Towards real-time systems education with PBL

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Abstract

In this report the plans for the spring term of the third year of the Information Technology *M.Sc. program in engineering at Linkping university is described. The adopted pedagogical form is inspired by the idea of Problem-Based Learning (PBL). Major ingredients in PBL are self-directed learning, and group discussions based on realistic examples. This induces a higher degree of integration among topics than is usual in traditional curricula. The spring term which is reported upon is organized around four themes of study integrating the traditional topics of concurrent programming, operating systems, real-time systems, automatic control, discrete time circuit theory, linear algebra, transform theory, and ethics. A team of several teachers from four departments of the university are involved in the implementation of this term's education.*

1 Background

Education in computer science and engineering in Sweden has been confronted with a number of challenges in the last decade. There are clear signals from the employers of computer graduates about the need for people who can face a real life problem in its entirety, and solve the problem through interaction with people from other disciplines (economists, mechanical engineers, psychologists, etc.), rather than being specialists in narrow fields or specific programming paradigms. There is also another need, becoming increasingly pronounced, which is due to the high rate of technological development in the area. That is, the call for a major goal of education being "learning to learn". A third problem, specific to the computer science and engineering educations, is the decrease in the interest of female students to choose these topics – the current levels being about 5-10% in Sweden.

In autumn 1996 a new 4.5 year educational program in computer engineering was started at Linkping university. The program aims to be an improvement over the existing programs in the above sense. The additional competence of the students in the *Information Technology* Master of Engineering program [1] is expected to arise from

- higher competence in communication and team work
- better understanding of the relationship of (traditionally) isolated topics and their integration in a real world situation
- more knowledge of humanities topics interacting with and affecting the role of the computer engineer
- the program being more attractive to female students and therefore countering the current extreme inbalance

Inspired by the *Problem-Based Learning* (PBL) pedagogical idea, a new set up totally different from the existing programs in computer education was selected.

2 PBL in an engineering setting

There are several implementations of PBL in non-technical curricula both in Sweden and elsewhere [2, 3]. We distinguish, however, between the project-based form of education common in technical education programs, and the PBL version described below. The main difference being that there is usually no "product" or result expected from the group work within PBL[1].

To describe the set up briefly, there are much fewer lectures (around half of the nominal lectures in traditional courses), and much more student group activities. Every term of study consists of a number of themes, with little or no overlap in time (i.e. no parallel courses). Each theme, however integrates a number (2 or 3) of topics normally taught in separate traditional courses.

There are regular group meetings with 6-8 students in each group and a specially educated tutor. The students' role in the group meetings is to define personal and group learning goals, given the predefined high level goals of each theme of study. The role of the tutor in this group is to act as an observer and coordinator of the group process so that all individuals achieve a high level of learning. There is no technical intervention by the tutor in the content of the discussions.

The role of the main teachers of the theme (examinators) is to define the goals and scope, the literature list, and provide a number of realistic problem scenarios (cases) to initiate the above group discussions, so that the search for and achievement of lower level learning goals is facilitated.

The whole educational program comprises 180 credit points. The parts which are covered here are the 120 points for years 1 to 3, prior to the forth year in which a specialisation profile is chosen and a final thesis is written.

The six terms designed so far cover integration of topics by teachers from different departments: mathematics, computer science, electrical engineering, physics and humanities. This report describes the design of the sixth term (the spring term in the third year) which includes real-time programming and automatic control. The author is, together with Dr. Inger Klein from the electrical engineering department, responsible for the design and administration of the team work leading to the detailed implementation.

The five earlier terms have been devoted to the themes ranging over introduction to computer science, mathematical tools, models in physics, electromagnetism, mathematical models, philosophy of science, programming, algorithms and optimization, design and construction. Moreover, there is a large project over the whole of the fifth term incorporating compiler construction and project management in interaction with the economics and psychology students. Also throughout the program there is a "communication" streak in which, among others, verbal and documentational communication is learnt in the context of the main themes of study.

[1]except for formulation of learning goals – compare with the result of a project-based activity which is usually an artifact or a piece of code.

3 Real-time systems and automatic control

The sixth term of study is currently organized around four themes. There are some details which have to be fixed prior to the first operation of this term in spring 1998, but the overall structure is already determined. The contents of the various themes, which provide 18 credit points altogether, can be summarized as follows.

- Theme 1: Fundamentals of multi-programming and operating systems. Concurrent programming, operating systems as soft real-time systems, other operating systems topics such as memory management, file systems, security, resource management and I/O interface.
- Theme 2: Hard real-time systems with emphasis on process control applications. Mathematical models for simple dynamic systems and their time-discrete approximations, feedback, scheduling for real-time systems, program development for automatic control applications.
- Theme 3: Linear systems with feedback. Linear time-invariant systems described by linear differential equations with constant coefficients, analysis of the solutions either as functions of time or as transfer functions over complex frequency variables, Laplace tranform and linear algebra, different notions of stability, observability, controllability.
- Theme 4: Ethics in engineering. Normative ethical theories and principles, technical development and morality, ethical criteria for choice of techniques, aspects in the engineers career, case studies with ethical issues in technical settings.

The organization and the real-world cases forming the basis of the group sessions are planned as follows. There will be a number of introductory lectures about ethical theories at the beginning of the term. The students are expected to try to identify ethical issues during the first three themes in order to prepare further analysis in the last theme. Other than that, lectures related to each theme's topics are provided during that theme, and supplemented by resource sessions where student questions are answered.

The group studies dealing with concurrency and operating systems are based upon usual scenarios and classic examples from this area (the details are not worked out yet). This will be complemented by practical individual programming using three exercises from Berkeley's Nachos educational operating system. To illustrate the techniques for deadlock avoidance we plan an exercise using the department's model train laboratory (also used in traditional courses). The exercise consists of adding an implementation of the banker's algorithm for allocation of rail segments to trains.

At the beginning of the second theme the students are introduced to a real application: a fine measurement robot for tool precision developed at a Swedish company. This application will be used in themes 2 and 3. Robot arm movements in three dimentions using three servo motors form the basis of the group discussions in the second theme. There will be a study of the stability phenomenon in a physical setting using an actual motor control exercise at the electrical engineering laboratory. This is followed by discussions around scheduling methods for real-time systems, in which the three servo processes together with I/O processes, with or without an on-line diagnosis will be studied. This exercise may even serve to illustrate the ethical issues connected wih safety of real-time systems and the "costs" for achieving safety. For the implementation exercises in this theme we are currently considering the choice between modelling and code-generation tools like Matlab or MatrixX and other scheduling and simulation environments. The ability to choose different scheduling policies and see the effect of the policy in the same example will highly influence this choice.

In the third theme transform theory, linear algebra and the theory behind automatic control will be integrated. The theme is of a theoretical nature but some exercises in Matlab are envisaged. The group discussions leading to definition of learning goals are however, expected to be focused around aspects of control fetched from the same robot application.

The fourth theme on ethics will be somewhat influenced by ethical issues appearing in safety-critical system development, computer security and connections to the operating systems theme. The choice of cases (scenarios) for group discussions is still open, but is expected to be an interesting exercise in multidicsiplinary curriculum design across two faculties.

4 Current state and future works

As mentioned above there are some detailed aspects of implementation of the sixth term left to be done. This report should therefore be seen as a description of work in progress. Once the program is implemented and run over a number of years, however, the benefits and drawbacks of the redesign in the PBL setting will certainly provide an interesting topic for further study. So far the program has had two annual intakes. Although too early to evaluate the program in its entirety, some facts can already be observed. Of the 37 and 35 students reading in the first and second year respectively, 14 and 17 are female students.

References

[1] See the web site for Swedish Council for the Renewal of Undergraduate Education, under ongoing projects:
`www.hgur.se/general/projects/hems.htm`.

[2] L. Wilkerson and W. Gijselaers (Eds.). Bringing Problem-Based Learning to Higher Education. Theory and Practice. San Fransisco, Jossey Bass Publishers, 1996.

[3] L.D. Distlehorst and R. Hobbs. Comparisons of Students in a Problem-Based Learning Curriculum and and a Standard Curriculum. Three Years of Data.. In *Proc. of the 3rd Education Innovation in Economics and Business Conference*, Florida, December 1996.