An overview of research and development activities in technology education carried out at the Faculty of Education at the University of Ljubljana

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Opening Address

ABSTRACT: The study of engineering and science disciplines is not considered to be trendy by the current young population. The low number of freshman students is not the only prevailing problem, even more concerning is the overall poor knowledge and skills of students entering engineering higher education studies. Nevertheless, the technology content of curricula in pre-higher education in Slovenia has been reduced during the last decade, as has also been the case in some other countries. To oppose such negative trends, research focused on teaching methods, strategies and approaches for technology teacher training was initiated. The research findings led to constructivist methods of teaching and learning, which could be used to renew courses on introduction to electrical engineering, electronics, robotics and mechatronics. Practical implementation of these methods also required development of low-cost teaching equipment, such as a microcontroller unit and electronics assembly kits. Using action research methods, the didactic approach was tested, including non-formal teaching situations.

INTRODUCTION

It is a worldwide phenomenon that the study of engineering and science disciplines has become less popular in the past decade. The reasons for declining enrolments in engineering schools include the general employment market for graduates, better salaries for graduates in other areas, diminishing attitudes to engineering in society, etc.

To motivate more pre-university students to study engineering disciplines, universities in several (especially technologically developed) countries have found it essential to organise summer camps, competitions in robotics, after school activities for pre-higher level of education, etc [1-3]. It seems that less effort has been made to improve the knowledge and experience of secondary school teachers on engineering topics. The reason might be that working directly with secondary school students gives short-term results, while the benefits of working with the teachers might only have a long-term benefit.

The major prevailing problems in engineering education in Slovenia go beyond the number of freshman engineering students. More concerning is the fact that the overall level of knowledge and skills of students entering engineering faculties has been significantly lower in the last ten years than previously. One reason is that the total number of candidates currently applying to enter engineering schools is low, so that nearly all candidates, who fulfil the formal entry requirements, have to be accepted. Another reason is the low proportion of pre-university engineering education content in general secondary schools.

How significant could the role of pre-higher education be in changing this tendency by improving the attitude of students towards engineering studies? In Slovenia, technology is a compulsory subject in the curriculum of lower secondary (or middle) schools for pupils aged 12 to 15. Formerly, the subject was based on the design and construction of simplified everyday objects fabricated from paper, wood, plastic and metal. In parallel with such handicraft oriented contents, some topics from mechanical engineering, electrical engineering and electronics were also included. At the age of 13 to 15, pupils choose one of a number of subjects, some of them related to science and engineering (electronics and robotics, electrical engineering, astronomy, ecology, etc). At the upper-secondary education level (age of students in Slovenia is 15 to 19), the most popular schools are general schools called gymnasiums. They include nearly 40% of the cohort, but they offer no engineering oriented subjects.

At the Faculty of Education, University of Ljubljana, there have been many efforts over the past 10 years to improve the skills and knowledge of trainee teachers of technology. In order to improve the competence of teachers to increase the knowledge and interest of their pupils towards science and technology, courses have been modified so that they could become more efficient, contemporary and more applicable to in-service teachers' practice. Some non-formal activities were initialised a couple of years ago by introducing (not only popularising) engineering studies, such as a summer camp on robotics and electronics.

Research related to course development pointed out some key didactic issues - what teaching methods, strategies and approaches (in short: didactic approaches) are the most efficient for the target group of trainee teachers, having a potential for long term impact on pre-higher technology and engineering education? At what level are such didactic approaches applicable directly to students aged 12 to 18? The study of contemporary teaching and learning methods emphasised the following terms - all closely related to constructivist methods in teaching and learning: active, inductive, problem-based, inquire-based, project-oriented, etc [4][5]. In order to implement the quoted methods, courses for the trainee teachers of technology have been developed, as well as for non-formal camps for students aged 12 to 18 years. Since the existing commercial equipment for the courses is not necessarily adequate and often too expensive, these courses were supported by novel state of the art self-designed and produced equipment. The core of the equipment consists of a microcontroller programmable unit, a kit for assembling electronics circuits and mechanisms, a collection of basic sensors and actuators, etc. The development of this equipment was supported by the EU life-long-learning programme Leonardo da Vinci (http://e-prolab.com) [6][7]. The research and development of the associated didactic approach, as well as the supporting equipment followed the so-called methods of action research in teaching and learning [8][9].

In this paper, example courses for trainee teachers of technology at the Faculty of Education, University of Ljubljana, are presented, as well as some efforts and achievements in non-formal education.

OUTLINE OF EXAMPLE COURSES FOR TRAINEE TEACHERS OF TECHNOLOGY EDUCATION

The Faculty of Education, University of Ljubljana, has incorporated technology education into the so-called *two-subject teacher* programme. The programme was re-developed in 2008 according to the norms for the European Higher Education Area, usually called the Bologna Process. The subjects are as follows: biology, home economics, physics, chemistry, mathematics, computing and technology education. When entering the programme, each student needs to choose two subjects from the list, but not all combinations are available. In the last couple of years, the policy of the Faculty of Education has been that technology education should only be available with physics, mathematics and computing.

The majority of graduated students obtain positions in low-secondary (middle) schools (80% of them teaching pupils aged 12 to 15). The rest of the graduates are employed in upper-secondary schools, business, government offices and services. In order to provide a contemporary and applicable programme for technology education, the courses have been modified continuously, both before and after the Bologna process. Outlines of some of the courses that focus on an integrated approach to science and engineering contents are given below.

Introduction to electrical engineering

This course, that introduces some basic principles of electrical engineering, is conducted in the second semester of the technology trainee teachers' programme. However, a course for trainee teachers cannot be arranged in the same way as one in an engineering school. Within the very limited time available for the course (a one-semester course comprising 60 contact hours), students need to be provided with enough practical experience with basic RLC circuits, as well as with electrical machines and devices so that they can later apply the knowledge and skills in their teaching practice. Laboratory exercises are based on low-cost, small electrical devices, such as bicycle dynamos, small DC motors, stepper motors and low power transformers. The laboratory exercises focus on quantitative analyses built around a multi-purpose data acquisition (DAQ) system also used in the school's science laboratory [10][11].

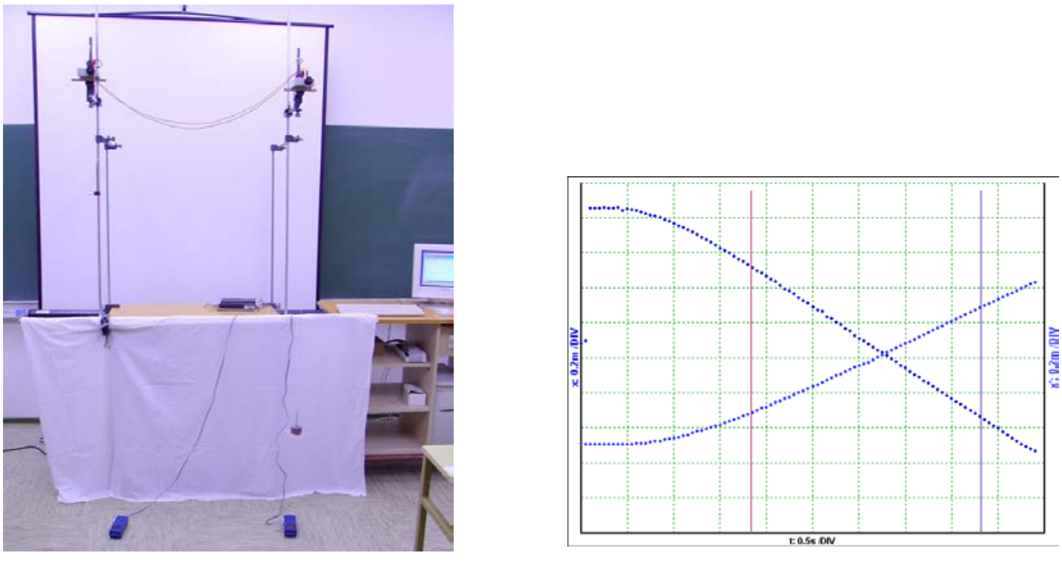

Figure 1: Photograph of the apparatus with electrically coupled DC generator (left) and DC motor (right), typical signals captured from a computer in position of weight driving the generator (negative slope) and in position of weight lifted by the motor (positive slope).

As an example, a laboratory exercise that combines an electrically coupled DC motor with a DC generator is described. The aim of the laboratory exercise is to measure the efficiency of a DC motor combined with the efficiency of a DC generator. A current through a DC motor at a known voltage is sampled by the DAQ system, while the motor lifts a known mass vertically. The velocity of the mass is determined by using a sonic distance sensor.

The exercise that follows combines both principles. Mass m_1 moves downwards to rotate the shaft of the DC generator. The induced voltage is used to power the DC motor, which raises another mass m_2. Two sonic distance sensors are used simultaneously to sample the positions of both masses (see photograph in Figure 1, left).

After a couple of seconds, the speeds of both masses become constant (Figure 1, right). The calculation of the efficiency of the system is straightforward: $(m_2v_2)/(m_1v_1)$. Students start with a fixed mass m_1 driving the generator and vary mass m_2 that is lifted by the motor. As in the previous cases, they plot how the efficiency of the coupled systems depends on one variable - mass m_2 in this case (Figure 2, left). While the curve that is obtained in this case is usually as expected, it is not simple to predict the dependence of velocity v_1 (speed of the mass that drives the generator) as a function of velocity v_2 (speed of the mass lifted by the motor) as seen in Figure 2, right.

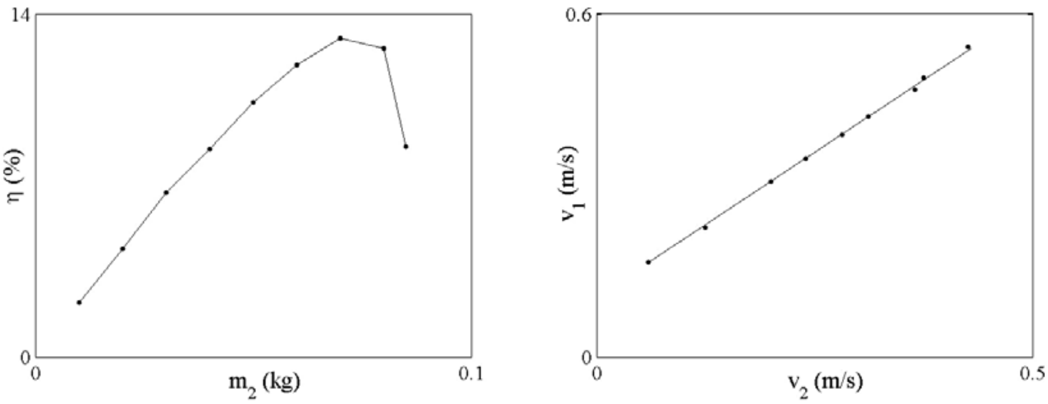

Figure 2: Efficiency η of electrically coupled system as a function of mass m_2 lifted by the motor (left), the dependence of the speed v_1 of the weight driving the generator on the speed v_2 of lifted weight (right).

Electronics

In the forth semester, students of technology, informatics and physics education, take a course in introductory *Electronics*. This course includes basic analogue and digital electronics. The analogue electronics incorporate circuits consisting of fundamental components: resistors, capacitors, inductors, diodes, transistors and operational amplifiers. The characteristics and implementation of typical sensors is included, such as thermistors, photo-components and strain gauges. Digital electronics is focused on logic gates, combination circuits and basic sequential circuits. The course is concluded with the application of microcontrollers, where students integrate their knowledge of analogue and digital electronics, as well as getting some insight into the practical implementation of microcontrollers. In addition to standard lectures and practical laboratory exercises, an electronics circuits simulation programme has been implemented (Yenka, http://www.yenka.com).

Projects in electronics is an extension course in the fifth semester compulsory only for the students of technology education. The course commences with the application of sensors and actuators integrated within some typical examples of basic electronics control systems. Students also obtain some insight into wireless communications and optoelectronics. Furthermore, the students obtain some additional practical instruction on the use of microcontrollers, also related to the implementation of a data acquisition system transferring measurement data to a personal computer [12][13].

The course concludes with student projects, in which each student needs to plan, develop, perform and evaluate a project of his/her own. The project content and aims need to be adequate for a curriculum of a chosen pre-higher education programme. The final project outcome is a presentation of 15 minutes' duration to their classmates, as well as preparing an e-report about the project attaching video clips, simulation data files, programme files for the microcontroller applications and Yenka simulations, etc.

Several general dilemmas had to be faced when planning the electronics course content and didactic methods for trainee teachers of pre-higher technology education. The most challenging one was how to interrelate so-called virtual laboratory exercises based mainly on computer simulations of electronic circuits with hands-on laboratory exercises dealing with real circuits. Based on interviews with in-service teachers, a blended method was selected [14].

Therefore, most of the lectures incorporate pre-prepared simulations (see example at Figure 3, left), while during laboratory exercises students develop their own simulations. Still, about 80% of the laboratory exercises involve students assembling and analysing real circuits. At the very end of the course, students combine analogue and digital electronics to design, assemble and test real electronics circuits comprising a microcontroller unit named eProDas-Rob1 (see example project in Figure 3, right), through which most of the students have their first experience with computer programming. The control unit based on Atmels' ATMega16 microcontroller was developed at the Faculty of Education [15], co-financed by the EU Leonardo da Vinci programme (www.e-prolab.com).

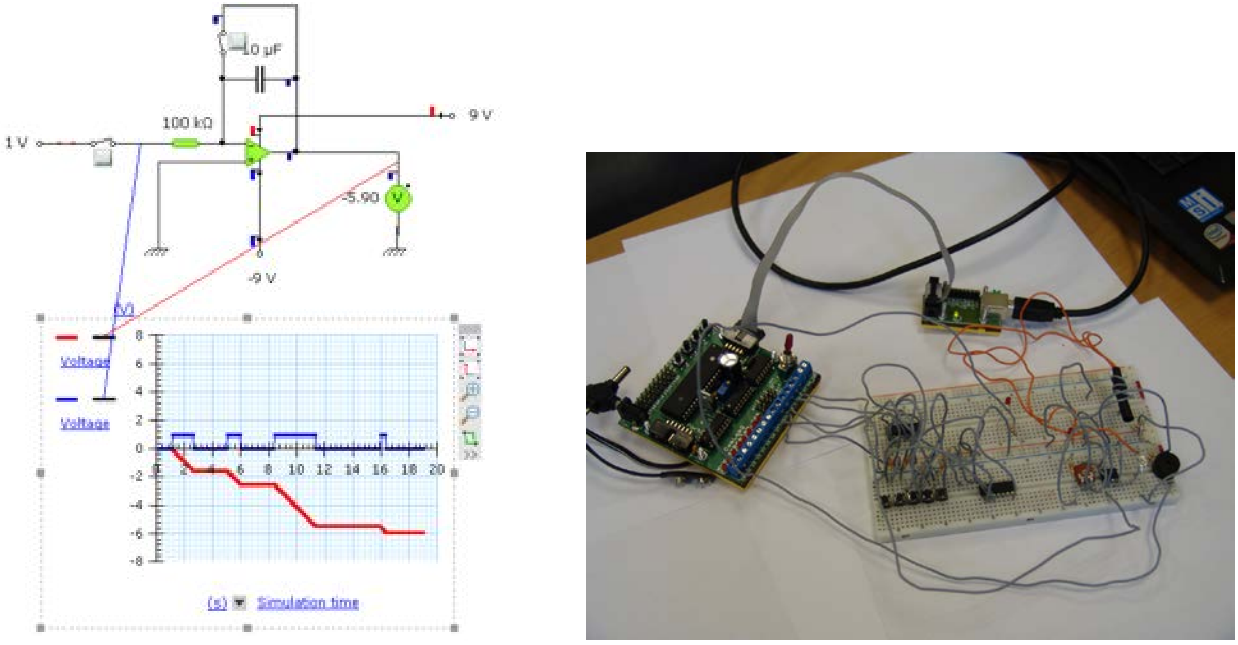

Figure 3: Example simulation of a circuit demonstrated during the lectures (left), and *real* circuit implementing microcontroller unit.

Robotics and Mechatronics

Students of technology education have a compulsory robotics course in their seventh semester, while the course called Projects in Mechatronics is optional. The aim of both courses is to integrate knowledge and skills that students were supposed to obtain during previous courses in electrical and mechanical engineering, as well as with general didactic courses. The courses themselves do not introduce many new concepts, but their focus is to encourage students to implement their knowledge in their projects, still focused on pre-higher technology education (see example projects in Figure 4).

A model of an autonomously operating drawbridge is presented as an example of a mechatronics project. When travelling by car over a river or from the mainland to an island, some bridges may be too low above the water level for large ships or yachts with high masts to get under. Some drawbridges open/close to road or water traffic according to a timetable. A *smart* drawbridge could operate according to sensors on ships or yachts detecting them, switching on the red traffic lights, then raising the bridge to allow ships to pass beneath and finally to draw the bridge back and allow road traffic to proceed. As an example, a wooden model of such a drawbridge is shown in Figure 5.

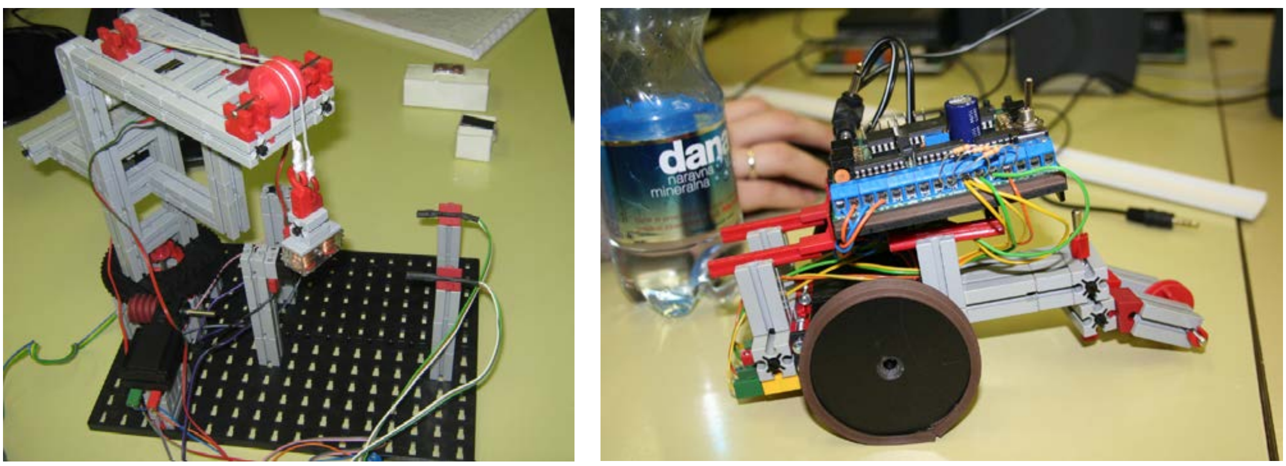

Figure 4: Models of robot arm (left) and mobile robot (right).

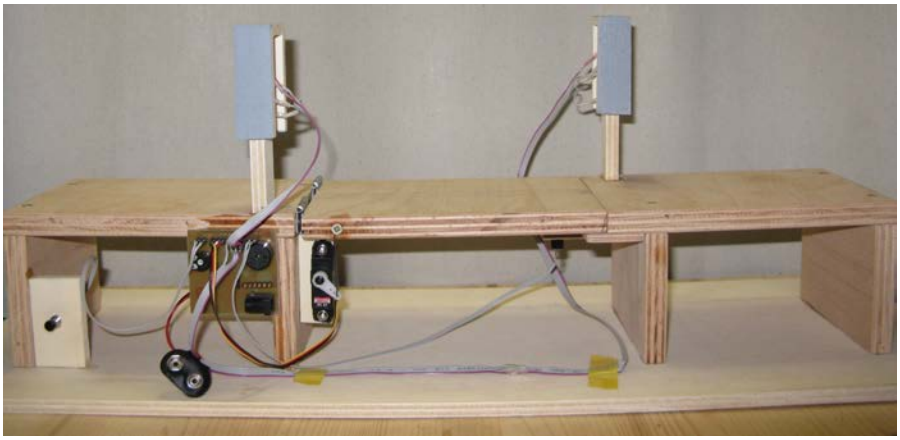

Figure 5: Operating model of a drawbridge.

SUMMER CAMPS OF ROBOTICS AND ELECTRONICS

The first robotics summer camp was carried out in 2007, while for the last three consecutive years, summer camps in electronics and robotics have been held as presented in Ref. [16]. The camps were organised by the Slovenian Association for Technical Culture and the Society for the Development of Technology Education, both based in Ljubljana, Slovenia, although the mentors were teachers, students and graduates from the Faculty of Education.

Unfortunately, female participation in the summer camps has been low. However, those girls who attended the camps achieved comparable results with the boys. As an example, a so called *micro car* project is presented (see Figure 6).

Figure 6: Girls can do robotics as well as boys.

Here is brief project description written by the participants:

The aim of the project: The purpose was to implement a pre-designed frame of a micro-car, which would follow a black line. If it approaches an obstacle, it should stop, turn blinking lights on and start to drive backwards. So, in consequence, it should avoid the obstacle, find the black line behind it and continue driving.

Design: For assembling the micro-car, a car frame with motors was needed, microcontroller circuit eProDas-Rob1, two light sensors, an infrared distance sensor and a battery. It has been programmed using a program called Bascom. During the programming, repeated checks for correct operation of the car are effected using a testing program eProLab.

Conclusion: It was possible to carry out the basic things that had been planned, although other feasible ideas could be tried some other time.

CONCLUSIONS

Trainee technology teachers are encouraged to developed more initiative in the developed didactic approach for integrated, project-based, mechanical engineering, electronics and computer science courses. Equipment developed for that purpose (i.e. microcontroller unit, electronics kit, etc) served as intended. Both, the didactic approaches and the didactic equipment functioned well for active methods of teaching trainee teachers, as well as for the children attending non-formal electronics and robotics summer camps. In particular, children attending the summer camps showed remarkable motivation for learning about new topics, such as control systems, remote control, microcontroller applications, etc. Looking from the aspect of innovation, the children developed better results as pre and in-service teachers of technology.

The first cohort of students trained in the courses summarised in this paper finished the study only a couple of years ago. However, positive feedback has already been received from them. They reported that the experience was transferred successfully to middle and high school teaching practice. Students being guided by these teachers already presented some successful projects at their annual *engineering days* meetings.

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