INTERNATIONAL CONFERENCE ON ENGINEERING AND PRODUCT DESIGN EDUCATION
6 & 7 SEPTEMBER 2018, DYSON SCHOOL OF DESIGN ENGINEERING, IMPERIAL COLLEGE, LONDON, UNITED KINGDOM

EXPERIENCES FROM A POSITIVISTIC WAY OF TEACHING IN THE FUZZY FRONT END

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ABSTRACT
This paper presents a project based graduate course in early stage product development called Fuzzy Front End. Based on a brief theory-based perspective and data from student interviews as well as stakeholders we provide a discussion ground for the format of the course. The main goal of the course is to educate confident engineers by providing a complete experience of an early stage product development process with all its positive and negative facets. Our findings indicate that the course provides strong motivational factors, as well as a collaborative mind-set amongst the teams that creates a motivational atmosphere for high quality project-outcomes. This insight is the starting point for highlighting shortcomings of a competition-based course format and discussing a potential alternative.

Keywords: Fuzzy Front End, Competition, Project-Based Education, Product Development

1 INTRODUCTION

Competitions and rivalry have throughout the human history driven innovation and pushed boundaries. In a learning context, competitions have become quite common and they create a lot of excitement and enthusiasm among students. In the engineering educational realm, there are many types of competitions present. Some may take place in the classroom or within small local groups, others are international competitions where student teams from different universities compete in various technical disciplines. Competitions as a pedagogical tool can be seen as a positive thing as it motivates effort or trains students for a potentially competitive career. However, it can also be seen as a problematic educational framing, as it dissuades cooperation and creates clear losers. Nevertheless, it would be interesting to reap the benefits from both camps: Present a motivating challenge which encourages extra effort without treading on classmates. Speaking from an educator's standpoint, we would prefer to see our students help, support and learn from each other rather than withhold information, denying access, and lose self-confidence.

This paper presents a graduate course in early stage product development, which is motivated by, among other things, this idea about competing without creating losers. Other aspects of our pedagogical perspectives spring from project-based learning, experiential learning and creative confidence/self-efficacy. The research question for this paper is about understanding if the applied methods, specifically the focus on wayfaring and SCRUM-like reflections, give the intended experiences to the students when they are tackling real stakeholder's challenges. The results provide discussion input for other educators.

The course in question is a one semester product development course where selected students are working on challenges from companies and research groups. Each project is tackled by a group of maximum three students, subsequently limiting the number of participants to ca. 25 students. Section 3 describes the course in more detail.

2 THEORY

There is little doubt in the field of engineering education that practical experience is of high value [1], [2], [3], and that motivation for the students during these often more labour-intensive teaching styles is crucial. One way of achieving this is through competitions, which is a regularly used tool [4], [5]. Common reasons for arranging competitions is that they are motivating and spark interest amongst the

participants [4]. There are, however, also researchers that highlight certain negative effects from learning in a competitive setting [6]. Competitions essentially mean that someone wins, and someone loses, success is therefore always experienced at someone else's expense. The winners might experience a boosted self-confidence, while the losers might have theirs reduced, according to Chan and Lam [7].
Bandura's concept of self-efficacy, says that a belief in your own abilities is created from experiencing success and getting positive feedback [8]. Laws has shown the power of self-efficacy in his research of creative self-efficacy, where the performance of R&D scientists was directly connected to their creative self-efficacy [9]. Elms also show that self-esteem is a valuable attribute for an effective engineer to have [10]. Cooperative learning activities are also highlighted as something educators should strive for [11]. In terms of creating motivating learning experiences, there are indications that letting students play with their imagination while encouraging them to build something functional is a great place to start [12].

2.1 Design methodology

Educating design engineers also entails a need to address the choice of methodology. Since all projects in the course are, as we call it, pre-phase 0 projects, when comparing it to the product development phases as described by Ulrich and Eppinger [13], they offer a shear infinite solution space for exploration. The three methodological corner stones that the students follow are as follows:
Firstly, the perspective on early stage development focuses on agile methods, and the authors attempt to make the students work according to the principles for a SCRUM sprint [14], not unlike the work shown by Grimheden [15]. In this course, the implementation of SCRUM is somewhat less rigorous, as some formal steps are left out, such as having a scrum-master. The backlog is kept by the student teams on a project wiki, and weekly scrum sessions are scheduled in the course.
Secondly, the overall approach to the early stage of design is represented in the Wayfaring model [16] [17], where design teams work with short sprints and explore the projects facets in an opportunistic hunter-gatherer style. This should not be confused with a trial and error approach, since each sprint consists of design probes that answer specific questions about one specific aspect of the project. The subsequent steps are based on these previous experiences. Since each sprint is short (<1 day), and potential time loss is small, the teams can afford to investigate the project with extreme freedom. Figure 1 shows a graphical illustration of the approach. The outcome of this method is a functional prototype that can be used as inputs and requirements for the following phases, e.g. as listed in [13].

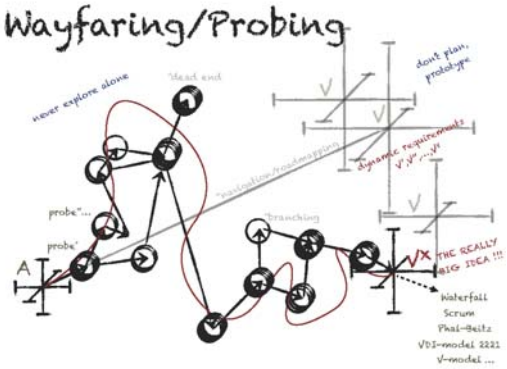

Figure 1. Concept development journey based on the wayfaring model [17]

Lastly, a strong emphasise is placed on bias towards action, and to actively use prototypes throughout the whole process [18]. Prototyping is a helpful method in order to quickly being able to test your ideas and bring the project forward [19], [13], [20], they also help the teams focus their discussion on a common ground.

3 FUZZY FRONT END

The course Fuzzy Front End (FFE) is currently running for the 5th time and is heavily integrated in the physical and mental context of our product development laboratory Troll LABS at the Norwegian

University of Science and Technology. Below, a short description of the course is given; who is taking part, and what the students are learning and achieving.

3.1 Troll LABS

Inspired from other product development labs like Stanford's d.school, Aalto University's Design Factory, and the Silicon Valley's Maker Movement, our early stage product development lab was founded in 2014. By providing tools, machinery, and materials for creating prototypes of various levels of complexity, the overarching goal is to create an environment for both, project work, and research based on the applied methods and outcomes. The very mobile setup of the machinery, as well as furniture allows for rapid, iterative adjustments of the layout in order to address emerging usage patterns and shortcomings thereof.

3.2 Educational Context

Within the FFE course the focus lies on the project work of the students and that they spend as much time as possible working on them. However, a fundamental understanding of the core ideas of the wayfaring method is necessary. Subsequently, students are preferably selected amongst the graduates of a previous course called Innovation by Design Thinking, which teaches the essential skills needed for applying the wayfaring method: Design Thinking, prototyping, iterating. Further down the road, the most promising students of the FFE course are invited to write their pre-master and master thesis within Troll LABS and related projects. The final subsequent step is to become a PhD student as part of our research group. ***Figure*** 2 displays the hierarchy of the courses mentioned.

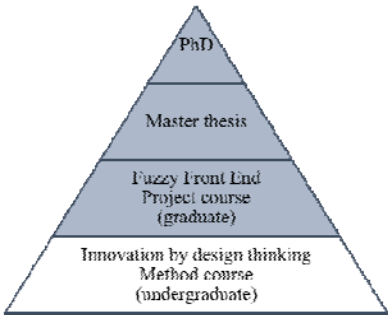

Figure 2. The Troll LABS research group educational path. Grey fields indicate access to the prototyping laboratory

3.3 Fuzzy Front End Course

The FFE course is at graduate level and focuses on project work, where the challenges are proposed by both, industry and research. Both contributors present real problems from their day-to-day activities with a focus on future products. It awards 7.5 ECTS and the official teaching time consists of two afternoon sessions over the week. The challenges provide a clear goal, but no clear path to it. Each project is independent and tackled by teams of three students, which also defines the maximum number of participants (usually 8-9 teams). In addition, each team has a coach (PhD and Master students) who provides guiding and advice to the team but does not do any actual project work.

Over the first three weeks of the course, initial lectures and project assignment takes place. During these weeks, the course mainly consists of introducing various PD methods that could be of use for the teams. Once the introductions are complete, the teams gradually focus more on their project work. In addition, the teams have to step on a stage every Friday and present their prototypes, progress, problems, and challenges to the whole class. Similar to a SCRUM session, these presentations force the teams to reflect on their current status, where they are heading over the next week, and it gives the opportunity to tap into knowledge of the classmates. Furthermore, it exposes all students to the progress of the other teams. At the end of the semester, all stakeholders are invited to partake in the final presentations of the projects and discuss the results with the students, in some cases this is the first time they see the results in any shape or form.

In accordance with the Wayfaring model, the projects can be roughly divided into three phases: one, the problem space is explored. Two, potential solutions are iterated and tested, subsequently reducing the solution space to the point where one fully functional prototype is built in the last and third phase.

The main deliverable of the course is a functioning prototype that is presented at the final event. Other course deliverables are short weekly quizzes, a short paper, as well as a project report.
Due to space limitations, and the poor justification of project results in pictures, Figure 3 provides a QR code and the embedded link to videos from the project demonstrations of the last two years.

Figure 3. Online link to videos from project presentation

4 PROBING THE COURSE

While the intentions from an educator's point of view are clear, it is – in accordance with the wayfaring model – essential to probe, and potentially iterate the course setup. With respect to the descriptions of competitions in section 2, the following two questions are the most interesting to evaluate: Do the students experience positive motivation without seeing clear losers throughout the course? And is the course creating useful output for the stakeholders, similar to a competition?
The purely qualitative data is based on feedback from stakeholders, as well as on the inputs from graduates of the course, in the form of three semi-structured interviews.

4.1 Student interviews

All three students that were interviewed are currently working on their master thesis within the research group and they took the FFE course one year ago. All three are male and among the higher achievers from the course. The interviewees were chosen due to availability, they did, however, exhibit quite different personality types. One being a tinkerer and hobbyist character, one a more traditional engineering type comfortable with defined tasks and one more of the artistic type. Two of the students have been following a 5-year integrated master-programme with the department and the third one is on a two-year master's programme.
The semi-structured interviews were conducted around the following three main topics: 1) How do you think back on the course? What memory stands out? 2) What do you remember about the project process? 3) How do you remember the Friday sessions?
At the end of the interview, the interviewees were also asked if they would recommend the course to someone else.
Our main objective was to investigate the value of these Friday-sessions in light of how they affected the project process and outcome, specifically when comparing to the motivational factor of competitions. Did they help the students identify the value of their ideas, did the presentation of their project initiate or facilitate reflection, or was it a stressful exposure?

4.2 Results

All three interviewees think back on the course as being very work intensive, whilst also being fun. The high workload is said to be mainly self-induced. The reasons for this internal drive varied: One stated a motivation to do well in the aspects of the course the student experienced as being influential on their grade, and two mentioned an internal motivation for presenting "something cool" every Friday. All students also saw each Friday-session as a deadline, which acted as a driving force for maintaining a high level of effort to produce prototypes and tests. The three interviewees also mentioned a prestige in presenting "something cool" to the other students.
When asked about the project process and the Friday sessions, the interviewees have fewer instant recollections. However, talking about the subject, several interesting aspects emerged: The value of getting feedback from the community; how the community can act as an "immune system" in terms of judging ideas and concepts. One interviewee mentions that he receives comments and feedback on his project more constructively now than before. One interviewee identified a synergy effect from the Friday-sessions, where groups could learn from each other. Since all project-teams were working on different projects, nobody was afraid to share insights and valuable methods with the others. This helped create a community feeling with a helpful and opportunistic atmosphere. The fact that PhD and master students also take part in the Friday-sessions helped to strengthen this community-feeling. In

fact, one interviewee makes a point of how motivating it is to see the other teams succeed with their project.
An unexpected outcome from the interviews is the value this course has as an introduction to the community of the research group. The authors have been a part of the group from the beginning and have had little experience with how it is to join from the outside. The interviewees all identified themselves as novices in the group during their time in the FFE course. Now that they are working on their master theses in the same group, they consciously take on the role as tutors for the current FFE class, as they themselves were assisted last year. Helping with introductions to the tools and machinery in our prototyping laboratory, as well as discussing projects and ideas.
Regarding facilitation and motivating mechanisms in the course, one interviewee specifically identifies the professor as an important factor. At least in the beginning of the course, presentations are mainly done addressed to him. However, later in the semester the value of having the community of the class present is identified. Two interviewees highlight the motivational effect of team autonomy regarding decision making. The effects of lectures on the project is said to be small, as it is somewhat disconnected from the day-to-day project effort. However, getting experience with the different methodologies presented there is said to be valuable for later projects, e.g. their master's projects.
When asked if they recommend the course to fellow students, the answers from all interviewees were aligned: "Yes, but you need to be prepared for a large workload and to take responsibility for your own progress." All three see the course as unique, and say it gives experiences not provided in any other course they have attended. Even though the interviewees had taken project-based courses before, this was the first time the project was as disconnected from the academic bubble. One interviewee reported that this was the first time he had started a project in a course without having an idea in the beginning of how the problem might be solved. Another interviewee experienced the setting as being facilitated to experience extreme degrees of freedom in the project. He identified a triangle of *resource access-freedom-task formulation* to be the most influential factors for allowing this project experience.

4.3 Stakeholder feedback

While there were a lot of positive, orally stated feedbacks from high-profile stakeholders, such as CEO's and CTO's, the most solid indicator of meeting or even exceeding the expectations is the fact that most companies and researchers are returning with new and more challenges every year. Furthermore, most stakeholders propose more in-depth master's projects based on the outcome of their FFE challenge.

5 DISCUSSION

The paper has presented a course which focuses on creating a high energy atmosphere with a pressure of advancing the project, without creating losers. While it is not possible to scientifically quantify and compare the outcomes from different projects and subsequent feedback, the statements from both, participants, and stakeholders, point in a general, positive direction.
The students experience that the course inspires a high self-induced workload and put in a lot of effort because they are driven to present their project progress on a weekly basis, and a failure to do this is not wanted. Any such failure is, however, independent of other teams' success. And seeing others succeed is a motivating factor rather than an explanation for their own failure. This atmosphere also seems to support a collaborative way of working, where students teach each other necessary skills as they are needed and they openly share their ideas, problems and solutions with each other.
Learning the process methodology is expressed as something happening silently in the background as they work on their projects. Confidence in applying methodology is slowly being built up, as they see that the methods actually work. They experience the effects and gain trust in the methods.
The fact that the stakeholders are almost exclusively "returning customers" gives a strong indicator for the high quality of the outcomes and that the projects at least satisfy their expectations.
The amount of data presented is very limited and can therefore not be seen as conclusive proof of whether or not the FFE course succeeds at picking up the best parts of a competition format, while leaving out the negative sides of it. It does, however, indicate that this format provides the experiences we desire to convey, with respect to the theory provided in section 2. It increases the creative confidence level of the students, and creates energetic atmosphere similar to a competition, while emphasising collaboration, as well as knowledge and skill-sharing.

For future work, we have already started collecting more precise feedback from stakeholders, as well as capturing the team's prototyping progress throughout the course. The aim is to provide a quantitative analysis of performances and outcomes and scientifically solidify the reasoning behind the course format.

ACKNOWLEDGEMENTS

We would like to thank our alumni students for accepting to be interviewed in relation to work on this paper. This research is supported by the Research Council of Norway through its user-driven research (BIA) funding scheme, project number 236739/O30. We also appreciate the constructive feedback from our reviewers.

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