Experiences, and student and teacher feedback, on the integration of hands-on project work in the first year engineering studies

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Conference Key Areas: Engineering Skills, Attractiveness of Engineering Education, Curriculum Development

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Keywords: Hands-on work, Curriculum development, Engineering skills, Study motivation

INTRODUCTION

All the time the requirements for university students and university studies are becoming more and more demanding in Finland. The students should graduate fast, so that they could work full-time as soon as possible. At the same time the teaching resources in Finnish universities are decreasing. Especially at university level engineering studies, engineering in higher education, the decreasing resources together with the aim for fast graduation of students, and the requirement that students achieve the manifold learning outcomes, make the actual teaching and planning of teaching very demanding. In engineering education lots of practical training and very many study subjects are essential to fulfil the requirements set to an engineer.

The engineering students in higher education should learn very versatile skills and various theoretical topics during their studies, including e. g. very complex theoretical mathematics and physics skills combined with firm practised hands-on skills. These various requirements for students, the versatile skill requirements together with the requirement for fast graduation, mean that the students' study motivation together with study results are demanded to be extremely good [1]. Especially high study motivation is needed to high and fast study success [2]. In the situation of these multiple different requirements the efficiency of teaching has to be really carefully thought in order to ensure highly skilled professionals to Finnish, and world-wide, careers.

Smooth and motivating start to university studies is extremely essential to students' further study motivation and study success, and later on to the personal career success and development. There are many factors affecting students' performance in university studies, including, of course, the interest and performance in theoretical topics of the subject matter, but what is surprisingly important to the later success both in studies and future work life, are so called generic skills [3, 4]. It has been found that Finnish companies that are employing master of science level engineers are demanding more emphasis on the generic skills in university studies [5]. In addition, every subject matter has its own special skills, these have to be known and understood, in order to achieve expert level and become a professional in that field. The subject-related skills can be combined with generic skills, both are something a student has to assimilate during his/her studies in order to fulfil the requirements of an engineer. Examples of the generic skills and subject-related skills in the study field of electronics include e. g.:

Generic skills

- Social skills
- Group working skills
- Project skills
- Writing skills
- Oral presentation skills
- Problem solving skills
- Creative and innovative thinking

Subject-related skills (Electronics)

- Basics of electrical circuits
- Electrical measurement skills

- Basic knowledge of programming
- Basic circuit manufacturing skills
- Soldering
- Basic circuit design skills

Practising and accustoming of the generic and subject-related skills of the study field should be started in as early stage of the studies as possible. The knowledge of these skills is best achieved when these skills are integrated in different courses in the curriculum throughout the whole student's study time, beginning already in the very first year's first study weeks. The integration of these kinds of skills to technical content courses is likely to increase student's study motivation, at the same time not forgetting the positive emphasis of generic and subject-related skills to the student's future career [3, 4].

1 HANDS-ON WORKING IN BOOSTING STUDENT'S STUDY SUCCESS

It has been recognized that active learning increases first-year students' social integration into a university setting [6], which is of crucial importance for study success. Integration to university life plays a significant role in the students' intention to continue their studies after the first year [6-9]. Active learning is argued to both promote students' motivation towards their study field and enhance their problem-solving abilities [10]. This is significant, because the key factor in all studies in higher education is student motivation [1, 2]. This applies also to engineering studies. In engineering studies the ideology of active learning can be easily utilized with different kinds of hands-on work tasks and projects during studies. A hands-on project work has been found to be extremely efficient in increasing students' further studies in engineering [11]. The feedback from students says that this way of working with real engineering cases combine theory and practice [11], which is remarkably important in engineering occupation. In addition, project works, where students are involved with the subject matter, and additionally combining many study areas of the subject matter, increase students' study motivation [12]. In the area of engineering there are always many possibilities for constructing subject-related devices and at the same time learning project working. The engineering study field enables lots of hands-on work for students during their studies, if the teaching resources are allocated to this kind of working.

Experience in laboratory work and other kinds of hands-on work have found to be particularly beneficial to student learning [13]. Especially engineering students are very motivated and eager to do hands-on work. When starting their studies engineering students wait to get involved with different kinds of hands-on tasks [9]. If this part is missing from the very beginning of the studies in higher education their study success is potentially decreased [14]. The idea of an engineering occupation includes hands-on working, constructing, and measuring something. This is very true in the field of electronics, and in electrical engineering in general.

1.1 Renewal of the first-year studies of EE and IT in TUT

Nowadays at university level electronics, and more generally in electrical engineering studies, soldering, knowledge of electrical measurements and basic knowledge of programming are examples of subject-related skills. These skills are essential in the development of the engineer's professional identity, and these skills are something a future employer will expect from an electronics engineer. Unfortunately previously these skills have not been in the curriculum of first-year bachelor level students of Information Technology (IT) and Electrical Engineering (EE) at Tampere University of Technology (TUT) in Finland. This has mainly been caused by the limited resources; the student number in IT and EE is big, yearly 180 altogether (90 in EE and 90 in IT).

It has been difficult to arrange group work and lab work for such a large number of students. However, the Faculty of Computing and Electrical Engineering (FCEE) at TUT started to develop first-year studies for bachelor degree students in IT and EE. The faculty decided to completely renew the basic studies of their bachelor degree program. The basic studies at TUT are during the first two study years. The core of the renewal process was to enhance students' learning, and lots of resources were decided to be allocated to the first-year studies. In the study renewal process the need for generic and subject-related skills was clearly recognized, and practising and teaching of these skills were planned already to the very beginning of the studies. Generic and subject-related skills were integrated in subject courses. This way students combine all kinds of skills already from the very beginning of their studies. These generic and subject-related skills are included in the first-year curriculum already in the first study period, that is in the student's first 7 weeks in the university.

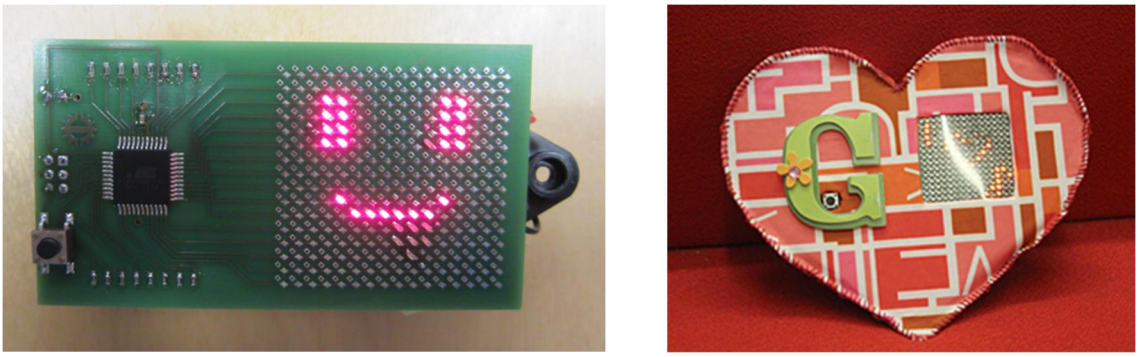
Compared to the previous ways of implementing first-year studies at TUT, the FCEE faculty's new curriculum included plenty of students' own work together with group work. To increase the amount of active learning, and this way boost the students' motivation and learning results, a hands-on project work was included in the first year's first study period's curriculum. The extent of the project work is 2 credits, which is approximately 54 hours of work per one student. The working hours are planned to be equally divided throughout the first study period. The project work combined almost all the generic and subject-related skills in the field of electronics. This way the students achieved an efficient start to practicing these skills. Students completed the project work in small groups of 3-5 students. The main intention in this project work was to help students to connect theoretical studies to real life engineering cases, and to provide them the basis of hands-on skills that every electrical engineer needs. In addition, the students were introduced to project working and business thinking. This way students developed their professional identities as they learned the skills needed in project and group work, as well as in lab working. The learning of generic and subject-related skills was effectively started in this project work.

2 HANDS-ON PROJECT WORK

The task in the project work was to innovate a product based on a light emitting diode (LED) device, and to think about a business idea behind the product. The students were also introduced to the basics of entrepreneurship; they considered the importance of marketing, planning, and design issues concerning a technical product. In addition, already in the beginning of the project work the students had to make a schedule for their project, and they had to think about the tasks for the group members. These both aspects are very important in all project-based working.

In the project work students designed their own animated light figure using basic electronics components. Students constructed hardware for the device; they soldered components on a printed circuit board (PCB). After soldering, they designed software for the device. Very easy and simple programming instructions were established for students, thereby providing basic experience in programming an electrical device. The programming of the device did not require any knowledge of programming beforehand, the students were instructed for it from the very basics.

Each student did his/her own program, because all the students had their own light designs based on LEDs. One example of a ready and programmed PCB is in *Fig. 1 a*. In final stage the student groups prototyped a case for their device. One example of a ready device with a prototyped case is presented in *Fig. 1 b*.



(a) (b)

Fig. 1. a) An example of a ready and programmed device, without a case. b) An example of a ready device with a prototype case.

In addition, students measured the current consumption of their device hereby getting slightly familiar with the basic laboratory measurements. The students also had to accomplish short follow-up reporting in order to practise the basic procedure of laboratory measurements. Follow-up reporting skills together with preliminary reporting skills are core content of laboratory measurements and laboratory courses and hereby essential generic skills related to the electrical measurement skills in electronics. At the very end of the project work the student groups presented their ready-made LED-based devices to other groups, thus practising the oral presentation skills.

Students were required to complete both written and oral presentations as well as to think about the commercialization and marketing of their electronic product. Even though the very big amount of students set extra demands on the amount of lab equipment and teacher resources needed in hands-on work, the hands-on lab work was decided to be implemented and the needed resources were planned and reserved for it. The core content and phases of this project work are presented in *Fig. 2.*

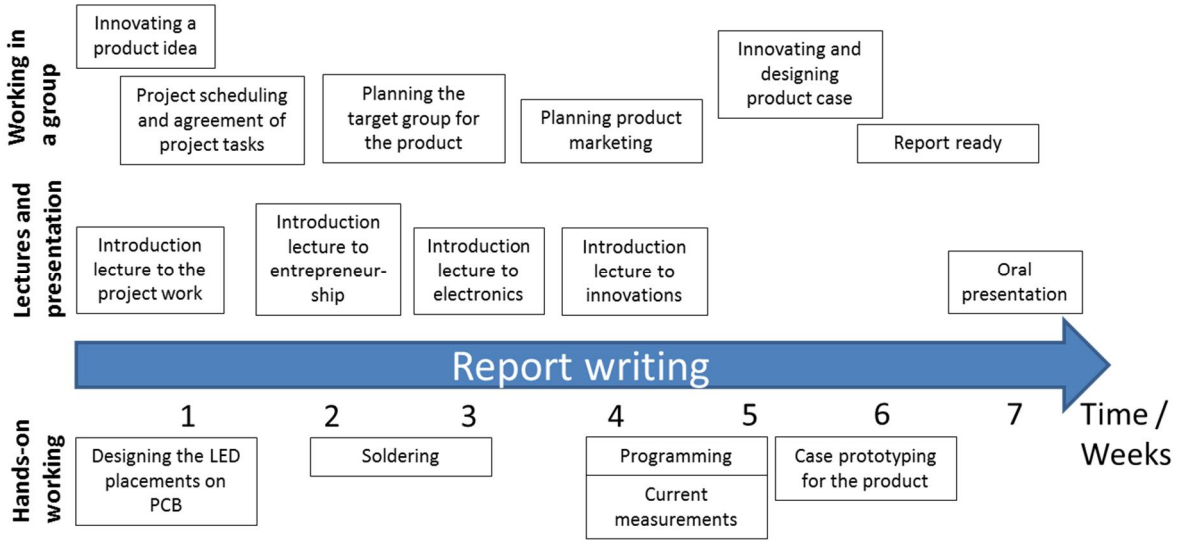


Fig. 2. Contents of the project work

3 RESULTS AND DISCUSSION BASED ON THE FEEDBACK OF STUDENTS AND TEACHERS

An electric feedback system for students is used at TUT. Giving course feedback is compulsory for the students. A student doesn't get his/her course credits unless he/she has given course feedback. The electronic feedback system hides student's credits until the feedback is given. A student can also decline from giving course feedback in the feedback system. Even though a student chooses this alternative he/she gets the course credits after this. This option is made available to minimize careless and non-accurate course feedback. However, in practise it is seen that very few students use this option, almost all students answer the feedback questions in the electronic feedback system. Thus the electronic feedback system ensures thorough and extensive student feedback, and courses are further developed based on this feedback. Among other things students can write free feedback of the courses, this free feedback from students related to the project work is presented in *Table1*, where the pros and cons are separated. Unfortunately, multi-choice questions or questions requiring numeric-scale answers related to the hands-on project work did not exist in the electronic feedback questionnaire of this course. All the feedback, which can directly be connected to the project-work, is free feedback, which students have written to the system. Thus the student feedback is based on the students' written comments, and exact statistical information cannot be calculated from that. Teacher feedback is based on the discussions among course teachers during and after the course implementation.

3.1 Student feedback

There were numerous answers in the student feedback with the same content, e. g. that the project work was good, great or fun. All the same answers are written only once in *Table 1*. When keeping this in mind and looking the *Table 1*, it is seen that the pros are multiple compared to the cons. In addition, when looking at the *Table 1* it can be seen that the cons are mostly related to practical issues, such as too short lab time or difficult handling of very small components. On the other hand, the pros are mainly related to other kinds of issues than practical issues, like learning, usefulness and interest firing. This indicates that the students found the project work interesting and it enhanced their learning. In addition, the project work helped some students to find out the study area for their further studies. Finding the most interesting study area increases the study motivation of the student. However, from the student feedback also some aspects were found that need further developing, e. g. the length of the reserved soldering lab time. Based on this feedback the soldering time is increased for the next academic year. In addition, the written instructions from every step of the project work are developed further to achieve even better level of clarity. Furthermore, from the feedback in *Table 1* it can be seen that not all the students liked the LED figure project work; one feedback even recommended removal of the project work.

The written feedback of students shows that the goals of the project work as situated already in the very beginning of the university level engineering studies have been achieved well. Overall the students' study motivation and interest in the subject matter have increased based on the written feedback. This lays firm ground on the students' further study success and rapid study progress, not to forget the probable positive effects on the future work careers of the students.

Table 1. Student feedback from the project work

Pros	Cons
· The LED figure project was: o good. o fun. o well implemented. o a nice and concrete way for learning. o was very useful and interesting. o a positive experience, it combined many study areas, business thinking and actual constructing of a device. o great! It was truly fascinating to solder and program it by myself! Now I want to continue in the same study field. · Making of LED device was nice. · Good that no skills in programming were assumed beforehand. · The group work and presentation were advantageous for future needs. · The time table was well done.	· Constructing of the device was challenging due to the very small components requiring footwork. · The construction of the device was so simple that it was almost boring. · An increasing hurry in the end of the project work. · The reserved lab time for soldering should be a bit longer. · All the written instructions should be in one place. · The LED project was a bit forced assignment. · More lab-hour choices are needed. · Better instructions for programming. · Too much work in LED project. · The LED project should be removed.

3.2 Teacher feedback

There were five teachers involved in the project work. One lecturer was the responsible teacher for the entire project work, giving also an introduction lecture for the project work. In addition, one professor designed the hardware and software for the device, and gave an introduction lecture in the technical topics and electronics related to this work, e.g. providing students the basics of micro controllers. In addition to these two permanent staff members of TUT, three assistant teachers were involved in the lab teaching together with the lecturer.

In general, the teachers found the teaching of this project work very interesting. Mainly the classroom teaching work was instructing the students in soldering and programming labs. This kind of lab teaching is motivating and at the same time demanding for the teachers. The students have very different needs in labs, and the teacher should adapt immediately to all these various needs in order to be able to help the student in the best possible way and thus to enable the student to proceed his/her work.

The tasks of the responsible teacher, the lecturer, included preparation of the written instructions for the different phases of the project work, and all the practical tasks related to this project work, e. g. room reservations, assistant teacher recruiting, and component ordering. The professor made the programming instructions, and the lecturer made all other written instructions. The written instructions for students need to be very clear and thorough, because of the very big amount of students doing this project work. Without very clear instructions the teachers would have to answer a excessive amount of questions from individual students, hence the careful preparation of written instruction is essential. This ensures that the allocated teacher's time is sufficient.

There is really a lot of work for the responsible teacher, mainly comprising of preparation tasks. The classroom hours of the responsible teacher are only a minor part of the time needed for the project work. Hence, the responsible teacher should reserve quite a lot of hours for this work. However, boosting students' study motivation and study success is definitely worth for this big investment in the teacher's time.

4 SUMMARY

In general, the project work was found very interesting by almost all the students based on the free written feedback. Inside the small project groups interesting tasks for all group members could be found: some students liked especially the construction itself, that is the soldering of the components on a PCB, some other students liked to innovate the product around the technical device, and part of students liked to think about the marketing issues. From teacher's point of view implementing a hands-on project work in the very beginning of engineering studies in higher education is very demanding. The teacher has to be familiar with many generic skills in addition to the study topics and subject-related skills of the study field. Furthermore, the teacher's work load is enormous in this kind of implementation. However, also the teachers found that implementation of this kind of a hands-on project work in the beginning of university level studies really enhances students' study motivation potentially leading to better study success in further studies.

The results based on the student and teacher feedback are very encouraging, thus ensuring that the recourses put to this project work were worth of the investment. The project work is further developed based on the feedback, and the resources are allocated to this hand-on experience also in the coming years.

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