the product offering. Working with more groups leads to different ways of solving the same issues as well as alternative user interfaces. This will prove very tremendously useful for user testing in the field and propel us forward faster than expected."

Furthermore the project serves as a preparation for the compulsory course "Innovation Pilot" on the 5th semester. In this course, students are also working on project based on wishes from external stakeholders, but without supporting courses (Nyborg et. al. 2016).

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