DESIGNING A NEW INDUSTRY-RELATED SPECIALIZATION IN ELECTRONIC SYSTEMS DESIGN

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ABSTRACT

Preparing students for real-life challenges is one of the crucial goals of engineering education. Nevertheless, gaining practical, industrial experience takes time and effort that usually lays beyond the classical curricular activities. This paper describes our approach, which promotes cooperation between academia and industrial partners to the benefit of both. Although the case described has been implemented while developing a new specialization at the master study program of Electronic Systems Design at Norwegian University of Science and Technology, the applied methods can be implemented in other programs. The key concept is to provide students with industrial projects to work on for the whole 2-year study period. The course portfolio is then individually chosen by every student to the benefit of project execution, which results in tailored skill profiles unique for every student matching the competence profiles sought by our industrial partners. Our partners have an active, formative role in the process of course choice and function as industrial supervisors of project work, thus the students effectively have access to both industrial and academic supervision. Gaining practical experience early during the project activities likely ensures a deeper understanding of the project-related challenges during the next semesters, resulting in a higher quality of the final delivery – the master thesis. After finishing the two-year practical project work, our students become more qualified for further cooperation with the partner company. To evaluate our approach, we have performed a student survey as well as collected feedback from our industrial partners. The results of the evaluation are presented and analyzed. Necessary adjustments to the implementation of the proposed scheme due to the COVID-19 outbreak are also addressed. Finally, the paper presents links to digital resources that provide more detailed information about the organization of the specialization that can be reused in similar cases.

KEYWORDS

Industry engagement, Workplace and community integration, Workplace learning, Engineering entrepreneurship, Standards: 1, 2, 3, 5, 7, 8, 11,

INTRODUCTION

In 2016, Norwegian University of Science and Technology (NTNU) merged with the University Colleges of Sør-Trøndelag, Ålesund, and Gjøvik to form Norway's largest university. The merger resulted in many administrative and educational changes, thus opened the possibility of designing a new industry-related specialization at the Electronic System Design study program. Although the merger resulted in a plethora of options regarding design opportunities around the new specialization, we wished to maintain the tradition of tight cooperation with local industry partners that used to be a signature of our former University College of Sør-Trøndelag (UCST). An example of such collaboration was the cooperation with the industrial cluster Norwegian Center of Expertise Instrumentation. This paper presents our proposal and first experiences in creating a win-win situation for all three involved parties: academia, industry, and students. In the first part of the paper, we describe a project-centric design of our specialization and the course structure that supports core and optional CDIO standards, while the second part of the paper describes the practical implementation of cooperation and teaching processes. The third part of the paper presents the evaluation of the proposed solutions and discussion regarding possible future enhancements and adjustments necessary due to the COVID-19 pandemic.

The necessity of incorporating CDIO standards was one of the conclusions of a recent internal NTNU report titled Sustainable Competence (Øien, et al., 2020) which results from the project Technology studies of the future lead by Geir Øien (*Fremtidens Teknologistudier - NTNU*, 2020). Also our colleagues at the Department of Electronic Systems Design at NTNU have long experience of using the CDIO approach in teaching, which resulted in many exciting projects, including the engineering ladder (Lundheim et al., 2015) and introducing problem-based learning for the first-year students (Bolstad et al., 2020). Inspired by their previous work and our experience with cooperation with industrial partners at UCST, we decided to design a CDIO based approach during the later study years, especially in the master program. Besides the core CDIO standards (Malmqvist, Edström, & Rosén, 2020), we wished to partly address the emerging optional CDIO standards (Malmqvist, Edström, Rosén, et al., 2020) in the process of specialization design that are of vital importance for understanding the broader context of engineering work. As we observed in the previous years, many students working on their master projects acquired a deep understanding of the challenges connected to their projects towards the end of the project semester. However, early exposure to real-life engineering problems and context-related knowledge accumulation is likely to produce better end results derived from a deep understanding of the engineering challenges (Martins et al., 2019). Therefore, we decided to set the project work as a central piece of our new specialization. This way of organizing the specialization allows students to iteratively work in the Conceive – Design – Implement – Operate regime on real-life projects. The students actively learn by being responsible for their part of the project activities and receiving feedback from academic and industrial supervisors. It is worth mentioning that the same framework can be used in a research-based project by switching industrial partners with research actors.

SPECIALIZATION DESIGN

While designing the course plan for the Smart Sensor Systems (3S) specialization, we wanted to ensure that besides gaining experience via project work, every graduate will also acquire knowledge related to innovation and entrepreneurship. Therefore, the course plan was divided into four distinctive parts (Table1). The first part is the project work represented by the green color. Please note that the amount of project work gradually increases during the study time, starting from one 7.5 ECTS point course during the first semester ending at a full-time project work during the master semester. The main goal here is to allow students to conceive, design, and implement their systems' first iteration during the early months of the project work. The second important part consists of core engineering and elective courses represented by blue and grey color in Table 1. The students can individually choose these courses based on their significance for the project work. Finally, the last part of the plan is related to innovation and entrepreneurship. The students start with a course in design thinking to get used to thinking about the end-user of their system. Then the course Experts in Teamwork prepares them to cooperate with colleagues from very different backgrounds. Finally, more business-oriented courses in the third semester ought to give them an understanding of the administrative and financial part of the process of designing electronic systems. Although the courses mentioned in the last part of the portfolio are of an introductory level, they will provide students with the necessary conceptual apparatus that will aid them while communicating with their business partners.

Table 1. The course plan of the Smart Sensor Systems specialization
(O) – Compulsory course; (VA) – Elective course – Coordinated in teaching and examination schedules; (V) - Elective course; (M1A) – At least one course from group A

<table>
<tr><th colspan="6">Course plan</th></tr>
<tr><td rowspan="2">2nd year</td><td>Spring</td><td colspan="4">TFE4930 - Electronic Systems Design, Master's Thesis</td></tr>
<tr><td>Autumn</td><td colspan="2">TFE4580 - Electronic Systems Design and Innovation, Specialization Project (O)</td><td>TFE4595 - Electronic Systems Design, Specialization Course (O)</td><td>TIØ5200 - Project Organizations (VA)
TIØ4146 - Finance for Science and Technology Students (VA)</td></tr>
<tr><td rowspan="2">1st year</td><td>Spring</td><td>TFE4204 - Sensor Systems Design II (O)</td><td>Elective (V) – from all NTNU courses</td><td>TTK4145 - Real-time programming (VA)
TTM4115 - Design of Communicating Systems (VA)</td><td>Experts in Teamwork (O)</td></tr>
<tr><td>Autumn</td><td>TFE4202 - Sensor Systems Design I (O)</td><td>Elective (V) – from all NTNU courses
TTT4120 - Digital Signal Processing (VA)</td><td>TDT4258 - Low-Level Programming (VA)
TTK4155 - Embedded and Industrial Computer Systems Design (VA)</td><td>TPD4142 - Design thinking (M1A)
TMM4220 – Innovation by Design Thinking (M1A)</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="2"></td><td>Project</td><td>Elective courses</td><td>Programming/ Electronics</td><td>Entrepreneur/ Innovation</td></tr>
</table>

As a result, our graduates will not only have a tailored course profile for their project work, they will also have a basic understanding of the functioning of the whole company environment around the project.

Dedicated courses

Let us briefly describe the design considerations around the two introductory project courses: Sensor Systems Design 1 (SSD1) and Sensor Systems Design 2 (SSD2). These courses are reflecting the CDIO principle of system development and provide a playground for introductory project work. Course descriptions have been developed according to the National qualifications framework for lifelong learning (*NOKUT*, 2011). In short, the delivery of the SSD1 course aims at being a “first working prototype” that is far from optimal, but that will enable students to make all necessary introductory errors and concentrate on understanding the project task, while SSD2 course aims at optimization of the chosen features of the system. Course descriptions has been designed in a way that is general enough to cover a wide variety of possible projects, however, at the same time reflect the best engineering practices of CDIO standards. We decided to use an IEEE conference paper template as a report template (*IEEE*, 2020). This teaches students how to use a standardized research template and makes the evaluation of the project work easier. The detailed description of Sensor Systems Design courses including content, learning outcome and evaluation can be found on NTNU course pages (*Course - Sensor Systems Design 1 - TFE4202 - NTNU*, 2020), (*Course - Sensor Systems Design 2 - TFE4204 - NTNU*, 2020)

After finishing the first year of studies, students continue to work on their projects, but since they build on the knowledge and experience acquired during the first year, they are able to effectively use it to the benefit of their project work. This happens during the course: Electronic Systems Design and Innovation, Specialization Project that is of 15 ECTS points. At the same time, they acquire specialized knowledge through the Electronic Systems Design, Specialization Course that offers 18 modules that students can choose from. After one and a half years of working on a specific project, students start the master thesis. Since the whole cycle has not been finished yet, we cannot evaluate the increase in the quality of master thesis deliveries.

PRACTICAL ORGANIZATION

Due to the involvement of many actors, the practical organization of activities necessary to create an environment that fosters cooperation is far from trivial. It was therefore, our priority to set up effective communication schemes that would allow the identification of win-win cooperation possibilities. Although we find working with the 3S specialization very inspiring, it is fair to say that there is a significant part related to the organization of the startup events and the coordination of the whole process with our industrial partners. It is worth mentioning that the whole process is conducted as informally as possible to reduce the communication threshold between parties. The details of the process are presented in interactive diagrams that describe the activities during the first and the second year of study. These diagrams that are available here: link1 and link2 are used for conveying the information to both students and industrial partners and work as a process guide.

Invitations and one-pagers

The first step in the process is sending e-mail invitations to our industrial partners that contain a one-pager – the PowerPoint template, that is accessible via link3 that will be used by our partners to prepare short descriptions of their project proposals. The one-pager contains necessary contact information for our partner, a brief description of the proposed project task, current project status, and descriptions of the skills essential for completing the project.

Collected one-pagers are shared with the students, so they could make a preliminary evaluation of the projects that seem to be attractive to them.

Kick-off conference

The next step is organizing a kick-off conference where our industrial partners present their project proposals, and students get the opportunity to directly communicate with the partners to learn more about the project proposals as well as about partner companies and their expectations. Every company gets only five minutes to present their proposal (and we call this stage “fast and furious” way of presenting). This ensures that only the most important information connected to the project is presented and makes the conference possible to digest for all parties. After five, 5-minute-long presentations, we relocate our partners to their individual meeting rooms, where students who are interested in their project proposals can ask follow-up questions and discuss details regarding projects. To sum up, every slot contains five presentations and a half an hour for discussions between companies and students, which can be performed in one hour.

Figure 1. Kick-off conference presentations

Project choice

After the kick-off conference, students have approximately one week to decide which project to choose. From this moment, students take over the communication with companies and are responsible for the next administrative steps that involve coordination of contract signing and health and safety analysis of their projects. They are also responsible for consulting industrial supervisors to choose an optimal course portfolio.

Peer reviews

During SSD1 and SSD2 courses, students are obligated to perform three peer reviews, which are individual meetings with their peers to discuss the project work. Their role is to act as “critical friend” (Biggs & Tang, 2011) and carefully listen and comment on the issues presented by their peer. Students have the freedom to decide where and when such peer review will take place as long as it is performed before the deadline. The only requirement is to choose a different person every time. We only evaluate if the peer review is performed by checking an online peer review table filled by the students. Peer reviews function as an informal arena to discuss project issues. One could think of them as a special version of an inverted classroom, with the fundamental difference that the classroom is interchanged with a single person, and the presentation is interchanged with a friendly but substantive discussion. In contrast to an inverted classroom approach, having only two people in the conversation ensures the full attention of both persons involved. The last, third peer review revolves around the submission of the project reports. Students are encouraged to read their peer's reports and point out places that are difficult to understand. The expected results of peer reviews are: creating a better group environment, enhancing learning through discussions.

3S Specialization wiki pages

To ensure effective information flow, we have developed a dedicated wiki-based platform where students can find instructions, course reviews, report guidelines, a student knowledge base, and a student forum.

EXPERIENCES

Although the students who enrolled in our new specialization have not finished the whole educational cycle yet, we collected feedback from involved parties to ensure formative influence on current activities.

Student surveys

To evaluate how students experience our new approach, we have performed two surveys. The data for the first survey has been collected from 10 students after finishing the first semester of the 3S study.

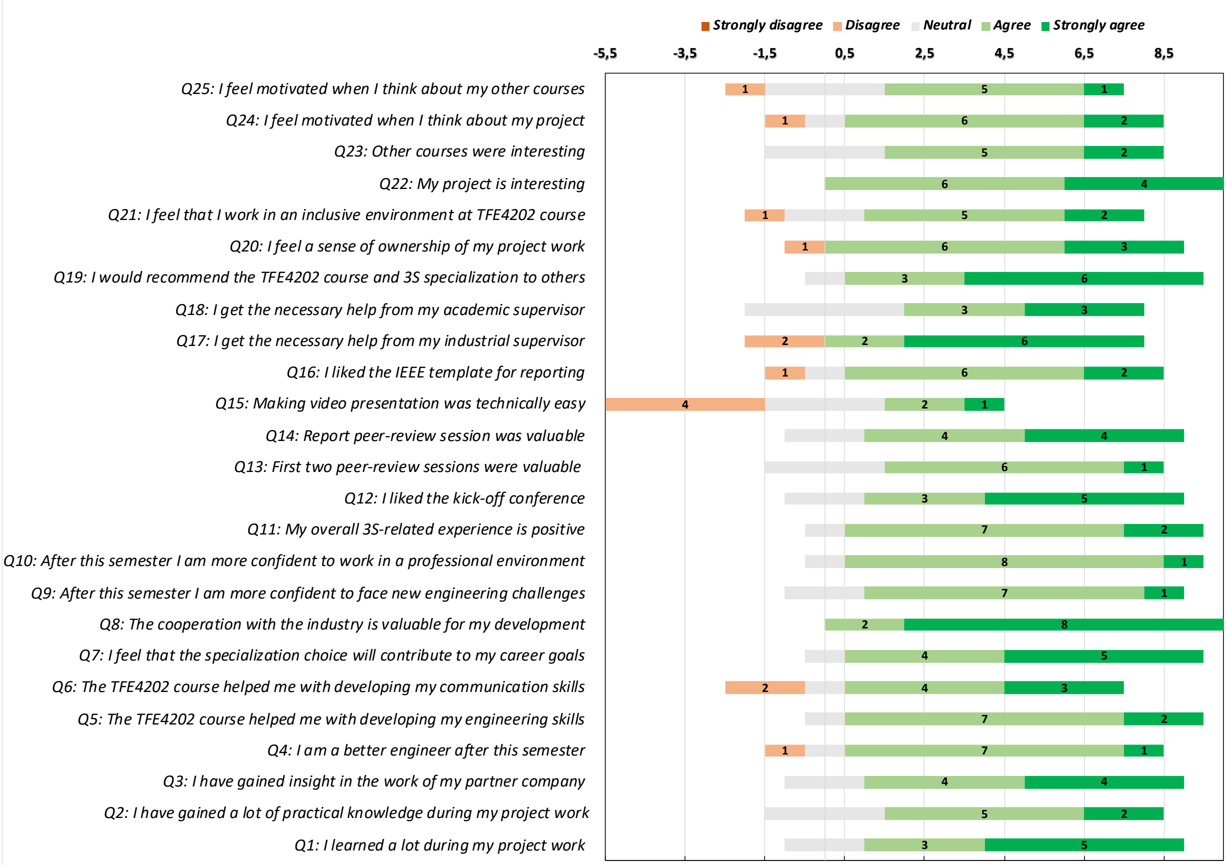

Figure 2. Diverging stacked bars chart illustrating students' responses after the 1st semester

In Figure 2, we represent survey results as a coordinated set of diverging stacked bars chart. Each student answered 25 questions on the five-level Likert scale survey. These questions can be categorized into four different groups. The first (Q1-Q6) and the second (Q7-Q10) group includes the questions that aim to measure the satisfaction level of the students about how useful the course was to improve their practical/theoretical skills and how the course helped them to learn new skills, respectively. The third (Q11-Q21) set of questions implies the student's satisfaction at each stage of the 3S structure, while the fourth (Q22-Q25) set represents the student's engagement in 3S program compared to other courses. The diverging stacked bars chart in Figure 2 is completely deviated to the right side, which shows that students are satisfied in all groups of questions.

Figure 3 presents results from the second survey performed at the end of the second semester. Data has been collected from eight students. Note that not all questions are similar to the first survey. The overall student evaluation of the specialization and their progress is positive, however the COVID-19 pandemic contributed to the critical evaluation of the amount of contact between teachers and students. This issue has been addressed immediately after this information has been collected.

Figure 3. Diverging stacked bars chart illustrating students' responses after the 2nd semester

Feedback from industry

After the first invitation round, we received spontaneous, positive feedback from our industrial partners that emphasized the need for practical cooperation between industry and academia. The general viewpoint can be illustrated by this quote from a Head of Sensor Technology at one of our partner companies:

> *"The study looks great! I showed the program to the group, and we thought that here are courses we should have taken :-)"*

We list more quotes that indicate the need for cooperation between academia and industry.

> *"This is very interesting for our company […] which develops and commercializes industrially certified sensors (IoT)"*

> *"Very interesting study specialization you open for. Here is a project proposal from us that we hope can capture the interest of the students."*

> *"This sounds exciting. Is this something you plan to implement permanently every year in the future? Do you know if there are other fields of study at NTNU that have a similar implementation of projects in collaboration with the industry?"*

We have also collected informal feedback by telephone conversations with our industrial partners after every semester. All feedback was positive.

Adjustments and adaptations to COVID-19

The black swan event embodied by the pandemic influenced our specialization by an inability to recruit international students. Furthermore, due to the more unpredictable future, many companies had to adjust their plans and focus on core activities. This resulted in a lower number of project proposals.

The necessary adjustments were implemented by moving the whole communication process, including the Kick-off conference, to the virtual realm. Although building a rapport between all involved parties is much more challenging without direct contact and a possibility to have a chat at the coffee table, we were able to partially recreate the friendly atmosphere necessary for establishing trust and open dialog. Another issue that needed to be addressed was the fact that students in our specialization mainly work independently on their projects. Since the campus was inaccessible to them, it was challenging to provide the necessary supervision and social background for student activities. This issue has been addressed with the newly recruited group of students by organizing weekly online update meetings. During these informal meetings, every student briefly presents no more than three main activities from the past week and no more than three main tasks for further work in the following week. Students are encouraged to actively participate during the meetings by asking questions and making suggestions regarding possible enhancements in their peers' projects. All students signalized that these short, informal sessions are valuable both for interpersonal contacts and for their project development.

CONCLUSIONS

We have successfully designed, implemented, and initially evaluated a new specialization in Electronic System Design by applying several cores and optional CDIO standards. Considering the positive feedback from a limited number of industrial and student stakeholders, we conclude that the proposed approach may have some advantages that could be transferred to implementations outside electronic design specializations. However, the proposed individualized approach brings challenges connected to student group formation, synchronization of the course schedules and extended supervision. These challenges were even more highlighted during the COVID-19 outbreak. Therefore, it was advisable to implement solutions ensuring regular contacts between classmates and teachers that have been realized in the form of brief weekly update meetings.

ACKNOWLEDGEMENTS

We would like to thank Morten Olavsbråten, Lars Lundheim, Ellen Hove and Torstein Bolstad for helping in the process of conceiving, designing, implementing and operating the 3S specialization.

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