The Model Railroad Project as an Inspiring Platform for Microelectronics Education

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Abstract—**This paper argues that on the one hand, e-learning tools provide excellent learning options to the students but that on the other hand, e-learning tools might also be the cause of an increasing gap between theoretical knowledge and its practical applicability. This paper reports on the experiences the authors have made with a very old teaching concept, the model railroad. The three main advantages of this project are: (1) teaching can be done on all levels ranging from simple wiring to high-level programming of graphical user interfaces, which all embed the teaching of micro electronics; (2) the subprojects of the model railroad often demand for collaborative work in small teams; and (3) the participating students experience and live soft skills rather than learning about them in a seminar.**

Keywords - problem-based learning, practical learning; complex tasks, model railroad as an example

I. Introduction

During the last twenty years, teaching has observed some major changes in how it is done: Due to the improvements in hard- and software, e-learning has become omnipresent in almost all disciplines, including engineering of various sorts. Frequently expressed supports for e-learning include: e-learning can be used anywhere and anytime; the link between teachers and learners can be loosened, i.e., they can work asynchronously in time; and certain tools, such as simulation packages, provide the learner with technically difficult insights in new ways [1].

In addition to the actual teaching content, automated quizzes and animated learning material can support the learners during their preparation for the exams. In this e-learning setup, the examination grades increase, even though the direct interaction between teachers and learners might decrease.

Based on the achievements of e-learning, most research activities focus on developing new and/or improving existing e-learning tools. However, in light of all these results, the authors of this paper have also experienced certain problems with e-learning-based education: the gap between *theoretically* learned concepts and *practically* applicable skills are *growing*. In other words, even though the students are able to precisely repeat the acquired knowledge on a *theoretical* level, they have more and more difficulties to apply it to technical (real-world) problems. A possible reason for this case might be the inconsistent use of didactical and pedagogical models for developing e-learning environments [2]. Another cause is the loss of sensuous experiences by using e-learning. The involving of several of senses can increase learning effects [3]. The approach of activity learning argued learning environments in which learners can learn by discovering and experimenting [4].

Knowledge that cannot be applied in practice degrades to a set of meaningless symbols, and is known as *tacit knowledge* in the literature [5]. Its existence in engineering sciences might be quite surprising for many readers, since engineering sciences are on physical entities by their very nature. The authors of this paper have observed that not only the teachers but also the students realize that they have collected a lot of practically non-applicable knowledge. This development has severe consequences for many students: eagerness, motivation, and enthusiasm are progressively substituted by laziness, frustration, and boredom.

To the authors of this paper, *motivation* is *the* key factor for any successful learning attempt. In order to provide more motivation to the students, the authors have started the model railroad project at the Institute of Applied Microelectronics and Computer Engineering. The intention of the model railroad project is to support activity learning by using several senses. The Model Railroad project provides a platform for problem-based learning (a very accepted and in medicine education current learning method, based on authentic and complex tasks) [6], blended learning (a mixed learning method between distance and attendance learning) [7] and discovery learning (a student centered learning method, in which students get the chance to discover and solve problems by their own) [8]. The project's physical setup is described in Section 2.

Many readers might associate a model railroad with playing and having fun. But besides having fun, i.e., motivation, a model railroad can also serve as a platform for serious teaching; the teaching content ranges from low-level wiring to high-level controllers that are based on field-programmable gate arrays. Section 3 provides an overview of the teaching contents that have already been covered within several subprojects.

Several formal and informal evaluations have analyzed how the model railroad project and its various subprojects affect the students' learning behaviors and outcomes, which are summarized in Section 4. It might be interesting to note that in addition to the pure subjects, the model railroad project also supports other skills, such as working in groups, communication skills, planning and organization, and reflecting learning strategies and learning methods as well as the adequate handling of tools. Finally, Section 5 concludes this paper with a brief discussion, which includes a brief description of future subprojects.

II. THE MODEL RAILROAD PROJECT

The model railroad is intended for the institute's students, which are mainly from the electrical engineering and computer science studies. Therefore, the three major design goals are (technical) functionality, flexibility, and simplicity. Furnishings, such as landscaping, tunnels, bridges, mountains, trees, lakes, cars, etc., which are a main focus of most home-owned model railroads, are less important or not suitable, since they might interfere with the intended technical experiments.

Figure 1. Overview of the model railroad project.

Due to space limitations in the laboratories, the project employs trains and tracks of size N, i.e., a scale of 1:160. The tracks are mounted on a board of 1m x 3m in size. Figure 1 provides a fairly good overview of the model. From the figure, it can also be seen that the model basically consists of two parallel circles, two main railroad stations, several side tracks, as well as an elevated plateau. The very many switches and crossings allow for a large variety of operational alternatives.

In contrast to most privately owned model railroads, the present project has employed a digital control mode of operation by means of the digital command control (DCC) protocol [9]. The digital control has the following advantages: every train can assume its own speed, thus playing is much more fun, and it allows for several exercises with the focus in micro electronics. Furthermore, a digitally controlled model can be connected to a PC, which offers plenty of software exercises.

In addition, the institute currently runs another project, called the model-railroad-in-a-suite-case in which a model railroad is put into a box of about 90cm x 90cm in size. Both projects are very similar with respect to the student work. However, the suite case project also tries to integrate the PC-based control by employing an embedded processor and a touch screen.

Figure 2. The model-railroad-in-a-suite-case.

III. TEACHING SUBJECTS

For the technically oriented reader, it should be obvious that the model railroad can be used as a problem-based learning environment [10] and that it offers exercises on all levels ranging from low-level wiring to high-level controllers. The model railroad project involves the following tasks:

- Simple wiring for providing common ground as well as power supply for all the tracks, trains, and controller boards. The latter have to be connected by wires to the actual switches.
- Since the entire model railroad consists of three physical parts, the project also requires some cross bars, which have to be layouted. These cross bars feature not just simple power supplies but also the communication infrastructure.
- Within this project, the students develop their own switch controller boards. Each controller board

consists of a processor, which handles all the communication to the host PC, and some hardware power drivers. Most students resort to ready-to-use Olimex development boards, but some use complex development boards that are based on field-programmable gate arrays (e.g., Altera Stratix II). The former approach involves just microelectronic basics whereas the latter involves the entire design process, including the usage of VHDL, the integration of a Nios II processor, and the attachment of the power drivers.

- The development of the switch controllers also requires the design and implementation of a suitable communication protocol. This encompasses low-level programming for controlling the output pins as well as the integration of a proper protocol stack, such as RS232, USB, and/or Ethernet.

- The entire model railroad is controlled by a host PC. This PC runs a graphical user interface that is to be developed by the students. Besides ``regular'' C++ programming, this task also involves the design of graphical user interfaces as well as the understanding of usability.

In summary, this project allows for teaching on various levels, below and above micro electronics. Thus, the teaching of micro electronics is not isolated but embedded, which requires the design and implementation of further interfaces. This in turn allows the students to understand the functionality of the entire system.

A further conceptual aspect is that teaching in the context of the model railroad does not happen on one of the layers described above. Rather, the teaching is embedded into small subprojects. Three examples are:

- **Wireless Train Control:** Normally, the digital model trains employ a small digital controller, which receives its commands via the rail tracks. This communication is *very* error prone; two student teams developed two different wireless train controllers. Such a wireless controller is based on a ZigBee communication node, a small controller, and the actual motor controller (H-bridge). Also, these two projects require the entire programming.

- **Step Motor Drive:** As an innovation, one student team has developed a new train drive that is based on a step motor. In comparison to a regular DC motor, a step motor allows a train to go infinitely slow. Because of the differences in technology, this subproject also requires the development of a dedicated power drive.

- **Embedded Touch Screen Control:** In a current project, one student team develops an embedded touch screen control system. In addition to all the task describes above, this subproject requires the integration of a touch screen and its programming. Currently, the students favor an architecture that consists of two Nios II soft core processors that are realized into one field-programmable gate array.

IV. RESULTS: FORMAL AND INFORMAL OBSERVATIONS

The model railroad project is constantly monitored by formal and informal evaluations. The formal evaluations are done by means of a questionnaire [11]. Briefly summarized, the main results are that the students do like the project, and like the rather informal working atmosphere. Although nearly half of the participated students did not expected motivational effects the project might have been on their learning effects, they experienced a very high motivation. Furthermore the students stated the casual contact to the tutor and they were able to identify their own interest by participating in the project. The results of formal questionnaire also show that they were able to fuse theoretical knowledge and practical experiences.

Figure 3. Brainstorming phase: Students discussed the main task and divided it into their subtasks.

The results of informal observation show that the students developed certain soft skills that are highly relevant in engineering jobs. For example, since the tasks are often explained in a rather open form, the students have to first specify and partition the work for all the group members. In the projects that have already been done, the students have done this in a very collaborative way. Furthermore, the students have maintained this collaborative attitude during the duration of the entire subprojects. A second interesting observation is as follows: Since the tasks are not presented in a complete, and instructional step-by-step way, the students have, as can be seen in Figure 3, to develop a plan how to accomplish the given goal. In so doing, they developed rather general problem solving strategies. Even after this project, they are able to handle and solve complex tasks. In contrast to soft skill seminars, the students not just talk about soft skills, they live them during the project.

V. CONCLUSION

This paper has presented the model railroad project as it is been done at the University of Rostock. Currently, the intermediate goal of the current activities is to develop a running system. The authors have observed that due to the nature of this project, the students acquire knowledge on various levels. It might be important to note that the learning tasks are not on separate items but that they are embedded into a broader context, which has major effects on the undergoing learning processes.

In addition to the technical contents, the students also develop several soft skills in an hands-on manner. These soft skills particularly include the collaborative organization of a chosen subproject, and the way, they mutually provide help to each other.

Future research will be going into two different ways. First of all, the project leaders will select subtasks for regular classes, once a first running system is completed. Second, the project will integrate even more educational support. The goal will be to get a better understanding of the underlying learning processes. Once this has been achieved, the second goal will be the development of improved tasks that will be leading to a better education.

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