Problem Based Learning in Microelectronics: Approach, Experience, Examples

Andreas Pester, Erwin Ofner, Herbert Grünbacher, Andrew Moore

School of Electronics, Carinthia Tech Institute, Europastrasse 4, Villach, Austria
Email: {a.pester, e.ofner, hg, a.moore}@cti.ac.at

Abstract - Problem based learning (PBL) as a total approach to learning has been widely applied in various disciplines, including engineering and was successfully introduced at Carinthia Tech Institute (CTI) three years ago. Two-semester projects focusing on core areas of electronics and accompanied by both electronic courses and assistance in project management are offered to students. Project topics, selected by students, must be practical, meet curriculum objectives, and have industrial relevance. In addition to the technical skills learned in the process of completing the project, students learn how to work as a team, develop self-directed learning strategies, manage time and resources, and present the results of their work in oral and written form.

1 Introduction

Problem based learning is usually understood as a learning environment, that facilitates the acquisition of various skills. Central to PBL is the concept of student-centered learning. The University Maastrich, which has 25 years of experience in PBL, describes the objectives of this method as, " to overcome the various drawbacks of traditional instruction methods, where students have a passive role during lectures, …, disciplines are not integrated, students are not prepared for continuing their own education after graduation, and most importantly, graduates are not trained to apply what they have learned in practice. " (See: 1). Other authors emphasize, "… the traditional curriculum does not sufficiently foster thinking and critical analysis, …students and staff have no real focus or understanding of the overall objectives of the curriculum." (See 2)

Developing the new curriculum for electronic students at Carinthia Tech Institute in 1999, we came to similar conclusions about the shortcomings of the traditional teaching method for engineering students, particularly in the second phase of the curriculum. It was decided that the main focus of the fifth and sixth semester would be to undertake one large project. Students working in teams of three to five spend typically about one or two days per week for one year working on “simulated” projects. They learn how to handle problems found in real-world projects. Students work on all phases of a project from specification to the final product.

During the fourth semester a list of projects is proposed. Students select topics of interest and form their own teams. All project topics are within the focus areas of the electronics curriculum and have a high degree of industrial relevance with some projects actively supported by industry. In addition to the purely technical work, students need to generate specifications, establish project plans, allocate resources, monitor development costs, hold project meetings, give technical presentations, and write reports. Accompanying courses are primarily selected by the advisors and are relevant to the technical content of the project. The students may select additional courses according to their individual interests.

2 The idea of PBL at CTI

PBL at Carinthia Tech Institute is based on the following principles:

- Electronic-relevant themes and freedom of choice

Project themes are suggested by professors of the electronics department and are usually part of the institutes’ research work in electronics or in relevant subjects: a test chip for the automotive industry, the optimization of filters and their implementation in silicon, or the development of teaching-aids, for example. Project proposals are discussed in the middle of the fourth semester. Students can choose one of the suggested proposals or propose one of their own. If students propose their own project, professors qualify the proposal based on the curriculum objectives. Students, who decide not to pursue a project, must attend regular lectures. Central to applying the principles of PBL in project work at CTI is the belief that freedom of choice results in greater interest and therefore increased motivation.

- Group work

Project teams are comprised of three to five students, which is typical of team sizes in the 'real-world'. Team spirit is fostered through collaborative learning/ activities, which increase efficiency and ensure its timely completion. The team leader is responsible for the overall organization of the group; from setting objectives, developing a project schedule and generating specifications to budgeting resources and reporting regularly on the groups progress. The professor does not teach in the traditional manner, but acts as a facilitator; guiding students, answering questions, acting as a resource and easing problems. Managing the project group is left to the project leader. Assessing project work requires considerable thought and planning even before the projects are begun. There is no 'off-the-shelf' assessment tool or standard for evaluating project work. Therefore, once all partners had decided on project outcomes; that is, what the goals and objectives of the projects were, the criteria by which they would be assessed was determined. Although there was common core assessment across the projects, the particular demands of a given project influenced, to some extent, the choice of criteria. In the end, the partners agreed that two main areas would be assessed: team work and individual work. Taking a page from quality management methods, this made it easier for the students to understand their grades and simplified the marking scheme.

- Accompanying courses

The courses that accompany project work (14 hours per week) are selected by the project supervisor. They complement and support both the technical content of the project and the soft skills practiced. Additionally, students can choose topics of interest from the syllabus, adding six hours per week. In our case, subjects could be, for example, special methods in mathematics and control theory, informatics, simulation techniques, chip design, and others. If students have course suggestions that fit with other subjects offered by the department, but they are not scheduled for these semesters, they may be taught by special arrangement.

- Soft skills

In addition to courses connected with the topic of the project, students acquire and practice soft-skills needed as a part of the project; for example, project management, time management, presentation techniques, technical documentation and some areas of business administration. Practicing these skills is a necessary part of the overall student project experience. Course leaders (tutors) can be members of the faculty or in some cases outside experts are called in. Students are expected to present the results of their project twice after the fifth and after the sixth semester to a broader audience. This is a part of the project assessment.

- Coaching

As mentioned earlier in this paper, the professors are not the project leaders, but rather facilitators or coaches. Their role at the beginning of the project is to introduce the project content, help generate the project specification, and to plan the whole project. They are also technical consultants should problems arise. Before the project starts, they do cost estimates and establish relationships with industry. A few weeks into the project a student is elected to lead the group. If it becomes necessary the students can elect a new leader during the project

- Project evaluation

A necessary part of the projects is the project evaluation. There are two evaluations provided: one during the project before choosing the concrete project topics and one at the end. The first evaluation covers technical content, teaching objectives and feasibility of the suggested topics and is carried out without students present (although sometimes with industrial partners). The final evaluation is an open self-evaluation, where not only the project results of the students are assessed, but also the project management of all projects as a whole. This also includes the feasibility of the project under real conditions.

3 Experience using PBL at CTI

CTI's three years' experience with a PBL approach is encouraging. Virtually all (99%) of CTI`s electronic students claim they prefer this approach to learning over the traditional method applied during the first two years of the curriculum. Major benefits are:

- Deeper understanding - the technical complexity of development work is mastered
- Springboard knowledge - previous knowledge acts as a basis for problem solving and insight into new information
- Interdisciplinary approach – knowledge from various disciplines is needed to solve complex problems
- Project management skills – practically applied information learned in accompanying project management course

4 An Example of PBL – The Development of a bit-serial FIR Filter

The goal of the project was the development of procedures to support the design of hard-wired bit-serial FIR filters for VLSI as well as the design of a demonstrator circuit (See 3). Such filters are often used in mixed-signal integrated circuits. The bit-serial approach is of particular interest for reaching small silicon areas.

The student team started the project with basic knowledge in *Digital Systems Design*, *DSP*, *VHDL,* and *Integrated Circuits* and had to study bit-serial implementation techniques for digital filters. Accompanying courses were on

ASIC Design with logic synthesis, *FPGA Design,* and *IC Design*. One of the students served as project manager and was responsible for scheduling, reporting project progress, presentating, and organizing regular project meetings with the advisory board. The board consisted of four advisors with overlapping areas of expertise. In addition to acquiring technical knowledge in microelectronics, the student team gained valuable experience in project management and teamwork.

Student team motivation was very high and a total of over 2200 hours of working time was reported. Activity was highest after the long start-up phase and declined in the last third of the academic year. The fact that detailed project goals and specifications had to be formulated by the team at the start of the project resulted in a slow start, while time conflicts with accompanying courses reduced activities towards the end. Tighter specifications, improved coordination of accompanying courses, and more assistance for project management tasks will reduce organizational problems and increase efficiency in future student projects.

5 Conclusions

The third year student projects in Electronics deliver attractive results both in terms of technical achievement as well as experience in applying problem-based learning strategies. In several cases project results lead to further research and development activities.

Acknowledgments

The authors acknowledge the valuable and enthusiastic contribution of the student team: S. Albel; M. Burgstaller; A. Hradetzky; A. Schilke and A. Schusser, as well as the advisors M. Castelli and M. Ley.

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