CHALLENGE BASED LEARNING IN ENGINEERING EDUCATION

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ABSTRACT

In this paper the implementation of Challenge Based Learning in Embedded Engineering as a part of CDIO Syllabus in Helsinki Metropolia University of Applied Sciences is studied and described. The Challenge Based Learning (CBL) method and its implementation is based on a study of project based learning in engineering education started in former EVTEK University of Applied Sciences during academic year 2004. [1] The project studied and described in this paper is the 6th challenge based learning project and will take place during the spring semester of academic year 2008 - 2009.

The paper focuses on introducing the implementation of the on-going project during the academic year 2008 - 2009, the study of learning outcomes and most important the amount of resources required from the lecturers and the amount of time students have used in the project. A discussion of the experiences of tutoring lecturers is also included as well as some recommendations for arranging a similar learning event.

KEYWORDS

Challenge Based Learning, Student Project, Teaching Resources

INTRODUCTION

The role of problem and project based learning is becoming more and more important in engineering education. Traditional teaching methods, e.g. lectures and exams, are often not adequate to serve the needs of modern day engineering education. Project based learning supports the development of skills such as life long learning ability and cross-cultural communication skills, which are required from modern engineer in addition to strong theoretical knowledge.

Various initiatives and projects have been started and studied in order to develop engineering education. CDIO Initiative [2] is one of the most successfully implemented and widely studied methods for modern engineering education and it has also been utilized in Helsinki Metropolia University of Applied Sciences.

The project based learning method in Information Technology Degree Programme of Helsinki Metropolia University of Applied Sciences is based on challenge based learning where the goal of the project is to respond to a product development challenge and test the results against other project teams. Challenge based learning has been studied in former EVTEK University of Applied Sciences for several years and some results have been presented in the 4th International CDIO Conference [3]. In the implementation of challenge based learning project, parts of three separate courses are combined in a form of multidisciplinary project with the goal to design, implement and operate a product and test the performance and functionalities of the product against other project teams.

CHALLENGE BASED LEARNING PROJECT OUTLINES

Information Technology course sequence

The flow chart in figure 1 represents the structure of courses for 2nd year information technology students in embedded engineering module and the combined multidisciplinary project discussed in this paper. First year of studies, marked with dashed lines in the flow chart, consists mostly of basic courses, e.g. mathematics, physics, digital circuits, and circuit theory [4]. During the 2nd year more advanced topics are studied and the combined project discussed in this paper focuses on combining the topics of three courses together using challenge based learning method.

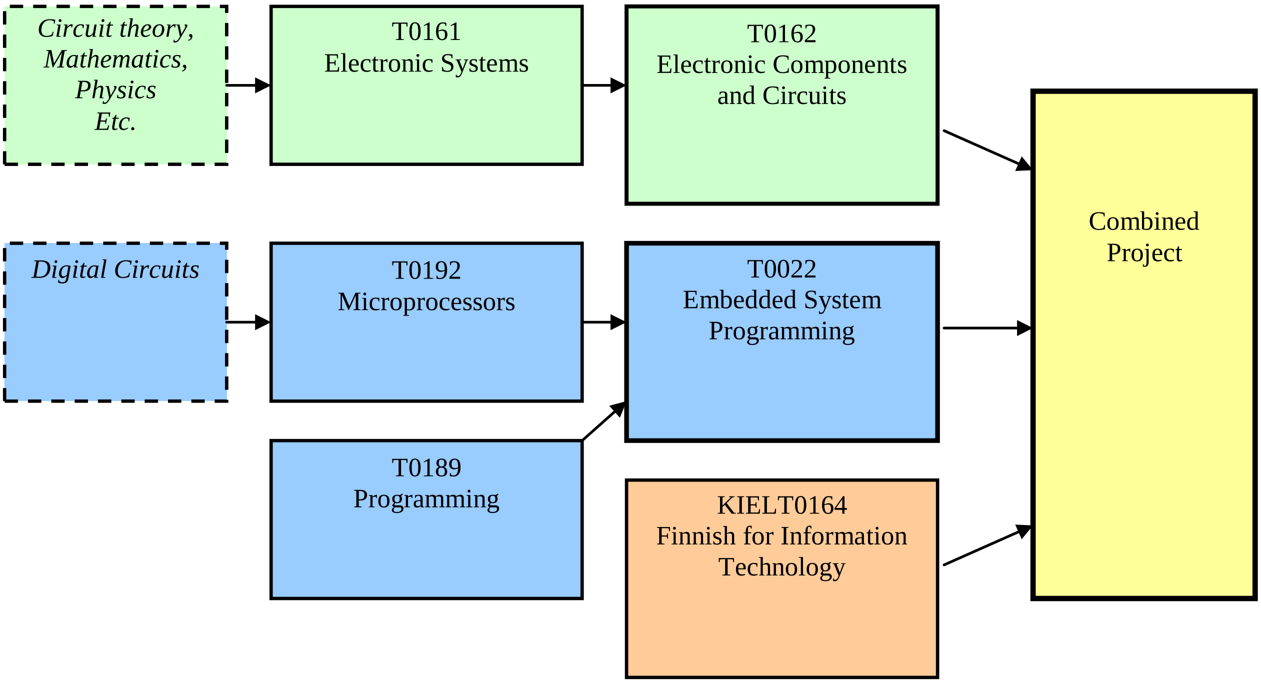

Figure 1. The structure of courses involved in the CBL project.

Electronics Courses

The primary goal of electronics education for information technology students is to provide students an adequate understanding of embedded systems hardware. Electronic Systems T0161 and Electronics Components and Circuits T0162 provide the foundation for understanding electronics [4]. 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 modifications to the syllabus. Some of the topics were emphasised in order to support the CBL project. Some additional laboratory sessions were also included in syllabus to provide guidance for the project groups.

Software Courses

The properties and usage of microprocessors are taught during the fall semester of second year on a course named Microprocessors T0192 [4]. Programming T0189 course includes the principles of C-language [4]. After those two courses, Embedded Systems Programming T0022 course [4] combines the previous topics and the new concept of embedded systems is introduced.

The Embedded Systems Programming course gives basic understanding on how to develop software for 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.

In Helsinki Metropolia University of Applied Sciences we have selected 8051-based microprocessors as our educational embedded systems platform. Students are using our own processor boards on the laboratories [5]. 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 CBL project.

Language Studies

Finnish for Information Technology KIELT0164 is a 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.

Problem and 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 [6]. 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 [6], 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' roles also change and the new learning method evidently causes some 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.

Challenge based learning is a concept adopted by the authors of this paper to indicate the fact that the subject of this paper is not only an implementation of problem based learning in engineering education in a form of product development project. Instead the Suvi-project is a research and development project with a challenge and a possibility to test one's ideas and results against other project teams who start from the same level of knowledge with the same tools and means to accomplish their goal. Thus the name challenge based learning. Based on our five year experience organising the project and on the results of our previous studies of problem based learning in engineering education we have concluded that the challenge within the subject of the project increases the motivation and dedication remarkably. [1][3]

Project Guidelines

The CBL project has been organized five times since academic year 2004-2005. The project has evolved during these years and in the recent project in academic year 2008-2009 the project teams' goal was to design, implement, and test a remote controlled robot with some given basic electronic components and to attend to a competition with their robot at the end of spring semester. The subject was chosen based on results of the previous study where remote controlled robot was found to be a motivating and challenging subject. [3]

Students were divided into project teams by lecturers and each team had 3-4 members. 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 2009 where the topic and the guidelines for the project were presented. The presence of each team member was mandatory. Two weeks after the kick-off meeting project teams attended a tutoring meeting where the teams had an opportunity to ask questions regarding the project plan and the fundamental designing problems were outlined.

Progress of student projects was monitored by several project meetings and written project minutes were submitted to a project portfolio which was inspected by teachers. After three weeks of project work, teams were required to make a 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
- technical documentation

Each team submitted their documentation to a project portfolio which will be submitted for evaluation at the end of the project. This time we decided to use a paper portfolio instead of a Web-based portal since the electronic services were under development when the project was started.

Evaluation

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 the courses are individually graded, 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 800 cm acceleration track. The competitors are sorted based on the times.

2. Robot Wrestling: The goal is to disable the opponent robot or push it outside the ring.

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. We estimate that in our case each teacher spent about one extra hour per student more than in traditional “lectures and laboratories” type course. However, when the project was implemented the first time, the planning and managing the project took at least twice the time.

One very important resource on the design part was that one of the authors, Mr. Anssi Ikonen, did his pedagogical research [1] as a part of vocational teacher education program, which is compulsory for a teaching tenure in a Finnish polytechnic.

Students Comments

Since this is a study of on-going project, the latest results will be available by the end of May 2009 and will be presented in the 5th International CDIO Conference.

Based on the student feedback from our previous study [1][3], we can say that a multidisciplinary project is a motivating method for learning. The teams evidently learned project and team working skills and gained knowledge and experiences on embedded systems design process. Some of the project teams faced problems beyond their engineering capabilities. 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

This was the 5th 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 robots.

Discussion

Based on our short, five 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. Additionally the challenging nature of the topic, a remote controlled robot and a competition against other project teams increase students' motivation and dedication to the project. 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 2008-2009 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 information flow between the teachers 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 and 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 do not affect on the problem solving process by providing solutions.

Get tools to help maintaining the project and test the usability before purchasing it. There are several learning environments commercially available, 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 avoiding too general topics. It is not recommended to let the students to make up their own ideas, simply because these 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 a 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.

In future, we are going to continue the series of Suvi-projects with some modifications. Due to merger of Helsinki University of Applied Sciences and EVTEK University of Applied Sciences, the academic syllabus of information technology students changed substantially. The students will be selecting their majoring option half year earlier as they did on EVTEK University of Applied Sciences. Practically, this means that there will be fewer students to attend the combined project. However, since they already have selected their majoring option, they are most likely well motivated to learn Embedded Engineering project skills.

Good practices learned from the Suvi-projects are going to be used in other CDIO learning projects in Helsinki Metropolia University of Applied Sciences. Some parts of it were adopted in the first year students' Introductory Project during academic year. We also have plans to expand the general idea of our concept to International Summer School on Embedded Digital Signal Processing, which will be organized together with three other European Universities of Applied Sciences.

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