COMPUTER SUPPORTED LEARNING AND ASSESSMENT IN ENGINEERING EDUCATION

Svante Gunnarsson and Inger Klein
Department of Electrical Engineering
Linköping University, Sweden
svante@isy.liu.se

Abstract
Some aspects of computer support in learning and assessment in engineering education are discussed. It is emphasized that the use of computer support, like e.g. simulations, computations, visualizations, has to be closely connected to the formulation of the expected learning outcomes and the assessment methods. Some examples of computer support are related to the CDIO Syllabus. Some experiences from more that two decades of computer aided learning and assessment within the Division of Automatic Control at Linköping University are presented.

Keywords: Computer support, CDIO Syllabus, learning outcomes, assessment

Introduction

The computer is a standard tool in all areas of engineering, and it is used for various types of computations, data processing, simulation, visualization, CAD, etc. Therefore it is, and has been for many of years, an integrated part in many courses in engineering education. Numerous examples of various kinds of computer support in engineering education have been presented in journals and at conferences, but it is not the ambition to give an overview here.

Even though this is an established part of engineering education it is still motivated to discuss how and why computer support is used. It is the authors' experience that many of the examples of computer supported learning activities that have been proposed lack the connection to the overall course goals and to the assessment of the expected learning outcomes. This becomes even more apparent in the process of formulating expected learning outcomes for courses and programs, by for example using the CDIO Syllabus, see [1], as background. In this process it is necessary to consider how the various learning activities support the desired learning outcomes of the course and how they are connected to the assessment methods. The purpose of the paper is to discuss various aspects of these issues and how they can be considered in a CDIO framework. The purpose is also to present some examples of how computer support has been integrated in the assessment process within a number of courses given by the Division of Automatic Control at Linköping University.

Connections to the CDIO Syllabus

It can first be observed that the use of computers is hardly ever mentioned explicitly in the CDIO Syllabus. One explanation of this fact is that the computer is such an obvious tool in engineering work that it does not need particular attention. Even though computer support is not mentioned explicitly it is meaningful to discuss which topics in the CDIO Syllabus that have the closest connection to computer support. Recall the sections of the CDIO Syllabus

1. Technical knowledge and reasoning
2. Personal and professional skills and attributes
3. Interpersonal skills: Teamwork and communication
4. Conceiving, designing, implementing and operating systems in the enterprise and societal context

The Syllabus represents a list of desired knowledge and skills of an engineer, but even though it is very detailed it is still possible to make different interpretations of what these knowledge and skills means. The sections and subsections that have the closest connections to the kind of computer support considered here, i.e. simulation, data processing, computations, etc, are Section 1, Sections 2.1 – 2.2 (Engineering reasoning and problem solving, Experimentation and knowledge discovery), and Sections 4.3 – 4.6 (Conceiving and engineering systems, Designing, Implementing, Operating). In the section below we will give some examples of uses of computer support in engineering education and how they are related to the Syllabus, expected learning outcomes and assessment.

Connections to expected learning outcomes and assessment

To start the discussion let us consider the following examples of computer supported learning activities:

- To use a software tool for symbolic calculations to avoid tedious calculations by hand.
- To use visualization to illustrate abstract phenomena in e.g. mathematics or physics.

These two examples, which are strongly related to Section 1.1 of the Syllabus, are both good examples of learning activities where computer support can be used, but they also lead to issues concerning how the learning activity is linked to the expected learning outcomes of the course and the assessment. For example, to have created a visualization of a complicated phenomenon in e.g. electromagnetic field theory doesn’t necessarily help when solving a conventional examination problem by hand using methods from vector calculus. In can hopefully help the overall understanding and act as inspiration and motivation for the topic in general, but to clearly connect it to the learning outcomes some additional assessment, using the visualization tool, has to be included.

Another aspect of computer supported learning activities is the role of the course. For example, to use a computer algebra tool to carry out symbolic manipulations can have a different role in a mathematics course compared to a design-build course. In the math course the role of the activity depends on the expected learning outcomes and the examination. The activity is probably of less value if the examination problems are supposed to be carried out by hand in a more traditional way. To require that a student is able to solve a problem of a particular type both by hand and using a software tool implies that the overall amount of required knowledge and skills of the course will increase. One way out of this situation could be to require that the student is able to treat "simple" problems (in case this can be defined) by hand and more complex problems using computer support. Another solution is to reduce the requirements concerning the skills to do calculations by hand. Given a fixed volume, e.g. number of hours, of a course there is however a sensitive trade off determining how much of the calculations done by hand, that can be replaced. In many subjects it is important to have done some calculations by hand in order understand the results from the software tool.

One issue that also arises when discussing the use of computer support is to separate subject knowledge from tool knowledge in areas that require extensive computer support. Modern software tools are powerful and can solve very complex problem, but this also means that they require some training before they can be used efficiently. In the formulation of expected learning outcomes it is important to distinguish learning objectives that are related to the subject itself and objectives that are related to the tool in use. It is natural to expect that an engineer has knowledge about the state-of-the-art tool in his/her subject, and it is therefore realistic to require that some kind of tool knowledge is stated in the learning outcomes of the program. These learning outcomes should, as far as possible, be distinguished from those related to the subject.

There are also subjects that hardly would exist without computer support. Examples of subjects of this character are digital signal processing, e.g. FFT-analysis, and various types of image processing. This means that a statement of a specific expected learning outcome implicitly means that it is supposed to be carried out using computer support.

Simulations of different types also play an important role in engineering work and engineering education. By simulations we here mean to carry out "experiments" using a mathematical model of a system, instead of carrying out experiments using the real system. A system can in this framework be of many different kinds, depending on the subject and the purpose, but it normally represents a well defined part of the real world that we have particular interest in. There are many reasons for carrying out simulations like, for example, that it is too expensive and dangerous to carry out experiments on the real system, that the real system is not yet built, etc. Also here the computer support can be used in different ways and with different purposes. One example is to simulate the motion of rigid bodies under the influence of forces and torques. It is then a huge difference if the expected learning outcome is that the student is expected to be able to derive and solve the necessary differential equations by hand, or if the objective is to be able to specify the properties of the problem in a simulation tool and let the tool derive and solve the corresponding equation.

Another use of simulation is to see it as a complement to, or in some cases replace, laboratory exercises. It is important to stress that laboratory exercises using real systems and processes play a vital role in engineering education and cannot be replaced by simulation. Simulation can however be used as a complement to laboratory exercises. Using simulation the principal properties of a system can be illustrated under idealized conditions. By comparing the outcomes from simulations to the outcomes from experiments using a real system the difference between the idealized and real conditions can be illustrated and lead to discussions concerning e.g. modeling methods, model simplification, model uncertainties, etc.

A third use of simulation is to use it as an intermediate step in the design-build-test process. A simple example is design an electronic circuit given some specification, simulate the circuit in order to evaluate its properties, implement it in hardware, and finally test it against the specification. Such a process, in which simulation plays an important role, is found in almost all areas of engineering. This type of computer support is closely connected to Sections 4.3 – 4.6 in the Syllabus, and in particular in Section 4.4 some explicit references to design tools are given.

Experiences from computer supported education in Automatic Control

To complement the more general discussion above this section will present some experiences from computer supported education in Automatic Control at Linköping University. The Division of Automatic Control gives courses in Automatic Control, Control Theory, Modeling and Simulation, Industrial Control, Digital Signal Processing, and a number of other courses The format of the different courses are rather similar and the activities in a course can roughly be separated in the following five parts:

- Lectures
- Problem solving sessions
- Laboratory sessions
- Student work
- Examination

The lectures, typically 12 times 2 hours, are normally given by professors or associate professors, and the problem solving sessions, typically 12 times 2 hours, are held by PhD students. Both the lectures and the problem solving sessions are voluntary, but the attendance is normally rather high. The laboratory sessions are compulsory, and a course typically includes 3 laboratory exercises, where each session lasts 4 hours. The point ``Student work" represents the time and effort spent by the students to prepare for lectures, problem solving sessions, lab sessions and the exam. Finally, the exam, which normally lasts for 4 hours, was traditionally of ``pen and paper" type. Using the different course components defined above we shall now review the different phases of development of computer support during the last two and a half decades

The mainframe phase

In this first phase the computer support was introduced in one (or several) of the laboratory sessions. See Figure 1. Using graphical terminals attached to a mainframe computer, different aspects of control were studied. The software included both specially designed software and some commercial software. Using these tools it was possible carry out simulations and to show the results graphically, draw Bode diagrams, etc. This meant a lot for the intuitive understanding of the subject in terms of e.g. the relationships between time and frequency domain responses, etc. Due to the limited resources in terms of graphical terminals the computer laboratory was however only available for the student during the scheduled laboratory session, which meant that the student spent less than five percent of the time using computer support.

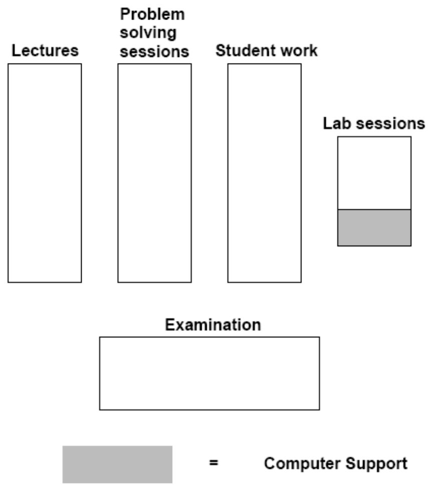

Figure 1. The mainframe phase

The PC/Workstation phase

The next phase was caused by the advent of the PC and the software MATLAB. This phase was entered during the second half of the eighties and the development was driven by two important factors. First, due to the flexibility of the software more aspects of the subject could now be studied. All relevant signals and diagrams could be computed and plotted very easily. Second, due to the decrease in price for a reasonably powerful computer with graphical capabilities more work places could be arranged. This lead to the introduction of computer aided problem solving sessions. See Figure 2.

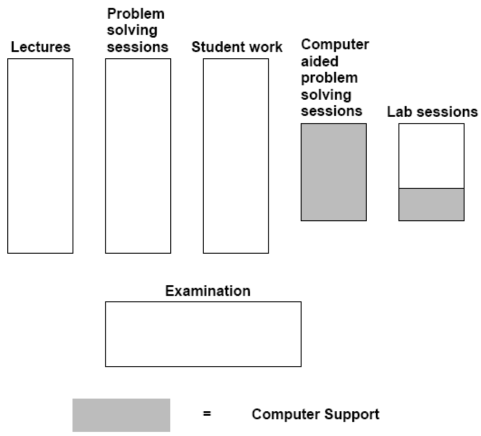

Figure 2 The first step in the PC/Workstation phase

One idea behind this step was to keep the group and the teaching assistant together and simply move the problem session to a computer lab. Specially designed instruction manuals were developed for the computer aided problem solving sessions, and these manuals contained introductions to the software combined with a description of how the different topics in a course could be illustrated using the computer. The main improvements obtained when entering this phase were that more aspects of the subject could be illustrated and that more time could be spent studying the subject using the computer.

Thanks to the steady decrease in prize and increase in performance the resources in terms of rooms and computers could be increased. With this improvement in computer resources it became realistic to consider examination carried out using the computer. See Figure 3. This was a very important step, since the properties of the exam have a big effect on how the students study the subject. It does not only affect the exam itself, but also the preparation before the exam. Computer supported examination was first implemented in the course in Digital Signal Processing in 1994 and has been used since then. It has later also been introduced in courses like Control Theory, Industrial Control, and Linear Feedback Systems. The format of a computer supported examination is similar to conventional ones, with the difference that a computer with e.g. Matlab is an available tool. The main reason for not having introduced computer supported examination in all courses is lack of resources. The infrastructure allows examinations with up to ninety students, but about twice that volume would be necessary in the courses with the largest number of participants. In the courses where the traditional examination still is used the computer supported part of the learning activities are assessed during one of the laboratory exercises.

At the same time as the computer supported examination was introduced the distinction between computer supported and traditional problem solving sessions was removed. The course just contains a number of problem solving sessions, where some or all of the sessions are carried out in a computer lab.

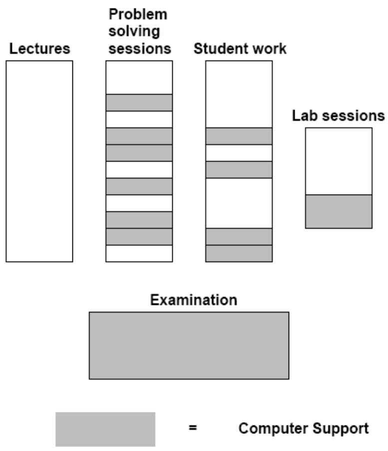

Figure 3 The second step in PC/Workstation phase

Due to the increased number of computers it was possible to let the students use the computer labs more than at the scheduled occasions. This is necessary in order to give the student possibilities to prepare for the exam. Gradually also the number of students having heir own computer has increased. These two factors have contributed to an increase in the time spent by the student using the computer in the preparation for problem solving sessions, lab sessions and the exam.

The laptop phase

Since a number of years the technical development has entered the laptop phase, and most students have their own laptop computer, but it is not yet required that every student has to have one. A difference, compared to the step between the two previous phases, is that the infrastructure that was built up in the previous phase is maintained. The department still has a number of laboratories with computers that are used for computer supported problem solving sessions, examinations, and other learning activities. The largest use of the impact of the use of laptops is found within the part denoted Student Work, since the laptops make the students independent of time and space when carrying out various types of projects and assignments.

Experiences from computer supported examination

A major step in the use of computer supported education was taken by the introduction of the computer aided examination. Since the character of the assessment has a big impact on the activities of the student the introduction of computer aided exams implies a rather fundamental change of the studies. The format of the exam is the same as before, and the big difference is that the students are sitting at a computer while the examination is carried out. The student decides if a problem is easiest solved by using the computer or if calculations by hand are more suitable. Manuals for the different software packages are available. With the computer available at the exam it is now possible to give problems of a type that is unrealistic to solve without the computer. We shall give two examples of such problems, where one example is from Digital Signal Processing and the second is from Control Theory.

Example 1: The file *data1.mat* contains a signal which has been sampled with sampling frequency 100 Hz. The signal contains three sinusoids hidden in noise. Find the frequencies of the three sinusoids.

First it can be noted that such a problem would be totally unrealistic to handle without a computer since it may require several thousands of operations. Second, such a problem in fact tests the student’s ability to use e.g. FFT-analysis and additional operations like windowing or zero-padding. In this way more real engineering like problems can be formulated.

Example 2: A linearized state space model of an inverted pendulum is defined by the matrices A, B and C, and they can be found on the file *data2.mat*. Assume that all states can be measured and design a state feedback such that the system is stabilized and that pendulum angle is less than 0.1 degrees after two seconds provided that the initial angel is ten degrees.

Problems of this type are more realistic than problems that can be given when only a pocket calculator is available. In general one finds that problems where the emphasis is on routine calculations are less meaningful to give, while problems that are evaluating the understanding of the subject on a higher level now are possible. Looking at traditional exams it is easy to find examples that are not meaningful to give any more, having the computer available

As a part of the Bologna process all courses have gone through the process of formulating and/or revising the expected learning outcomes in order to provide a much more explicit formulation of what is expected from the students in terms of knowledge and skills. This implies that also the courses using a large amount of computer and computer supported examination have gone thorough this process. In most of these courses it is therefore stated explicitly that it is a course goal to be able to use modern software for solving the problems that are covered in the course.

Conclusions

Some aspects of computer supported engineering education have been discussed. We have stressed that it is important to have clear links between the computer supported learning activities, the expected learning outcome and the examination. Some examples and experiences from computer supported control education and examination in Automatic Control at Linköping University have been presented.

References

[1] The CDIO Syllabus. Available at www.cdio.org

Biographical Information

Svante Gunnarsson is Professor in Automatic Control and Chairman of the Program Board for Electrical Engineering, Physics and Mathematics at Linköping University, Sweden. His main research interests are modeling, system identification, and control in robotics.

Inger Klein is Associate Professor in Automatic Control and Vice Chairman of the Program Board for Computer Engineering and Media Technology at Linköping University, Sweden. Her main research interests are discrete event systems and model based diagnosis.

Corresponding author
Professor Svante Gunnarsson
Department of Electrical Engineering
Linköping University
SE-58183 Linköping
Sweden

Tel: +46-13-281747
Fax: +46-13-282622
svante@isy.liu.se