Teaching robotics and embedded systems as a learning chain of different subjects

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Abstract—**Study programs in Estonian IT College (EITC) cover Information systems development, administration, system analysis and technical communication. Studying embedded systems is a relatively marginal part of the curricula.**

However, EITC runs Robotics club which is popular amongst students of all curricula. Students appreciate learning programming by building robots and gaining practical experience during this process, following learning-by-doing or serious-gaming study model.

Curriculum development is a continuous process of improving the coherence of the curriculum materials to improve the relationship between the subjects. Since robotics is an interdisciplinary field covering different subjects areas, it can be used as glue to create a link between different courses over curriculum.

Using virtual and game-like environments is a contemporary approach for teaching programming. Combining programming with real hardware provides valuable platform supporting studies of math, physics and other IT-related topics. Separated experiments on base on gaming elements have been provided since establishment of Robotics club in 2002.

Developed environment and contemporary teaching methods results motivated and skilled students. Special robotics classes for children are provided by several Universities to raise interest in IT and science in Estonia.

Experience can be further extended by attracting students and lectures of other areas. For example, creating smart products in cooperation with students of the Estonian Academy of Arts was a challenging and motivating process both for students and tutors. Joint efforts of people with different background expanded their horizon of knowledge and provided a good product development experience for those who participated in the project.

Robotics and embedded systems can be used to make studies more interesting both for students in different fields, for children and tutors. Cooperation of curricula tutors is a key factor to achieve results and link curricula subjects. We expect to have results of coherent teaching to be available in 2010.

Keywords: Teaching, Embedded systems

I. INTRODUCTION

Learning Robotics and Embedded Computing is a regular and routine part of the curriculum of ITC education now. Study of embedded systems can be conducted in many ways, combining lectures, practical sessions, simulations and laboratory work.

Teaching relies largely on laboratory work because students acquire knowledge more effectively when working with actual hardware, compared to simply listening of theoretical lectures. Also, the acquired knowledge is deeper when everything has to be discovered in the process of trying out and testing.

The students of Estonian IT College show great interest towards these subjects and their motivation is higher compared with the subjects which do not cover any practical tasks.

The Robotics club of Estonian IT College brings together these active students who want to learn more than required by the curriculum. Practical hobby robotics motivates them to learn different subjects of natural sciences more thoroughly and let test the acquired knowledge in practice. In Robotics club

robots are constructed to participate in Estonian robotics contest Robotex [1]. Students turn to different subject teachers for help and guidance, for example they need to know something in mathematical statistics and ask their math teacher about a specific area. Quite often students are not able to express their problems clearly enough to get real help from subject teacher because students cannot explain their problems in proper mathematical terms. The subject teachers have difficulties to pose the problem in terms of mathematics by themselves since they typically lack the relevant skills and knowledge in robotics and programming.

The curriculum of Estonian IT College includes mathematical analysis, physics, linear algebra and graph theory. This range constitutes rather sufficient basis to acquire the area of specialization.

General subjects can often become obstacles on the students' way of education. Sometimes they even take the attitude that the general subjects have to be studied and forgotten just to pass on. They might not be able to associate their future job with Euler's formula or learning the function. During a job interview no-one will probably show much interest towards the mark in mathematical analysis but rather towards interesting projects and programs the applicant has done or participated. Thus it can be assumed that such an attitude derives from a practical point of view, which is why the general subjects are not considered important. High-school graduates will find themselves in university and won't link the first year courses to their future job, yet they have motivation and belief that everything taught will become useful in the future.

Until it is believed that probably everything taught in the high school is useful, there is some motivation. When it comes to general subjects, it is difficult to hold and deepen this interest. Even when it is mentioned in lectures, that this or that formula can be used in a particular IT project; it will be distant knowledge for students because they won't see a direct link and applicability. Therefore students will not be convinced just by claim about how wonderfully practical this formula is. The students prefer to gain knowledge in the course through interesting practical work.

II. THE PROBLEM

It can be concluded that in case of learning ICT subjects the following motivation problems occur.

- Students are not interested in learning of mere theory
  - The formulas are not seen necessary nor linked to their study area or future job
- Theory that is not used will be forgotten quickly. In a few years students won't even remember was a specific topic covered or not.
- Interest towards technical and natural sciences is not high enough which can be seen in the applicants' motivation. There are not enough applicants to fulfill available student places in technical and natural

sciences. Many people opt for IKT specialty because they can count on getting a job that pays well but they won't have enough inner motivation to get to know the given area.

- The subjects of curriculum are often not connected with each other and their content will therefore be easily forgotten. Learning outcomes of one subject are rarely linked to the outcomes of another subject and the required input of other subjects, which is why cohesion between subjects is not guaranteed.

III. IDEAS

We are convinced that using of robotics, which is an interdisciplinary science, as an gate to better teaching of natural sciences. We suggest creating of teaching materials and methods following those principles:

- Learning has to be playful, fun and interesting
- The tasks students are going to solve have to be associated with the practical applicability of the theoretical knowledge.
- Mathematically formulated problems should be avoided letting students to discover the task formalism by themselves.
- Have students do practical work, measure, solder, and assemble robotics kits.
- Involve more experienced students in teaching of others, using Web2.0 means such as weblogs, forums, wikis, etc.
- In order to increase pupils' interest toward technology, involve pupils of basic and secondary schools. Ask university students to help in running of workshops and classes of robotics.
- Allow students to experience actual work involving them in different product design projects in co-operation with Product design students.

Have students make something using their own hands, for example let them prepare a soldering plate or other electronic devices. Although it is not directly connected to mathematics and other similar subjects, it lets students to experience how it feels to do something practical. Positive experience remains in memory and gives a awarding feeling of success.

IV. DETAILS

There are several existing methods and environments connecting different subjects in a playful way that correspond to the ideas listed above. Lego kits, different robotics constructors and simulators are widely used. Web-based playful teaching materials covering different mathematics and physics problems can easily be found in the Internet.

A. Robocode

Robocode was created to teach Java programming language in a playful way. It is open-source software that is feasible even for a learner who does not know how to program. [2] The under laying software is robot tanks attack simulator where students can design their own robot, program it to destroy the opponents tanks and move around in a smart ways to survive in hostile environment.

Robocode is great program for learning programming in Java language. In EITC curricula Java is used for study of basic programming and it is used also in Algorithms and data structures course.

Robocode is interesting and fun for students compared with usual way for learning because it includes fun, direct visual feedback and competition.

Trigonometry and also mathematical statistics are needed to create a successful tank. Often it is not obvious until when the student who has passed a math course of secondary school, will understand the content of trigonometric expressions and associate it with physics of the simulator by programming.

Illustration 1: RoboCode battle

Students continue developing robots even after the end of the course because it has been exciting and attracting. Moreover, they took over the initiative and started their own internal RoboCode competition in the college, which gathered popularity and where the secondary school pupils were also invited to observe and participate. In addition, students are motivated to participate as the teachers of different programming courses award the three best students by extra points. Excitement to win drives the students' motivation to make an effort.

B. Sumorobots

Raising young peoples' interest towards technical sciences is one of the priorities of Estonian higher education. It is likely that candidates choose ICT-specialty relying on the subjects that interested them in secondary school.

EITC students co-operate with the pupils of Tallinn School No. 21, where one of the informatics courses was replaced by a short course of Sumo robots programming. Formerly the course content was limited to teaching text and data processing but the school was interested in improving the course.

A simplified version of the same course was taught to a group on 10 years old children and all the participants succeeded in programming their robot. When teaching a course to children, it has to be kept in mind how soundproof the room is because the competition at the end of the class will be cheered loudly.

Initial test-course using robotics kits in the informatics classes in secondary school lead to need to educate secondary school teachers, so that they would be able to teach this course independently. Next step is in process – the course content is to be associated with the tasks solved in mathematics and physics class.

C. Product design

Along with Estonian Art Academy a Smart product development project was completed [3]. The aim was establishment the cooperation between students of higher education institutions active in completely different study domains. The result of project was a set of diploma works and master classes. The original ideas were proposed by Art Academy students whereas students of EITC created matching smart technical solution of the problem. For instance, products for people with hearing or visual disabilities were developed. The most attention earned two sub-projects:

1. Vibration pillow, which was designed for everyone who is annoyed by the sound of the alarm clock.

2. Drum and Cat, which is a peculiar device for listening to music: it extracts the most pleasing frequency and this can be tuned to purring-like vibration.

Projects were challenging for EITC students because full embedded system has to be developed along with sensors, actuators and software. Additional experience was obtained on assessing ideas and analysis of feasibility due to fact that students at Product design curriculum of Art Academy had somewhat ignorant knowledge about contemporary technology possibilities and restrictions. During the project, Art Academy students got a picture of embedded system extent and limits, and obtained cooperation skills along with students of technology fields. The most important – participants recognized mutually that embedded system studies can be well combined with studies of different study domains. Students were highly motivated and cooperation continued long after official end of the project.

D. Using Web 2.0 tools

Contemporary students are open to use daily different communication environments like blogs and various Web-based content generation tools. This background can be used to increase contribution of students during regular lectures or seminars, giving them few topic related questions or problems and asking them to describe solutions in wiki or blog. For instance, teacher in RoboCode programming class can issue a task to find and describe different robot movements and targeting strategies on base of Web information. Findings will be presented by the students at the end of study hour. The task can be organized as a group work, preparing only titles and let student groups to fulfill corresponding wiki chapters. Methodology is supporting well cooperative activity during study hours and improves the acquisition of knowledge. Experiments have shown that students can manage well multitasking and multiple focus points during lectures. An effort by teacher is required to direct multi-focus readiness of students in frame of topic to be covered. Successful implementation of methodology is leading to situation where more aware students will start to educates others taking away some of teacher's load. Open nature of wiki and blog helps to accumulate the knowledge and can be used as starting point during next runs of course. Comparing with traditional e-learning environments like Blackboard or Moodle, which are course centered, wiki and bog techniques are better for studies in interdisciplinary areas, being free of walls built between different course materials.

Students complain often, that amount of available information is overwhelming and can't allow systematic approach. E.g., the typical complaint is that basic material combined with all appendixes, attachments and additional readings is too complicated to unravel. In such of cases, the mind-map methodology can be used to build up semantic system of knowledge area to aid orientation in available information space. Author (here, M.Ernits) suggests to use FreeMind software [4]. Generated by FreeMind mind-map as Flash of Java applet can be easily integrated with home page of the course.

V. COOPERATION IS KEY FACTOR

Deployment of interdisciplinary project to teach different subjects does expect tight cooperation of subject teachers. All practical hours and labs have to be designed on base of joint projects. E.g. to program RoboCode, student has to use trigonometric equations, statistic methods as well parts of algorithms and data structures. Study material in those subjects has to be developed having combined goals in mind. This is time consuming process requiring good cooperation between subject teachers. Our experience does suggest that for teachers it is beneficial to pass programming and RoboCode short course, where problem specific physics and mathematics will be covered. Despite confirmable positive yield, to get teachers on problem specific courses is difficult, needing encouragement and personal support.

VI. RELATED WORK

RoboCode is used in Estonia beside EITC by Tallinn University of Technology (TUT) in master level course Object oriented programming. TUT Department of Mechatronics is participating in international AUTOSTUDY project [5] which is combining practical training with wiki-technology to support teacher's cooperation.

Sumo robots and Lego Mindstorm kits are used in schools around the world. In Estonia, the matching project is named "Koolirobot" (School robot) [6]

In several schools of Estonia new interest groups in robotics have been emerged, where problem solving is successfully combined with practical activities and real prototyping.

Universities participate along with enterprises and third sector institution in selected natural and computer science popularization activities. A good example is Science bus tour in cooperation of Tartu University, Ministry of Education and Research, and Estonian Nanotechnology Competence Centre. Science bus has visited more than half of general schools in Estonia demonstrating science and robotics experiments [7].

EITC is participating in similar tour Roadshow [8] along with Estonian Association of Information Technology and Telecommunications, demonstrating robotics and helping school pupil to get acquainted in ICT studies at higher schools.

VII. FURTHER WORK

Our experience is telling the usage of robotics as a linking component in teaching different subjects to increase student motivation against general studies to be worth-while. Due to number of different subjects to cover, future work is focused on elaboration of different tasks and interweaved study materials.

Subject teachers at universities and general schools will benefit of intentionally designed course about robotics and programming basics. In addition, to increase acceptance among students in humanitarian areas, usage of 3D virtual environments like OpenSim [9] can be used as higher abstraction layer over programming (scripting) of 3D-objects in physics enabled simulation environment.

Basic sumo-robot constructor kits can be improved offering partial solutions with different complexities according to user skills and knowledge level. For instance, there are always students, who are ready to solder and program electronic kits by themselves. School pupil are willing to give personal shape for own sumo-robot using machine-tools in industrial arts study program. Consequently, specific guidance and teaching materials has to be composed for teacher in industrial art class.

Our main goal is to educate subject teachers to recognize robotics and programming opportunities to enrich their own subject letting students to demonstrate usage of equations and rules on sumo-robot platforms or simulated tank combat sessions.

VIII. CONCLUSION

Gaming combined study (serious gaming) has proved to be more challenging and natural than purely abstract and theoretical problems in lecture form. It is sufficient to describe a problem in terms of robot behavior and let students to discover knowledge and test their own skills. Robotics as truly interdisciplinary engineering science is offering good opportunities to teach various general subjects in attracting and interesting ways. Teaching of general subjects can be improved combining theory with study games, simulation and building of robots and other microcontroller based systems. As a rule, simulation environments like RoboCode or OpenSim can be relatively easily integrated with study process compared with building and running of robots, where teacher has to be provided with building blocks of acceptable complexity to not convert main problem in own subject into endless chain of small problems in another area. For better and faster understanding it is always useful when for teaching of mathematics, physics, complex programming techniques or data structures, teacher can set up a problem connected with available practice. Motivation in subject classes e.g. mathematics can be increased starting with overview how different subjects are interrelated and how connected with practical lively problems.

Students are already accustomed with Web 2.0 technologies largely through background peer-education process. Subject blog and wiki, content of which is developed and controlled by students themselves, is cooperation encouraging, is reducing teacher's load and keeps away boredom so often emerging in theoretical lectures. Robot simulations and construction kits are interesting (interactive) and encourage students to dig more deeply into study domain even after official end of course, establishing more permanent skills and knowledge trough inconspicuous repetition.

To establish motivating trough serious gaming study environment a good cooperation between teachers of different subjects is assumed. The networked study material does not consist only of lectures and exercises but contains simulations, hardware prototyping, Web2.0 tools usage and teamwork. Even using of a simple ruler can be challenging. Understanding what students can achieve using of robotics kits and soldering iron demands efforts by subject teacher, cooperation and continuous improvement of study tasks according to changing technology.

We have seen that implementing of real things and programming complex behavior of objects is highly motivating. Web2.0 based study materials, opposite of printed text which is aging fast, preserve and increase their value and attractiveness in time. Interest against general subjects can be restored and improved enriching theoretical studies with robotics, embedded system programming and letting teams and classes to compete for the best solution. The resulting knowledge is consistent and usable for future problem solving.

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