CHALLENGE BASED LEARNING IN ENGINEERING EDUCATION

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Abstract

In this paper, we describe how Challenge Based Learning in a form of multidisciplinary project is applied to teaching of Embedded Systems Design as a part of process of implementing CDIO Initiative in EVTEK University of Applied Sciences, Degree Program of Information Technology.

Keywords: Challenge Based Learning, Student Project

Introduction

Educational projects have always been an important part of engineering studies. They have repeatedly proven to be effective and meaningful way to apply theoretical studies in practice and to deepen learning of the topic. Students are welcoming the projects, since they can apply their theoretical knowledge in a real work mimicking problems. Solving a practical problem helps students to enhance old and create new knowledge structures and therefore learning process becomes deeper and more personal experience. CDIO Initiative's goal is to provide guidelines and standards for educational institutes to develop their pedagogical strategies to meet the requirements set for modern day engineering education. In addition to strong technological knowledge skills like communication and group working skills are becoming more and more important for engineers. This can be seen also in CDIO Syllabus which states various learning objectives for engineering education [1].

Traditionally engineering courses contain a short compulsory project having the goal to deepen the knowledge gained during the theoretical part of the course. Unfortunately in a typical syllabus there are usually several courses going on at the same time resulting in a danger of learning outcome to be far from optimal. The students' work will suffer from simultaneous deadlines, overlapping tasks, and lack of or contradictory instructions. This fragmentation leads easily to overwhelming work load close to the deadlines, which shows up as a late submission of poor quality project reports. In the worst case, students are feeling more obligated to complete the course than to learn from it.

A group of information technology teachers of EVTEK University of Applied Sciences, Finland, awoke and started seeking for a cure to this evident problem. The antidote to this problem was quite obvious: combine the separate course projects into one bigger one, and apply problem based learning methods for management. This reduces the number of projects without sacrificing any of teachers or students resources. However, the transition from fragmented to combined project has a plenty of challenges. The planning, intensive cooperation between teachers, implementing, maintaining, and evaluating the results will take considerable amount of time. Compared to this, teaching of a course which only contains a small untied project is rather straightforward task.

EVTEK University of Applied Sciences organizes annually an Embedded Systems Engineering project. The project is targeted for second year students of national Information Technology Degree Program. It combines teaching resources of three obligatory courses: Electronic Circuits and Devices, Embedded Systems Programming, and Finnish Language and Communication. In addition, the students are solving mechanical and other practical problems, which require self learning and skills learned in other context. The project is meant to be as realistic simulation of a real life industrial

development project as the teaching resources allow. The multidisciplinary project described in this paper relates very closely to learning objectives set in the CDIO Syllabus and provide an excellent starting point for EVTEK University of Applied Sciences in the process of implementing CDIO Syllabus to the engineering education.

This paper describes the project plan, reports the learning outcomes, and discusses about lessons the teachers learned during the project.

Description of the Project

Information Technology course sequence

The block diagram in figure 1 presents the sequence of courses for 2nd year information technology students regarding embedded systems design and the combined project discussed in this paper. First year of studies, marked with dashed lines in the block diagram, consists mostly of basic courses, e.g. mathematics, physics, digital circuits, and circuit theory [3]. During the 2nd year more advanced topics are studied and the combined project discussed in this paper focuses on bringing the subjects of three courses together using a problem based learning method.

Electronics Courses

The main goal of electronics education for information technology students is to provide students an adequate understanding of the embedded systems hardware. Electronic Systems T0161 and Electronics Components and Circuits T0162 give the foundation of understanding electronics [3]. The studies begin from understanding the principle of negative feedback on operational amplifier circuits, followed by most common operational amplifier applications, and concluding to active filters. After finishing the usage of operational amplifiers, the discrete active components are introduced with application examples. Practical application examples from the world of microcontrollers are constantly introduced throughout both of the electronics courses.

The combined project required some changes to the normal study plan. Naturally, the course content needed to be adjusted to support the project topic. For example, since the project involved driving an electrical motor, some corresponding examples along with exercises were given to the students. We also allocated three extra two-hour laboratory sessions to provide supervision on harder to solve problems.

Software Courses

The properties and usage of microprocessors is taught during the fall semester of second year on a course named Microprocessors T0192 [3]. Another course Programming T0189 teaches the principles of C-language [3]. After those two courses, Embedded Systems Programming T0022 course [3] combines the previous topics and the new concept of embedded systems is introduced.

In the Embedded Systems Programming course gives basic understanding how to develop software for an embedded processors. The course extends the knowledge acquired in the Programming course by introducing the usage of C-language in an embedded system. Laboratory work introduces students the debugging methods of an embedded system. Processor interrupts are an important focus point and the programming of interrupts is taught. However much of learning in the embedded course is achieved by debugging different problems faced in the laboratories.

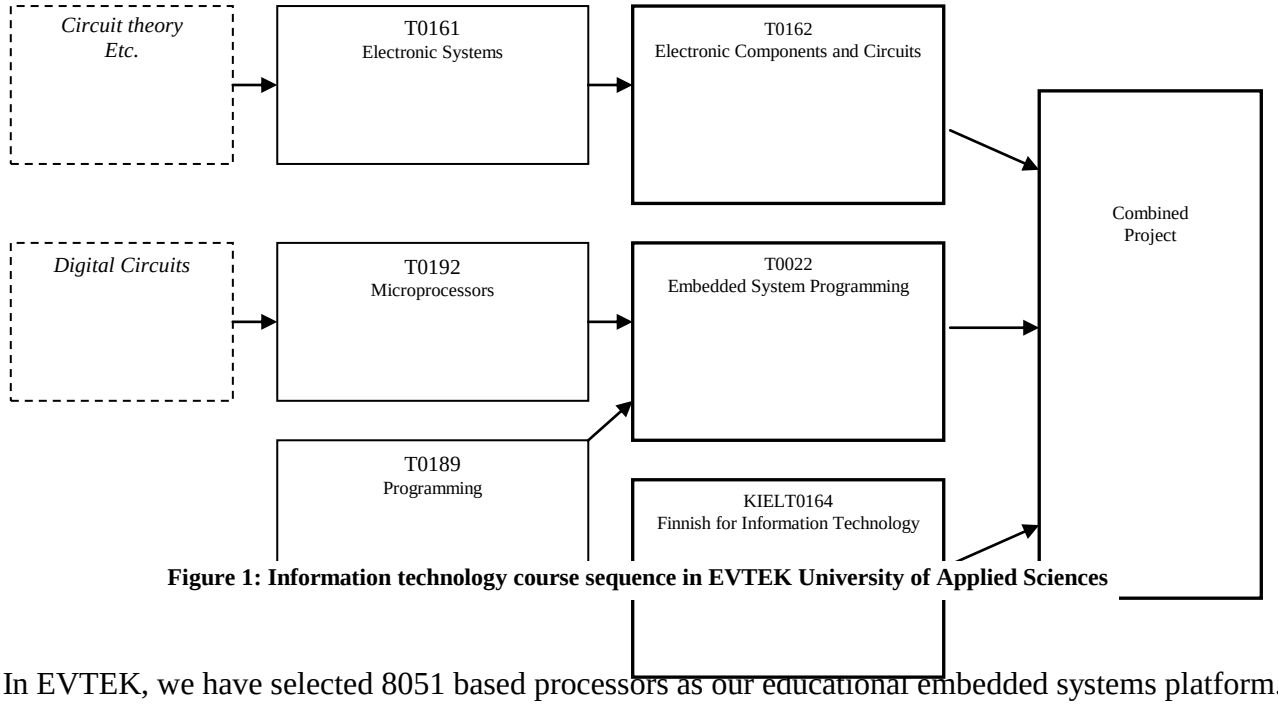

Figure 1: Information technology course sequence in EVTEK University of Applied Sciences

In EVTEK, we have selected 8051 based processors as our educational embedded systems platform. Students are using our own processor boards on the laboratories [4]. The boards are designed to simplify adding new hardware modules into microcontroller in order to evaluate different types of input and output devices. Even though an educational 8051 hardware platform is used during the theoretical part of the Embedded Systems Programming, the teams designed and build their own microprocessor boards as a part of the project.

Language Studies

Finnish for Information Technology KIELT0164 is compulsory course, which teaches group meeting practices, writing standard documents, and giving short professional presentations. The main purpose is to give students adequate communication skills required in their future position as an industrial engineer.

Project based learning requires that documentation is done in real time. Documentation should consist of not only the facts about what was done, but also how it was done and description of used methods. Self reflection has an important part on problem based learning. Well made documentation will also support student in future learning and working careers.

Challenge Based Learning

The major ideas of problem based learning are that it uses a realistic problem as a basis of the studies and the students will learn by solving the problems [2]. The teacher's role varies from a lecturer to tutor, whose functions are more to do with controlling the learning process rather than giving the facts. Teacher's duty is still to plan the sessions by selecting the topic for the problems, organize the students into working groups, and keep the process rolling. Teacher does not anymore know everything about the problem, but the students will come up with their own valid approaches to solve the problem.

There are some reported problems in literature [2], which we should be aware of in our case. First, the teachers' role change is not straightforward, since the activity will change from the traditional lecturer-instructor into tutor-facilitator. This may cause some resistance among some teachers, which means that the teachers must be open minded to adapt new pedagogical ideas. Second, the students' role also change and the new learning method may cause confusion in the beginning. Third, the teacher colleagues may exhibit some resistance just because the idea is new. Fourth, keeping the

student teams together may be hard. For example, the team can break up easily if the personal values are different or if small argument just happens to escalate out of the proportion. Last, but not least, the teaching of the required process skills is difficult for most teachers. Therefore, without the direction and support the problem based learning will become almost impossible to handle.

In our multidisciplinary project we have developed the concept of problem based learning one step further by introducing *competition* as an additional element. This increases productivity by changing the problem solving task to a *challenge*.

Project Guidelines

The combined project has been organized four times starting from academic year 2004-2005. Project has evolved during the years and in the academic year 2007-2008 the students' goal was to build a remote controlled robot with some given basic components and to take part to a competition with their robot at the end of spring semester. The subject was chosen because it was considered to be a motivating subject for the students.

Teachers divided students into 3-4 member teams. When assigning members into team, each student's skills were considered. Additionally each student was asked to assess their personal interest in electronics, software development and documentation prior to the forming of project teams. In this way well balanced teams (considering hardware versus software) were constructed. After the teams were formed each team named responsible persons for software, hardware, and documentation.

Project Implementation

Project was started with a kick-off meeting in January 2008 where the teams were formed and the topic and the guidelines for the project were presented. As the engineering skills of 2nd year students are still rather low, a lecture of electronics design process was given to help the teams to get started with their project. The lecture was followed by team sessions where a teacher was present. During these sessions the fundamental designing problems were outlined.

Progress of student projects was monitored by several project meetings. Teachers were not always present at the meetings. Instead written project minutes were submitted to the learning platform and inspected by teachers. After two weeks of project work, teams were required to make customer presentation about their project. Teachers were in the role of customer. In the implementing phase of the project when the basic prototypes were under construction project teams were required to make another customer presentation. Real customers were invited to the presentations to provide feedback to the project teams. In addition, voluntary laboratory sessions were reserved to the schedules every other week during the spring semester. During these sessions at least one teacher was present to guide the teams with building and testing their prototypes.

Documentation

The progress of the project work was documented and the final documentation consisted of:

- project plan
- customer presentation documents
- project meetings minutes
- project technical documentation

Each team submitted their documentation to the web-based learning platform used in the project. For each document a deadline was given to help the students to plan the schedule for their project and to follow their plan.

A Web-based learning platform called NetPro [6] was applied as a learning platform for project teams. NetPro is developed especially for maintaining student projects. It provides a common place

where all teachers can manage the project and students can maintain a structured document database dedicated to their team only. There are both public and private areas on the system, which means that the student groups can share documents within the group and selected documents can be shared with other groups. For teacher, this system really makes a difference, since all group reports are on one single place accessible anywhere and anytime.

Grading

The project is treated as a compulsory part of the courses Electronics Components and Circuits T0162 and Embedded Systems Programming T0022 and it directly affects on the evaluation of both of the courses. Although both of the courses are graded separately, they both use the competition results as a part of the total grading.

The students' grades from the project have several parameters. The grades are ranging from 0 (=failed) to 5 (=excellent) and it is a sum of competition (from 0 to 2 points), group excellence in electronics and software (from 0 to 3 points), and achievements in documentation (from -1 to 1 points).

The competition points are combined from three different categories:

1. Speed: Three trials on 400cm acceleration track. The competitors are sorted based on the times.
2. Slalom: Two poles are placed on the acceleration track. The car starts from start line, it has to go loop around both poles, and it has to go through finish line. The competitors are sorted based on the times.
3. Tuning: The appearance of the cars is judged by other students. Three marked papers are given to each group, where they can give votes to any other group but their own. The competitors are sorted based on the votes.

Final competition results are then calculated by adding the sorting numbers of each group together and sorting that list of merits. This final list is then divided into three parts; two points are given to highest group, one point is given to middle group, and no points are given to the lowest part.

Teaching Resources

Designing and maintaining a problem based learning project requires always more resources than traditional classroom teaching. In our case we used the teaching resources that were reserved for normal, self guided student projects. Unfortunately, the resources are quite minimal and without any additional hours spent on designing the project would not have been possible.

One very important resource on the design part was that one of the authors, Mr. Anssi Ikonen, did his pedagogical research [5] as a part of vocational teacher education program, which is compulsory for a teaching tenure in a Finnish polytechnic.

Students Comments

At the end of the project teams were asked to give feedback and to evaluate their own team work and learning process. A questionnaire was used for survey. The feedback from the project teams indicate that majority of the teams found this multidisciplinary project a motivating method for learning. In addition to only enhancing engineering skills the students learned project and team working skills and gained knowledge and experiences on embedded systems design process.

There was a minority of teams who had problems with their team work or who faced technical problems beyond their engineering capabilities and thus their learning experience was not as positive as it could have been.

One of the project teams made an excellent remark when they were asked to define the most important learning outcome during the project. Their response was that "we found out that designing embedded systems is 5% of planning and implementation and 95% of testing and debugging".

Teachers Observations

Project discussed in this paper was the third of its kind in EVTEK University of Applied Sciences and each and every time the project has been educational also for the instructors. The project has been evolving each time we have arranged it. The major outcome of the first project in academic year 2004-2005 was that increased supervised laboratory time and increased guidance was required. Additionally a procedure to manage component purchases was developed. The second project in academic year 2005-2006 was implemented based on the experiences from the first project, but unfortunately the topic was too straightforward and learning outcome was not optimal.

Third time we may have picked too ambitious topic. However, the topic of remote controlled cars did not leave any student cold, but instead they worked extra hours to get it to work. We cannot argue that the extra hours are a good idea during hectic student life. While we were getting very good results in our project, the opposite happened in many other topics they were supposed to work on. For example, the students were skipping lectures, which did not have compulsory appearance.

This was the fourth time the project was organized and the choice of topic and the over-all management of the project appear to be well in balance. Only a minority of project teams had difficulties in getting the project started and the progress of the project is very well in schedule. Project teams did work some extra hours due the challenging nature of the project. Most of the project teams were not satisfied with a basic designing solution, but additional features and ambitious solutions were developed.

Furthermore, ECTS system study unit is based on the estimate of students working time on the topic. We had allocated about 50 hours of students work on this project, but it seems that in average the students did more than that. However, the students majoring in Embedded Engineering will get acknowledged their good work in future courses, where they can continue developing their project robots.

Discussion

Based on our short, four years experience in combined Problem Based Learning project in the area of the Embedded Engineering, we have noticed it to be an effective and activating method of teaching. Based on the feedback from the students we can conclude that a combined project consisting electronics, embedded systems programming and documentation is far more motivating than having three separate project works. The percentage of the projects finished before the deadline indicates also that the students found this way of working very motivating even though the subject for the project in academic year 2007-2008 was rather demanding for 2nd year engineering students.

Based on our experiences we give some recommendations for arranging a similar event:

Having enough of planning resources play a crucial role on getting the project started and completed successfully. The instructors of each course must spend considerable time together outlining the main goals, synchronizing the course curricula and agree on the evaluation of the project work. Also the flow of information between the teachers involved has a major effect on the success the project. Project outlines must be planned carefully in advance and students should receive same information from each teacher regarding the project or there should be one source of information available.

One major factor affecting to successful project work and learning process was the guidance provided by teachers acting as tutors. Active involvement and guidance was required especially during the first

weeks of the project. Most of the guidance took place during the first team sessions and in the laboratory sessions. There were noticeable differences between project teams. Some teams were more innovative and got started with the project very fast and they were able to decide the role of each team member easily when others required more support. It requires professional skills from the teachers to evaluate the team forming process and to see where and when additional guidance was required, but still remain as a tutor and not affecting on the problem solving process by providing solutions.

Get tools to help maintaining the project and test the usability before purchasing it. There are commercially available several learning environments, which fit or doesn't fit for problem based learning in competitive project setup. The system must support student groups and allow public and private areas. There also has to be a quick look area, which the teachers can use for evaluation.

Select the project topic carefully. Avoid too general topics and it is not recommended to let the students to make up their own ideas: projects are less likely to be completed. This recommendation is based on our experiences organizing the first project. In the academic year 2004-2005 project teams were allowed to come up with their own topics. The result was high motivation and enthusiasm in the beginning of the project, but lower number of projects was completed before the project deadline. Major factors affecting the results were too complex and ambitious topics and the lack of competition and support between project teams. In academic year 2005-2006 project topic was selected by the customer, i.e. teachers, and the result was higher percentage of successful projects.

Do not let the students to form their own project teams. Instead let the students to evaluate their own experience and interest on different categories of engineering skills like electronics design, programming and documentation. Use this information and your own knowledge to form the project teams. This presents a real life situation where project team must go through a team forming process in the beginning of the project. Additionally this ensures that all teams are more or less on the same level of engineering skills.

Eliminate extra variables to simplify project maintenance. Especially, do not allow any exemptions or special arrangements.

The Problem Based Learning requires extra time and effort from instructors. Do not think that dividing students to groups and giving them a common task means implementing PBL method for teaching. A successful learning process requires guidance and support. Also adequate amount of resources should be allocated for planning and managing the project. In addition the teachers involved should be highly motivated and devoted to learn and try new pedagogical methods. This requires more resources compared to traditional class-room teaching and the allocation of the resources should be agreed in advance with the employer.

Conclusions

Introducing Embedded Engineering for second year Information technology students can be effectively done by applying Problem Based Learning principles in a combining student project. It requires seamless cooperation between course instructors, some extra resources, and interesting topic. This means a lot of hard work for both students and teachers, but when the project is a success, it gives very gratifying moments for everyone.

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