EARLY INNOVATION PROJECTS: FIRST EXPERIENCES FROM THE ELECTRONIC ENGINEERING LADDER AT NTNU

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ABSTRACT

Ideas and experiences are shared on using project work for an external partner during the first two years of a study program in electronic system design and innovation. Challenges and possible solutions are discussed and a case is described in more detail. The initiative was started in 2014, so a full cycle of the approach has not yet been carried out. Experiences reported are thus somewhat preliminary, but indicate that students find working with real-world problems highly motivating. Important findings include that measures must be taken to counter variability of skills and interests among the involved students.

KEYWORDS

Electronics, project, innovation.

INTRODUCTION

It is generally agreed that some kind of project work should be included in an engineering education program (see e.g. Zhou, 2012). The amount of this mode of learning and at what stage it is introduced varies from institution to institution.

At the study program *Electronic System Design and Innovation (ELSYS)* at the Norwegian University of Science and Technology (NTNU) students are given a project early in the first semester that they will conclude in the fourth semester of their education. Moreover, the project is defined in cooperation with an external partner. A new partner with a new project is assigned for each class. We call it an *innovation project*, as it aims to solve a real-world problem for a specific problem owner. In the following we will discuss intended outcomes, challenges and solutions with this approach.

The approach is incorporated in *the Electronic Engineering Ladder* (Larsen & Lundheim, 2014, Lundheim & al. 2015), which is an integrated sequence of four courses during the first four semesters of the program. These courses are taught by a team consisting of 4-5 teachers accompanied by a number of teaching assistants. Presently, the team is identical to the authors of this paper. The first class of the program started in the autumn of 2014 and their innovation project will be fulfilled in spring 2016. The present paper is written before the finalization date, and reports experience gained so far.

MOTIVATION AND INTENDED OUTCOMES

One of the main motivations to introduce project based learning at an early stage, is better to motivate the students to learn the more theoretical fundamentals necessary to become a successful engineer. The motivational aspect is reinforced by choosing a real-world problem by an external partner. The stipulated outcome is that students will be well suited to adapt technical knowledge and skills to both technical and non-technical problem areas and customers.

CHALLENGES

We have identified three main challenges that have to be addressed in order to secure a positive outcome.

1. An obvious challenge with a first semester project is that most students are still technical novices at this stage. That is, focus has to be on how to formulate a project in such a way that the students can, based on their level of technical knowledge and skills, start studying possible solutions to the problem presented by the external partner.
2. How to ensure that the chosen problem allows and points towards solutions that support intended learning objectives of the study program? This includes how to ensure that the project based teaching builds up under the theoretical skills to be acquired. Especially, how to relate to the wide range of skills and personalities within a class, and how to properly compose functional groups where all members get activated and have a good learning experience.
3. How to fulfill the challenges above, and at the same time generate a project with an outcome that is useful for the external partner?

SOLUTIONS

To meet the challenge of putting novices to a real engineering problem, one important measure is to set up a progressive project organization. The teacher-team is responsible for that, and it has been addressed by dividing the project into two well-defined parts. The first stage is performed during the first semester, while the students are following courses in mathematics, circuit theory and computer science in parallel. The second stage is undertaken in the fourth semester, at which time skills and knowledge have been significantly improved enabling them to finalize the project for the external partner.

In the first stage, low-threshold problem solving technology is used to enable the students to realize their ideas. For this purpose we have chosen the Arduino Uno together with sensors, actuators and components that are easily interfaced with this platform. All student activity during this stage is concentrated on one full day each week. Students work in groups of six, and the day is structured with guest lectures and student presentations such that group work typically occur during two sessions of 2-3 hours each during the day. Using the Arduino is learned during the first weeks of the course by examples taken from a text book (Fizgerald & Shilo 2012). No formal teaching of programming is given in the course; it is assumed that the students should acquire sufficient skills from working out the problems in the text book and from the actual problems originating from the project work itself.

The challenge of obtaining well-functioning groups has been met in two different ways. For stage 1, we use a questionnaire surveying interests and previous experience among the students. Groups are then composed with the aim of securing diversity. During the first weeks, where activity is centered round learning the technology platform, students who finish assignments early, are encouraged to help the less skilled (peer instruction).

For stage 2 we use a matrix organization where each student is part of two different types of groups. Each student is given a predefined responsibility within a *group specific project*. Students with the same responsibility area form *expert groups*. An example of how this can be done is given in the case study below.

Finding good external partners and problems is a task that can only be solved by planning ahead. We start considering possible ideas at least a year before a class is started. Using our network, we discuss two or three different possibilities. Usually more than one alternative may be suited. Six month before start, we choose the one partner that seems most promising and continues the dialogue in order to find a problem formulation that is both relevant for the partner and likely to produce intended learning outcomes. It is important that the teaching staff involved is well acquainted with syllabus and skills that can be expected from the students during the project period.

A CASE

The first class of the Electronic Engineering Ladder was enrolled in 2014 and at the time of writing, the partner for the class starting in 2016 has recently been chosen. A summary of ongoing and future projects is given in Table 1.

Table 1 Innovation projects for the three first Elsys classes.

Project start	Project end	Partner	Topic
Autumn 2014	Spring 2016	Kystlaget Trondhjem (see below)	Vessel surveillance
Autumn 2015	Spring 2017	Vitensenteret i Trondheim (local Science Center)	Interactive exhibition models
Autumn 2016	Spring 2018	Adresseavisen (local newspaper)	New modes of interactive communication.

In the following we will describe in further detail the project for the first class, who is in the middle of the second stage of their project at the time of writing.

The partner for this group is *Kystlaget Trondhjem*, a society of owners of antique boats. The partner needs an inexpensive surveillance system for monitoring the state of a vessel and giving the owner an alarm on his mobile phone when a potential unwanted condition occurs. The owner can then open a web page to inspect a log of temperature, humidity, motion, etc. of his vessel.

Organization

During Stage 1, the students met with the boat owners. They inspected the vessels and got acquainted with peculiarities and special needs. They then started experimenting with various types of sensors connected to the Arduino platform. Realism was not given priority at this stage. Rather, the aim was for the students to get some experience with the technology and problems involved. The course was completed with a one-day conference where project results were presented in talks, posters and demonstrations.

Stage 2 takes place after the students have had several additional courses in circuits and systems, programming, computer architecture, mathematics and physics. Contact has been established with six different boat owners, who cooperate with the students in specifying and developing a solution for their vessel. The students are divided in six *boat groups,* each responsible for the successful development and installation of a surveillance system for a particular boat. Hence, there will be different requirements and solutions for each group.

In order to secure sufficient competence in each boat group, and to stimulate involvement from all group members, seven *expert groups* have been defined as listed in Table 2.

Table 2 Expert groups

Expert group	**Responsibility**
E1: Sensor system	Sensor solutions dependent on specific needs for various vessels.
E2: Detection system	Algorithms and parameters for sampling and processing of sensor signals for detecting anomalies and giving alarms
E3: Communication system	Securing communication between vessel installation, server and boat owner.
E4: System integration and project management	Overall responsibility for a functioning system at the end of the semester.
E5: Physical integration and installation	Power supply, encapsulations, PCB, cabling and installation on vessel.
E6: Implementation platform on vessel	Microcontroller platform and programming.
E7: Data base and user interface	SW on server and application software at user.

Each boat group will have at least one member in each expert group. Meetings are held alternately in boat groups and expert groups according to the following scheme:

1. Boat groups meet and discuss problems and solutions.
2. Open problems are taken to the respective expert groups.
3. Problems are brought up in the expert groups and solutions are compared and discussed.
4. Shared experiences and solutions are brought back to the boat groups.
5. The sequence is repeated.

For each expert group an advisor is appointed. This is one of the teacher team or a member of the Department's technical staff.

The weekly schedule for the course is organized with two for hour sessions. Some weeks these sessions are used for group work without interruption. In other weeks, in particular at the beginning of the semester, plenary meetings in auditoriums are held. During the first weeks the following plan was used:

Tuesdays
0815: All meet in an auditorium. Information is given and plans are discussed. This session is led by a teacher.
0900: Work in boat groups
1200: End of session

Wednesdays
1215: Students meet in expert groups. As these meetings finish, boat groups continue project work.
1515: All meet in an auditorium. Results are presented and discussed. This session is led by students (Expert group 4).

Documentation

Written communication skills are an important part of any engineering education. In the innovation project we emphasize that all written communication should serve a purpose and the documentation style should reflect this purpose.

Three types of documentations are required.

1. In order to make each boat group able to find a good solution for their vessel, it is important that they have the best possible knowledge of available technology and methods. Ideas discovered by one group will often be relevant for others. To obtain this, each expert group maintains a Wiki page containing relevant information within their field of expertise.
2. In order to aid future modifications and repair, the installed system should be documented by a technical report. Each boat group is responsible for preparing this report.
3. An easy-to-read user guide must be written for each installation must be provided. This document should be readable to persons with no technical background.

Assessment

Each student is given a pass/no pass mark. To pass the course, three requirements must be met.

1. The student must attend and actively participate in his/her boat and expert group.
2. The Wiki page of the expert group in which the student participates must be approved.
3. The technical report and user guide written by the student's boat group must be approved.

The students are actively engaged in the assessment. Monitoring of attendance is taken care of by each group. If a student fails to fulfill his/her responsibility, the teacher team is contacted by the group. A warning may be given to the student in question. Moreover, the expert groups' Wiki pages are assessed by the boat groups.

The teacher team gives feedback to drafts of technical reports and collects comments from boat owners on the user guides before final assessment of these documents are given.

EXPERIENCES

As a complete cycle of an innovation project is not yet completed, in the following we will mainly concentrate on experiences from the first stage, i.e. from the autumn semesters of 2014 and 2015. The discussion is based on personal experiences of the staff, formal and informal meetings with students and a student questionnaire given at the end of the semester.

The main feedback from the students is that working with the Arduino platform is *fun*. In particular, they seem to appreciate the hands-on experience this gives as a supplement to the circuit theory course they have in parallel. The extent to which students actually gain command of solving problems by programming the platform varies considerably across the class. An unintended outcome of this is that during the project work, much of the actual design and coding is left to the most skilled students, and some group members become passive. The use of expert groups in the second phase of the project seems to have reduced the problem of passive students considerably.

Working with a real-world problem for an external partner seems to be very motivating. Asked whether they rather would have a (safer?) school-defined project, none of the respondents answered affirmatively. 18% said it did not matter, while 82% said working for an external partner was important.

An important experience is that in both classes so far, all groups have actually been able to present *some* solutions to the given problems at the end of the first semester. Assigning the presentations of these solutions to an open conference is motivating, and positive feedback from audience has been encouraging for the students.

In this first stage, the students sometime show a slight frustration over not being able to realize all their ideas. This is not a bad thing, as rightly addressed it motivates them for learning those skills in the following courses.

Ending each project day with presentations from selected groups has been quite fruitful. Aside of training students to address an audience, it serves as a means of exchanging ideas and getting feedback from peers.

As mentioned, it is early to sum up experiences for the second stage of the innovation project for the first class. At the time of writing (February 2016), all boat groups are engaged in design and preliminary test of subsystems. The matrix structure seems to have made the activity level more uniform among the group members.

FURHTER PLANS

An important issue to be addressed is the variable involvement within some of the groups due to different levels of skills among the students, in particular with respect to programming. Measures that are under discussion are

- Extending the introductory first weeks to secure better familiarity with programming.

- Using a more diversified approach during the first stage where special attention can be given to students who need it.
- Supplement learning from examples with more formally organized teaching of programming.
- Better organizing of peer instruction.
- Organize the project work in such a way that non-technical tasks become more explicit and appreciated. Thus, students with a lower technical command can both be activated and experience that their effort is important.

The composition of functional groups is a challenge both for the first and second stage of the innovation project. Using personality tests may be a useful tools (Sæbø, Almøy and Brovold, 2015). Some initial trials of this has been done in composing the boat groups in the case described above, and this work will be further developed based on experiences gained during spring 2016.

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BIOGRAPHICAL INFORMATION

Lars Lundheim is a Professor in Signal Processing at Department of Electronics and Telecommunications, Norwegian University of Science and Technology (NTNU). His research work spans several fields of signal processing, such as speech coding, satellite communication, image compression, power efficient VLSI implementation, software radio, digital filters, radar signal processing, mobile communication and ADC calibration. The last three years his main focus has been on education.

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Bjørn B. Larsen is Associate Professor in Digital System Design at the Department of Electronics and Telecommunication, NTNU. He worked 12 years as a Research Scientist at SINTEF, with hardware for communication and signal processing. His current interests in teaching, research and development include what make student groups effective, and how students can learn from their peers.

Thomas Tybell is Professor in Micro and Nanotechnology at Department of Electronics and Telecommunications. Tybell has solid experience in scientific leadership via project leadership, responsibility to direct and promote a cross-disciplinary nanotechnology effort at NTNU, NTNU Nanolab, developing a new 5-year curriculum for the MSc study program Elektronikk at NTNU, and taking part in external scientific evaluation and task force committees. He is currently deputy head of department at Department of Electronics and Telecommunications. The main research interest of Prof. Tybell is synthesis and nanostructuring of epitaxial complex oxide thin heterostructures and superlattices. Present research includes interface engineering of ferroelectric and magnetic systems for non-volatile device applications.

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