CREATING AND IMPLEMENTING ROBOTICS FOR SCHOOLS

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Introduction

Robotics is something frightening and yet it excites interest among people. Society doesn't realize how much they depend on robots in their everyday life. Robots are among us, but not in form of walking humanoids. Which raises a question - what is a robot?

There can be different explanations of what robots are, but in this document, we consider a robot to be a sensor-controller-actuator system. It can be compared to a human being. We have senses, we smell with nose, we feel the touch with skin, we see with eyes, hear with ears and taste with tongue. Robot's senses are called sensors. In case of robots and human beings, sensors and senses are the only way to perceive the environment. Robots have controllers, humans have brains. It is our control center - information from sensors and senses go to the controller/brain. The brain makes decisions based on received information. The result of a decision could be, for example, a movement for which we use muscles. Robot's muscles are it's actuators such as motors which complete sensor-controller-actuator system.

Robotics finds usage in industries, medicine, transportation. One of the usage is in education, because robotics is interesting for students, it requires critical thinking, problem solving, programming, designing and many other skills. Yet, without proper use of methodology, it is not easy to make students use math and physics and enjoy learning. Students use computers and other smart devices every day, but it does not train them to be programmers or IT engineers. They use devices only as tools for information exchange. They don't create new value although computers are very powerful tools. In case of robotics, students can't just use robots, they need to create and test them. That is an important difference between the use of robotics and computers. In order to use hardware one needs proper methods. This document presents some of the methods used with educational robotics worldwide, especially in Estonia, Finland, Sweden and UK. Additionally, we present the ways robotics is included in education and schools. Hopefully you will get new ideas and approaches about how to richen your education with robotics.

Figure 1. Children in a robot competition

This document introduces different types of methodologies, including practical guidance on creating a range of activities and methods and ideas for implementing Robotics in Schools in a teaching or training situation. The example Robot for Schools model - Estonian model - is described in detail and practical guidelines are given. The main target group is primary school to upper secondary level (gymnasium level) but also vocational level is sometimes kept in mind.

Methodology for teaching robotics

Around the world, there are many robotic platforms available, but fewer methods for teaching. In classrooms, many teachers use a mix of methods or transform them into their own, more convenient methods. There are several approaches that could be classified into 6 categories [7]. Following approaches will be shortly introduced and discussed:

- discovery learning;
- collaborative learning;
- problem solving;
- project-based learning;
- competition-based learning;
- compulsory learning
- inquiry-based learning

Discovery Learning

This method is the most time-consuming out of presented approaches. The approach is open and almost guidance free. This makes the method also more stressful because students are free in their search and are expected to find out answers themselves. Questions are expected to be answered with Socratic method which means that no direct answers will be given. Students are rather guided towards their own answers. This method takes more time and might be frustrating because it is difficult to witness improvement in skills among students. The approach of finding answers on your own has a very strong mental impact on processing and storing new knowledge.

Collaborative Learning

This approach could be used with any other method in educational robotics. The key is in communication between students or between groups of students. Collaboration is shown if students and groups share the same goal of task realisation. In most cases, groups have two students where one is responsible for hardware and the other for software. Collaboration means sharing knowledge, skills and strategies between groups. The method also reduces the gap between teachers and students as teacher will be involved in learners' interactions. When teacher does not know the answer, they are on the same level of knowledge with students and they learn together.

Problem solving

Problem solving with robots is inevitable. Building a new system will show the engineer about the faults during the pilot phase. This also teaches another valuable skill - planning. The more time is spent in planning phase, the less problems arise later.

Students need to be presented with right problems. For example, let's take programming. When a fresh programmer starts working in new programming language, he/she needs some pre-knowledge about the language and syntax. More time spent programming results in easier and shorter time when a new programming language is learned. This happens because programmer has developed transferable algorithmical thinking skills. The new language requires only knowledge about the syntax. When young students start with programming and they struggle with syntax, they lose motivation because of slow results. Instead of syntax errors, they should be dealing with their thinking errors. Programs should be linked to wishes very easily. A robot fulfilling users' program will be reflection of one's thoughts. Learning with physical objects enhances a learner's cognition. Problem solving with physical objects shouldn't be connected to details of the usage, such as syntax of the programming language.

Project-based learning

Tasks of project-based learning(PBL) are assigned to students divided in teams. Tasks can include investigation or searches. This method has a strong connection with collaboration. PBL is a good method for learning but it has a critical phase - division of tasks. When students are not able to divide tasks and define roles in a bigger group, success rate of this method decreases. Teamwork plays an important role in this approach. PBL consists of exploration, experimentation and creation phase. Groups of students are presented a project which requires more work than one or two students would be able to do on their own.

Competition-based learning

Competition-based learning is one of the most used approaches in educational robotics. Students take part in robot competitions with their own robots. While preparing for a competition, students build and test hardware and programs. They will encounter problems, but they are more motivated to solve them due to the competition factor. They will also use math, physics and other subjects in order to achieve their goals. The knowledge obtained this way has a bigger effect than fact-based learning. Competition-based learning is recommended to be used not only between schools but also in classroom. You might have to take into consideration that some students don't like competitions and "being on edge" or competing against each other. The solution might be competing against standards not against classmates.

Compulsory learning

Compulsory learning is a method less used. There are few examples of robots being used as a part of curriculum. This approach is good for students that discover their skills while using robots. On the other hand, with this approach robotics loses its volunteer principle which is a strong factor in education. This means that robots could be used as a part of compulsory curriculum to only some level from where students have a choice to continue with educational robotics.

Inquiry-based learning

Inquiry-based learning can be seen as a new promising approach to increase the effect of robotics in education. Inquiry-based learning itself is a highly self-directed constructivist approach of learning and discovering through experiments and observation. Inquiry-based learning includes phases of setting hypothesis, planning experiment, collecting data, analyzing results and making conclusions. Robotics has a strong input into this system as a tool for experimentation and observation. The approach requires specific worksheets and lesson planning.

Robotic Teaching and Learning Concept - RTLC

Didactical Concept - Blended Learning Concept

The didactical part of the concept consists of a strategy for implementing the blended learning concept in daily education and a set of learning materials. Figure 2. and Figure 3. illustrate the coherences between the parts of technical concept and their application in the pedagogical context. Figure 2. is based on two roles, “Teacher / Instructor” and “Student / Learner”, whose intersection is the Network of Excellence (NoE). Teachers' tools consist of a teaching methodology, pedagogical collaboration with other teachers in an international platform and supervisor-specific content, available through NoE and teacher training (for instance 'train the trainer' seminars), enhancing teacher's knowledge of usable and available tools and content.

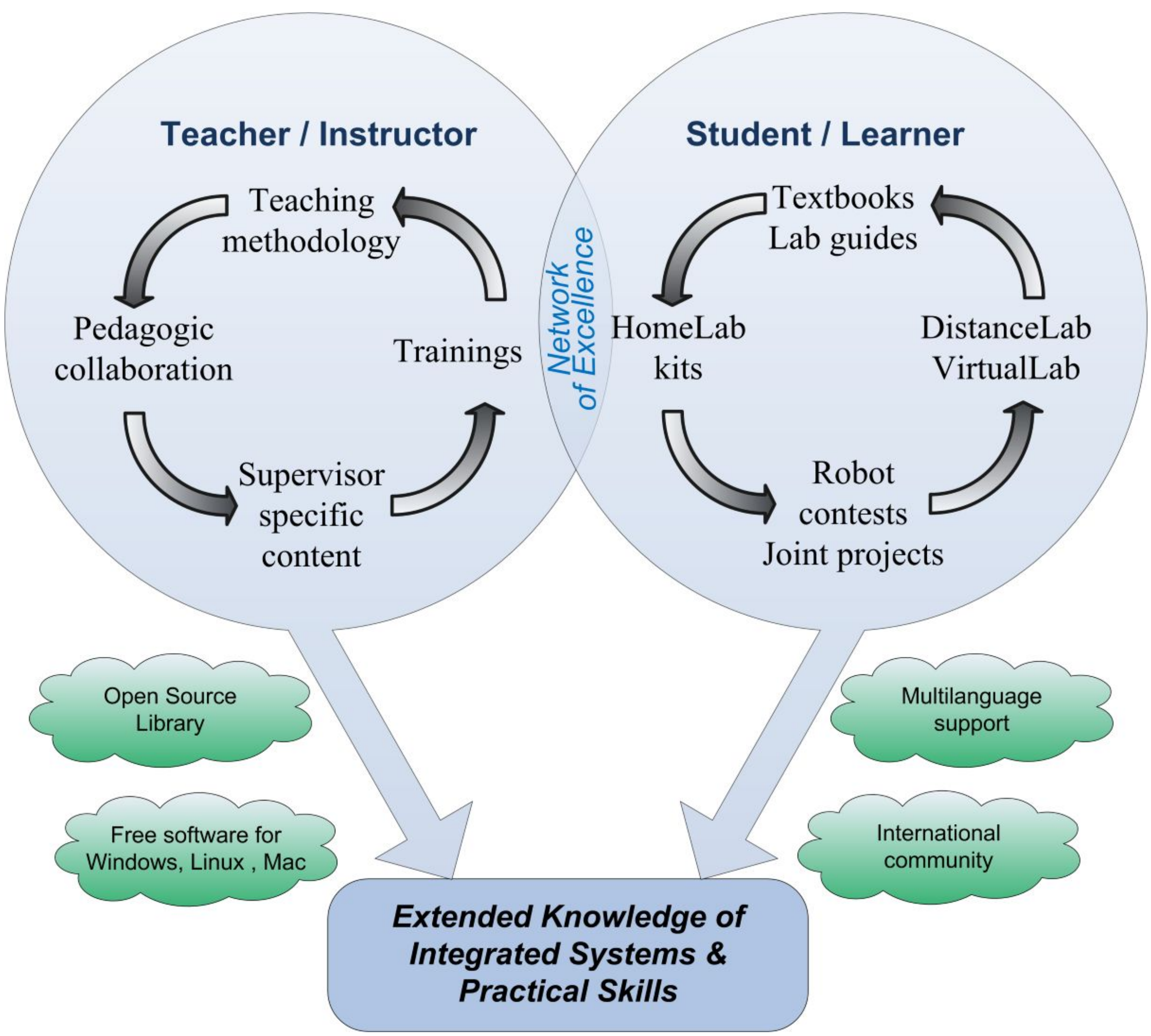

Figure 2. Didactical overview of Robotic Teaching and Learning Concept (RTLC)

The learner is supported by textbooks and lab guides and other eLearning materials, which are freely accessible online through NoE. In addition, the Robotic HomeLab kit, DistanceLab and VirtualLab are the tools for leading to a robotic contest or joint student projects utilizing the introduced material. The overall goal of the concept is to extend the knowledge of integrated systems and learners' practical skills.

The RTLC concept ensures that the technical and didactical parts complement each other. The idea is that students develop software using a regular programming tool (such as AVR Studio or Code::Blocks) and run this software on virtualized hardware. Since the program code is developed with a standard tool, it will work on real hardware as well as it does on virtual hardware. Thus students gain practical experience in programming that can be applied to real-life problems and applications.

The sequenced use of the tools in the concept is illustrated in Figure 3. Learners are given a task by the instructor that involves all important parts of the system. The task is first performed on a VirtualLab device that is available in multiple instances, only limited by the computing power of the student's machine and the connection rate of the server where the VirtualLab is located.

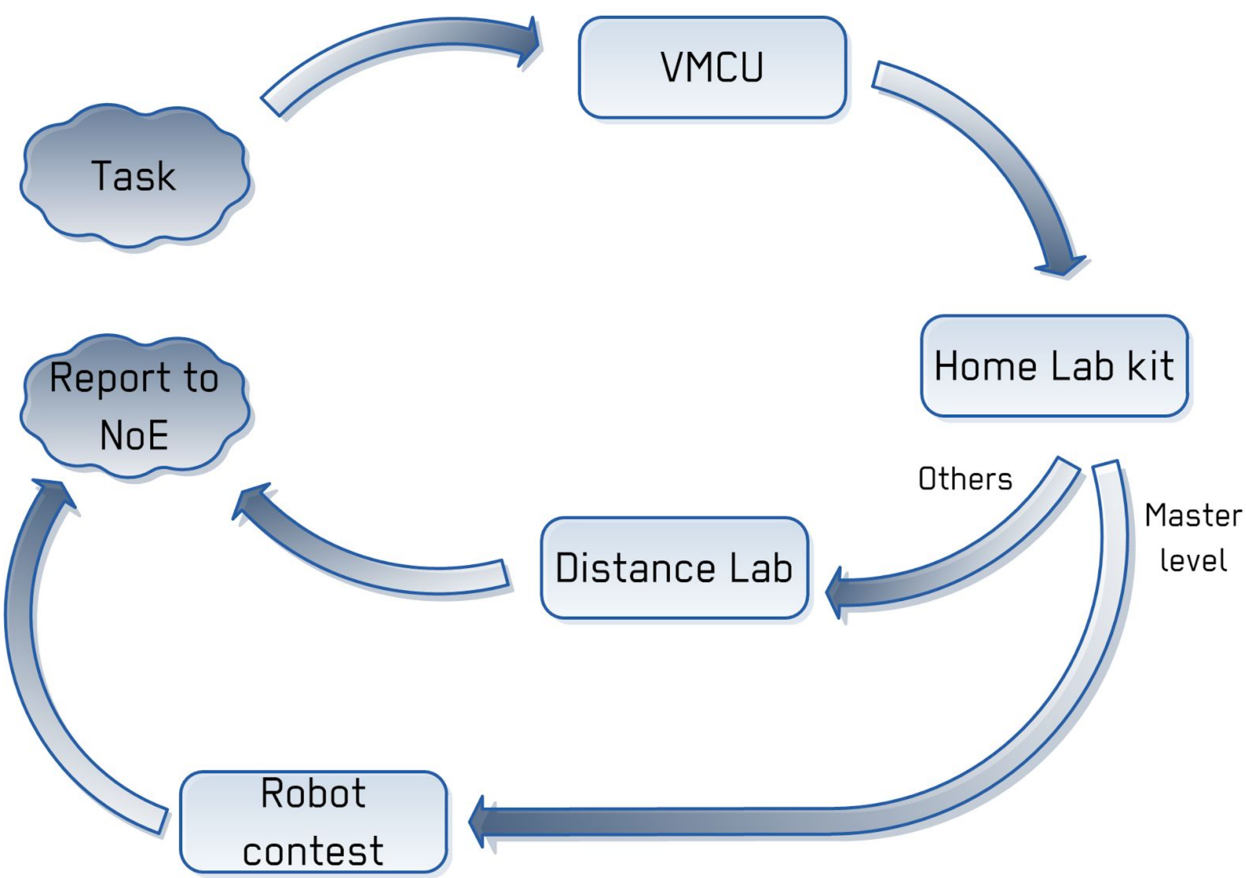

Figure 3. Coherence between the different concept levels

Once students are familiar with the hardware, they can test and evaluate their solution on Robotic HomeLab kits. The penultimate step differs depending on the learner's educational level. Master students in mechatronics continue with a robotic contest in student groups, building robotic applications based upon HomeLab kit hardware. All other users continue their practice by using robots available through the DistanceLab system.

Online Experimentation in Engineering Curricula

Remotely accessible laboratories, where students use the Internet to monitor and control physical laboratory apparatus remotely, provide a viable alternative to individual experimental laboratory kits. Remote experimentation as a virtual learning space allows individual and collaborative teamwork.

Remote labs have the following benefits in engineering curricula [2]:

- Students can login and carry out experiments from anywhere in the world;
- Remote labs provide extended access to expensive and/or highly specialized devices;
- Unlike simulations remote labs provide real lab experience and this is of great importance in teaching engineering;
- Remote labs give students the opportunity to work in remote mode, which will eventually become important in engineering jobs.

Remote Lab Portal

Today's engineering education needs remote access to experiment over the Internet. In this chapter the remote lab system DistanceLab is described and the connections with learning and teaching tools are presented. The e-environment DistanceLab (http://distance.roboticlab.eu) is a part of the robotic teaching and learning concept presented above and can be studied further here [3], [4]. The concept offers a wide range of tools and methodology to teach embedded systems and robotics effectively and interactively as well as exploit the latest web technologies.

The whole environment consists of several logical servers which can be physically located in one server or distributed to many different locations. The current set-up consists of one portal server and every lab location has its own programming server. In addition, all labs and also all devices can have their own real-time audio-video feedback system. The structure of the remote lab system is shown in Figure 4.

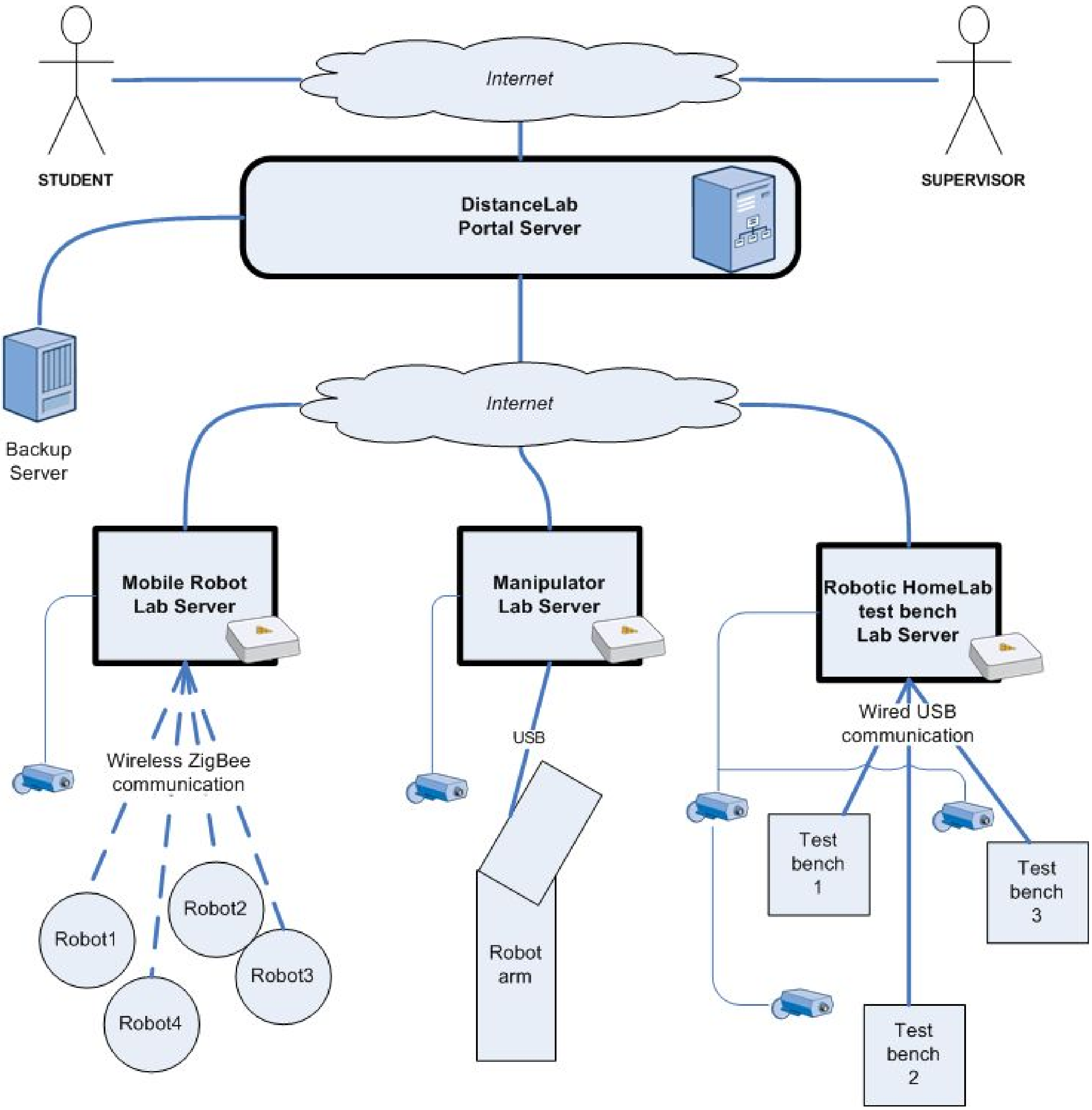

Figure 4. Structure of DistanceLab e-environment

The lab is comprised of a number of similar devices with wired or short-range wireless communication modules. The site is fitted with a real-time camera and a server which communicates with the robots. The server has a master communication unit which can make contact with any robot on the field and reprogram it when necessary. The site server is connected to the portal server, passing and validating the communication between the robot and the user input. The remote lab environment portal offers a complete remote lab management and programming environment for remote labs, whether distance labs or virtual labs. The functionality connected with the remote lab is as follows:

- User and group management
- Location, lab and device management
- Source code validation and version management
- Wireless device communication
- Device booking and booking rights.

Taking a broad perspective, the system supports three levels of grouping:
- Location – the organizational level where different type of devices and labs can exist
- Lab – the virtual room where physically or virtually different devices can be located
- Device – a set of the same type of devices in one location.

Devices have additionally been grouped into several sub-groups according to type, e.g. mobile robots, manipulators, smart house, etc. A video feedback system can be connected to one lab (usually two cameras) or to every device. The number and focus of video cameras is related to the nature of the lab. In the case of moving objects like mobile robots, the lab usually has a general camera focusing on the arena where robots can drive around. In the case of attached devices like the Robotic HomeLab kit test bench or manipulator, every device has its own camera, so that the camera can focus precisely to the device. The remote lab management website http://distance.roboticlab.eu is an interface from which different remote labs can be accessed [5].

A remote lab centre (RLC) is a specific location-based lab which can be accessed over the Internet. It focuses on specific equipment or a series of experiments by giving online access, enabling control and monitoring of the process. Remote lab centres are located in different organizations like universities, vocational schools and SMEs and through a resource-sharing concept offer different remote labs, e.g. a mobile robot lab, a microcontroller test bench, an automotive lab and a smart house lab. In principle, an RLC can either be equipped with real hardware and constitute a DistanceLab or offer a virtualized hardware simulator, VirtualLab. Remote lab centre prototypes are currently up and running in Estonia, Germany, Finland, Lithuania and Portugal.

Learning Situations in a Remote Lab Centre

A learning situation is a new approach; it aims to support independent learning and presents a problem as a whole. Knowledge and skills are provided through practical activities and result-centred learning, not just as a declarative presentation [6].

In order to apply a learning situation in a specific school, the relations with existing study areas and curricula of the school are first determined. If a suitable learning situation is found, its relative importance in the curriculum is determined, and the learning situation is usually fitted into part of a course or the contents of the whole course. The actual volume of the learning situation (students' working time and the number of credits) depends on the preparation level of the students as well as the level and subject area of the curriculum. For example, a specific learning situation within the higher vocational education curriculum of mechatronics may take

approximately 100 hours, whereas in vocational training after basic schooling, in the field of electronics, the same learning situation would take a student about 280 hours of study. When the learning situation is planned, study results are defined and study processes and evaluation planned. Study results are usually described through obtained competences and skills. For example, as a result of solving the learning situation, the student obtains the ability to divide a complex technical task into subtasks, solve the subtasks and document the solutions.
Important competences:

- The ability to divide a complex technical system into subsystems
- The ability to depict and describe subsystems according to the norm
- The ability to interpret the functions of subsystems with the help of practical schemes
- The ability to use proper methodology to describe relations in mechatronic systems
- The ability to use methods of analysis of mechatronic systems
- The ability to interpret, calculate and measure electrical parameters
- The ability to assemble, program and use microcontrollers and microcontroller systems.

When the study process is planned, the forms of study and work are determined, such as:

- Individual work, work in pairs, work in groups
- Independent work with technical documentation and datasheets
- Study in class, lab or e-environment – remote lab.

It is important that students are given proper references and access to study materials, e-environments and remote labs and, if necessary, equipped with required software or links to download and install resources.
Embedded systems are one of the most important parts of robotics and mechatronics systems. Today's intelligent products and industrial systems almost always have a controlling subsystem that works with a pre-programmed controller. The importance of software to today's products is growing and so is the demand for specialists in this field. In the literature [6] there is a list of learning situations which have been developed:

- Die-cast process automation
- Line-following robot
- Navigation robot
- Manipulator-type spot-welding robot
- Pneumatic motor
- Smart greenhouse.

All learning situations are chosen from different subject areas but can use the same robotics systems. The Robotic HomeLab kits used in the project are equipped with a software development package, instruction materials, user manuals and sample exercises in various languages. When a school has purchased Robotic HomeLab kits, they can either be used in the study process directly or be customized to the needs of the school's curriculum. The described learning situations have sub-exercises in design, automated regulation, microcontroller control, programming in C and technical documentation. This approach enables the usage of other freely chosen solutions as study materials, e.g. LEGO Mindstorm sets for younger and less experienced students or the Arduino microcontroller platform (only in this case, the specific instructions and sample codes of the platform will not coincide) [6].

Robotic kits

Overview of different kits and classification as well as position on educational levels.

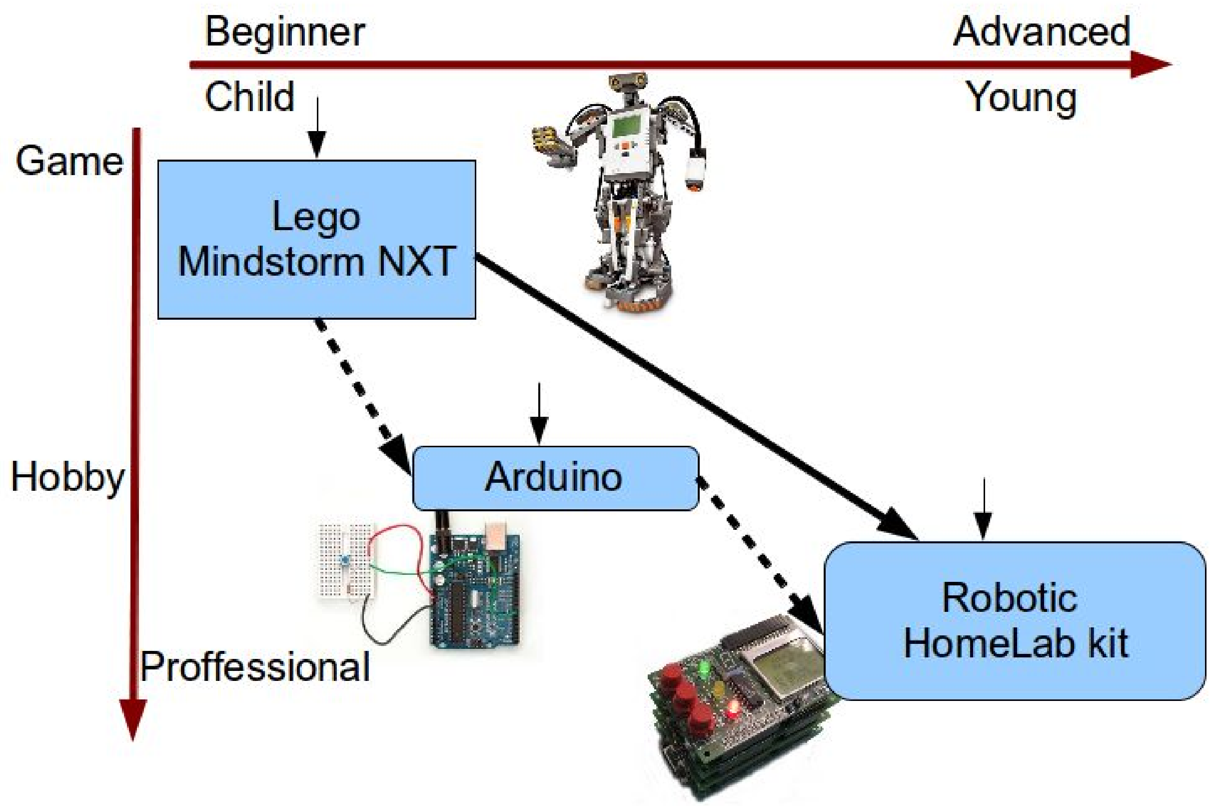

Figure 5. Robotic kit position on educational levels

LEGO Mindstorm

LEGO Mindstorms is probably one of the most used robotics kits in education. It has a basic controller that can connect with motors and sensors.

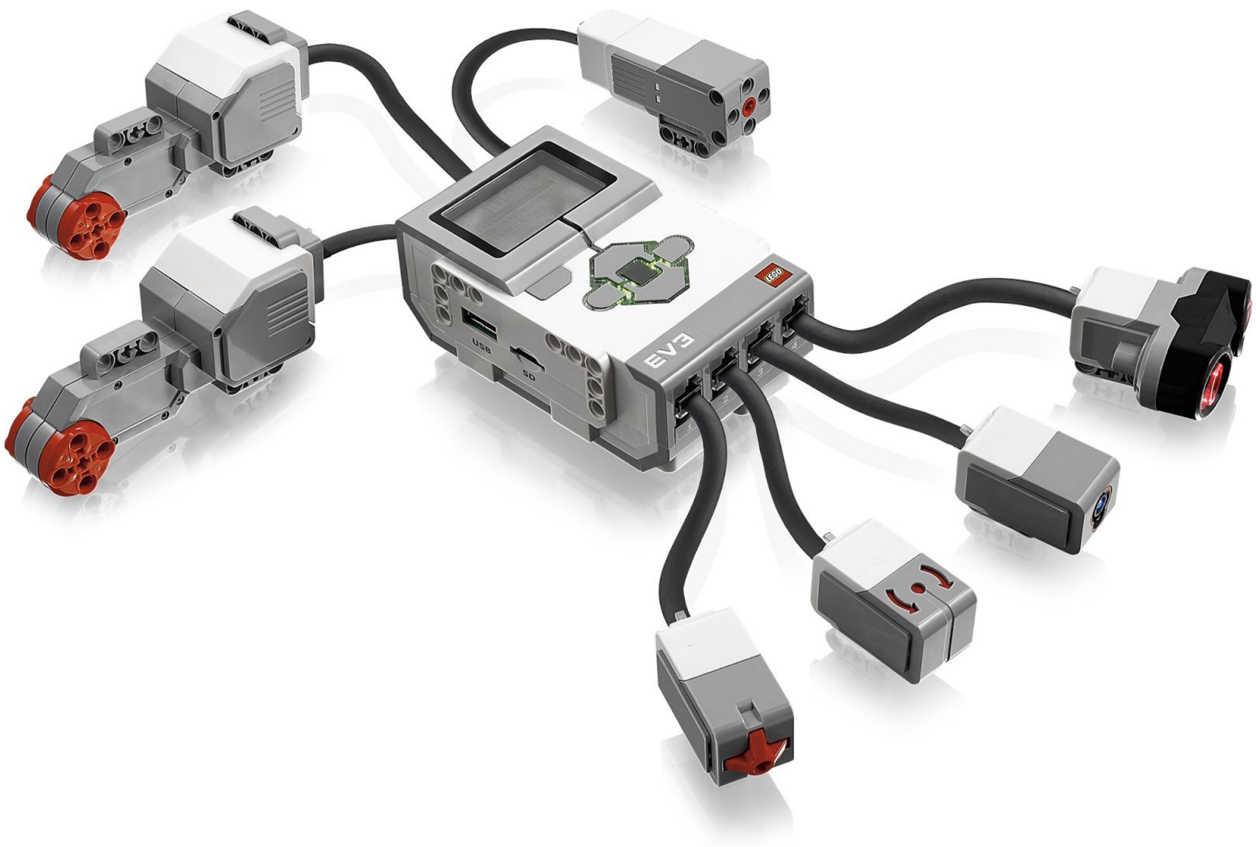

Figure 6. Mindstorms EV3 robotic kit

Brick has four ports for motors and four ports for sensors that act on plug-and-play principle (see Figure 6). All pieces are LEGO elements and they can be attached to each other accordingly to LEGO Technic principles. Real advantage of LEGO Mindstorms is programming language for fresh students. New students can start in graphical programming language within minutes and get the robot moving (see Figure 7). Graphical programming language has also one disadvantage - complex programs require high level programming skills. Students don't tend to reuse code when applying long algorithms. Main reasons for that is lack of knowledge and programming skills. EV3 brick is also programmable in other languages such as C, Java or Python. It gives a variety of possibilities to use this platform in higher education for learning opportunities. LEGO Mindstorms construction is time-friendly. Rebuilding robots doesn't take much time and it is flexible to errors in planning phase. Building a hard, metal robot requires careful sketches of construction and later changes can be expensive.

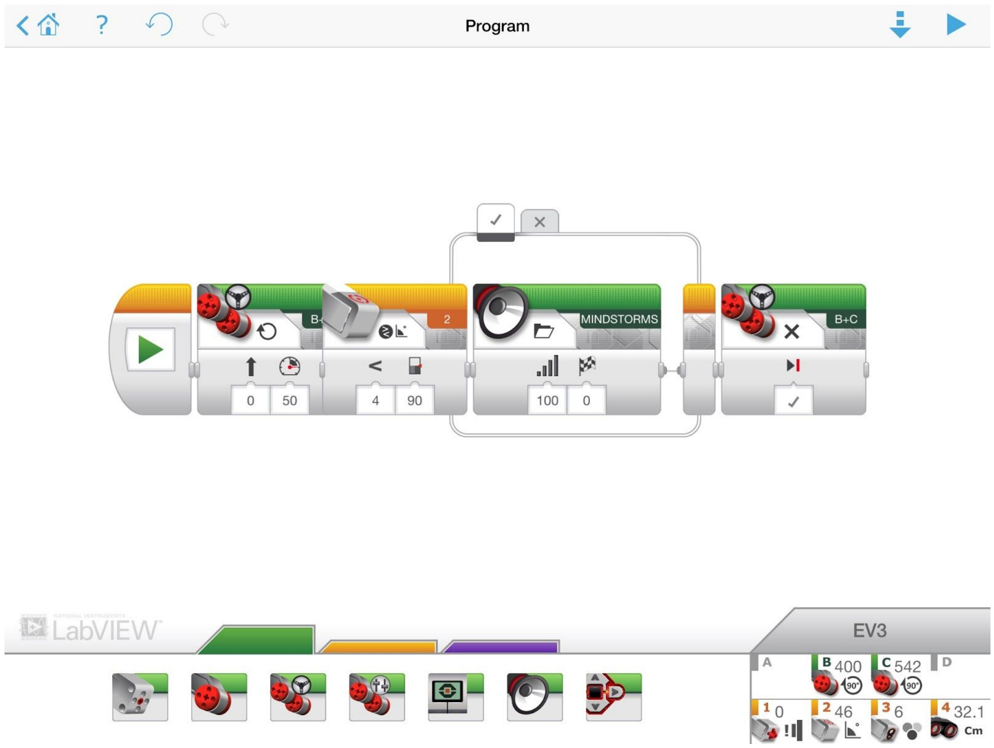

Figure 7. Mindstorms EV3 graphical programming environment by LabVIEW

Robotic HomeLab kit

Robotic HomeLab is an AVR microcontroller based inter-related set of modules that are contained in a portable case. Various mechatronic and robotic experiments and exercises can be carried out with Robotic HomeLab kit, ranging from a simple flashing light to a complex device construction. Robotic HomeLab is primarily intended for schools and universities, as it includes methodological materials and exercises with solutions in addition to hardware. Robotic HomeLab kit has been integrated into a web environment, which is aimed for students and teachers to boost interaction between each other. In short, the Robotic HomeLab kit is a mobile tools suite with the purpose of learning and practicing at home, school or workplace.

Robotic HomeLab kit has been developed by Tallinn University of Technology and Estonian company ITT Group in cooperation with European partner universities and Leonardo da Vinci program support. Robotic HomeLab modules are bundled into different kits. The basic suite, which teaches simple digital input and output operations, is called Robotic HomeLab Basic kit. The Add-on kit contains a set of sensors, motors and modules for different experiments and communication experience.

The Robotic HomeLab Basic kit and Add-on kit modules can be successfully used as a robot base platform and other mechatronics control systems. VirtualLab and DistanceLab give a significant value to Robotic HomeLab solution, allowing Robotic HomeLab hardware platform to be used through the web.

Figure 8. Robotic HomeLab kit

Arduino Starter kit

Arduino Starter kit walks through the basics of using the Arduino in a hands-on way. It consists of several creative projects. The kit includes a selection of the most common and useful electronic components with a book of 15 projects. Starting with the basics of electronics, moving on to more complex projects, the kit will help you control the physical world with sensor and actuators.

Figure 9. Arduino Starter kit

Raspberry Pi

The Raspberry Pi is a series of credit card-sized single-board computers developed in the UK by the Raspberry Pi Foundation with the intention of promoting the teaching of basic computer science in schools.

Figure 10. Raspberry Pi robot

Society and robotics

Robotic fields have attracted the attention of numerous educational, scientific and industrial parties during the last decades. Having started incredible growth and spread around 1960s, mainly in the United States of America, due to its inarguable contribution to the science, technology and society, robotics research continues to affect almost all aspects of human beings' lives. The applications of robotics research and technology could be categorized into the areas of manufacturing, healthcare, etc., each of which having significant advantages, as concisely introduced and discussed below.

Robotic systems, despite human workers or operators, offer high level of accuracy, precision and repeatability. In other words, human beings can never perform as accurately as robots since they possess limited odometry capabilities, and do not have the competence to distinguish intricacies to more than a certain extent. On the other hand, they are considerably prone to making mistakes due to, for example, tiredness, anxiety or anger, which is tantamount to unsatisfactory repeatability.

Besides, robots perform much faster than humans, especially when designed and controlled optimally. Although initially demanding thorough investigation and exhaustive manipulation of the parameters involved, once having reached the desired combination of the available options, robots usually work reliably, even under conditions that might be considered harsh for humans, with a reasonable certain amount and level of regular check and maintenance. For instance, robotic mechanical manipulators, being of serial and parallel types, were considered a classical type of robotic systems, which led to a bloom in the manufacturing industry, and hundreds of researchers devoted their research career to optimizing their design and control, aiming at the highest possible degree of dexterity and manipulability. Moreover, they function constantly, meaning that, in spite of human workers, they do not need any break or rest, except in case of failure.

Robots also save human lives through obviating the necessity of them being present in, either expectedly or unexpectedly, dangerous working conditions. More clearly, they are much more robust than humans in terms of sustaining physical and mental pressure or sudden variations, if correctly designed as such. Furthermore, robots are capable of performing tasks in both miniature and gigantic scales. The former concerns micro- and nano-scale electromechanical systems, which have various applications, such as the ones connected with medical treatments or surgery, while the latter might offer possibility of lifting giant objects or creating such forces that could never be even imagined to be done by humans. Finally, when it comes to functional efficiency and gain, robots are obviously preferred to humans – they can operate with minimum waste or loss.

All in all, robotic systems are opening their way to infinite domains of experimental and practical applications and affecting almost all branches of science and technology either directly or indirectly. From another perspective, one could think of it as a phenomenon influencing all the people's lives in many senses. Therefore, inevitably, for making the world a better place, sooner or later, every person will have to familiarize themselves with robots, and incorporate them into their living circumstances correctly. Especially educated people are in more urgent need for being equipped with such a knowledge and information, which is of paramount importance in most of the fields of study. For the latter reason, it seems necessary to try to involve students in robotics-related activities as soon as possible, for example starting from high-school.

Estonian model

In Estonia, school robotics is mainly a part of extracurricular activities, but there are some initiatives where robots are being used as a compulsory part of education. One of the examples is facultative course of robotics and mechatronics. The whole concept is built on a cycle. You can download the summarizing presentation at the end [10].

Robotic theatre

If schools want to start with educational robotics, the first thing they do is invite "Robotic Theatre" to school [8]. During a 45-minute interactive lecture with robots students are introduced the basics of robotics, laws and shown a real theatre in the end. It is usually followed by a workshop where groups of up to 24 students can make their first program and drive the robot through an obstacle course. The idea of this road show and workshop is not to entertain kids but to show students, teachers and schools' board members that programming and using robots is not difficult. The aim is to raise awareness and build interest towards ICT tools. Robotic theatre always visits schools that already have the robots to encourage them, see their progress and help with problems.

Trainings

After the theatre, we offer teachers a free two-day training. After the training, participants should have developed a way to think with robots, not to know how everything works. Having passed the first-level training, teachers can return after a year to take part in the second-level training.

Teachers are shown new opportunities of how to connect robotics more with curriculum in math, physics, biology, chemistry and informatics.

Robots

Schools should have their own equipment, which is always a tricky part since robots are not cheap. In Estonia, schools have usually been fiscally supported by governmental or third party institutions. The percentage of the support has been from 50-80%. Preconditions for the support are usually having a trained teacher and taking part in competitions.

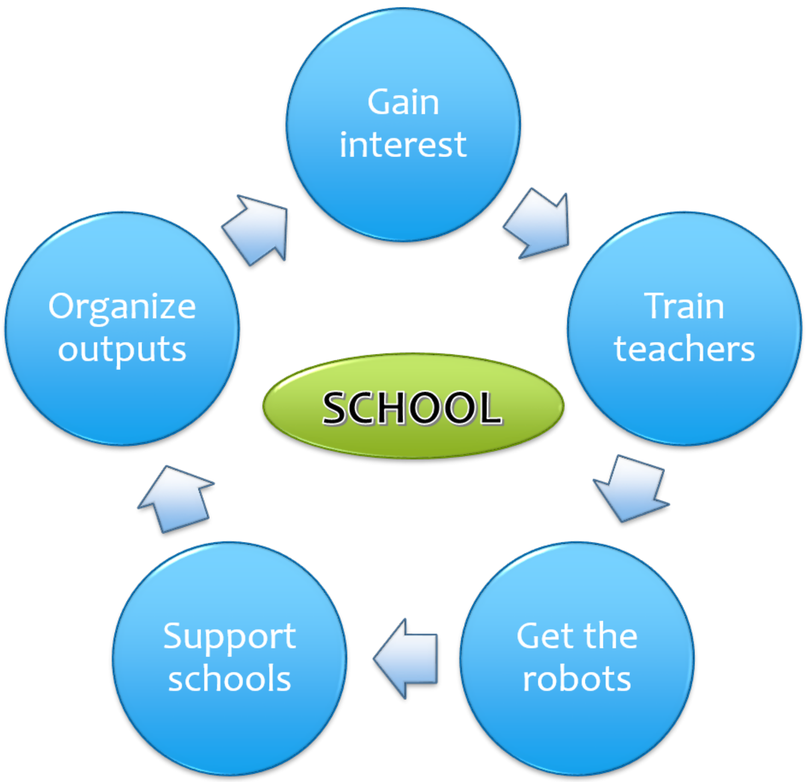

Figure 11. Concept of educational robotics in Estonia

Support

The support is provided by materials for students and methodology for teachers. Additionally, teachers can contact specialists to ask about problems they encounter in classroom with robots. There is also an e-mail list available to ask for help concerning different issues or to share good practices.

Organizing outputs

Teachers, kids and schools are not left alone to work with robots and materials. They are encouraged to take part in competitions and programs. It is important because it follows CBL methods. Usually schools spend the whole school year filling their robotics course with preparing for some competition.

Official curriculum for Estonian gymnasium level robotics

State curriculum Annex 4

Detail information and downloads see here [11, 12]

4.2. Cross-border elective-course "Mechatronics and Robotics"
Short description of the Course The course deals with the basic concepts and systematics of the robotic- and mechatronic system, application fields and specifics of these systems, general base of the equipment design; integration of the mechanics, electronics and software; introduction and overview of the sensor technology on the use of the general principles of the sensors; introduction to microcontrollers and programming; introduction to actuator systems and their working principles and composing of the mechatronic system concept. The course is modularized, enabling to organize practical hands-on projects and robotic competitions between schools or special projects. Teaching and learning is supported by the methodology specially developed for mechatronic teachers and supporting environment in the Internet. The course consists of four integrated modules which are supported throughout by practical exercises and teamproject.
Objectives of the teaching and training in the gymnasium The course applies that a student: 1) acquires an overview of mechatronics and robotics in the world and in Estonia; 2) has an interest in the field of technology; 3) knows structure and components of the robotic-systems; 4) is able to solve simple problems in the technical field through the mechatronics and robotics; 5) acquires an overview of the various sensors and motors and knows their operation principles; 6) is able to use and program microcontrollers; 7) is able to document and present their work; 8) acquires and embraces a “do-it-yourself” concept.
Learning outcomes At the end of the course the student: 1) knows mechatronics and robotics terminology, basic concepts and fundamental principles; 2) knows the structure and physical working principles of the various sensors and actuators; 3) is able to select, according to requirements, a suitable mechatronics component; 4) is able to program microcontroller using at least one programming language; 5) is able to produce and design a simpler mechatronic system; 6) is able to document the product; 7) is able to introduce and present the product to a wider audience;

8) is motivated to educate him/herself and continue the study in the field of engineering sciences.

Learning Content
Design of the Mechatronic and robotic system: peculiarity of the design of integrated systems; planning the work, safety; design tools and software; robotic components, including electronic components; finding suitable components and reading data sheets; documentation and presentation of the work.

Microcontrollers: different microcontrollers and their architecture; structure and instructions of the microcontroller; microcontroller programming, debugging and compiling of the program.

Sensors: an overview of the sensors and their application area; digital and analog sensors; analog-digital converter.

Actuators: electric motors, DC motor control (H-bridge, speed control); servo motor control (pulse width modulation); stepper motor control; overview of the alternative actuators (linear motor, solenoid, artificial muscles).

Practical project: building a robot or a practical mechatronic system.

Learning Activities
Each topic contains an introductory theoretical overview, followed by practical exercises (except the first module). After the last topic, the course continues with practical work - a team project, which may be a robot or another practical problem that can be solved with the mechatronic- or robotic system. The results of teamwork will be presented periodically to other teams and the instructor. Project development, technical solutions and problems encountered are presented during project demonstrations.
The course ends with the presentation of the result of the practical work (eg. robot competition, demonstration of the working solution, etc).

Activities:
1) Practical exercises with microcontroller;
2) Practical exercises with sensors and motors;
3) Team work (2-3 members in a team): preparation and design of a simple mechatronic system;
4) Gathering information from the Internet and manuals (thematic forums, pilot projects and video material);
5) Creativity activities: developing a solution to solve some technical problem;
6) Teamwork skills development: time and workload management, methods of problem solving, budgeting;
7) Presentation of the work (if possible, to a public audience);
8) Design of innovative projects.

Physical Learning Environment

For a practical hands-on training, a computer and mechatronics / robotics educational kit, which includes modern programmable microcontroller, sensors and actuator systems is needed. Depending on the practical project team, additional resources and tools to reach a solution may be needed.
Recommended software:
1) Microcontroller programming IDE;
2) Software for electronic circuit design;
3) CAD system;
4) Presentation and documentation software.

Topic plan and course breakdown [9].

Robotic activities and support for Estonian schools are divided into two levels. Both levels share the same theoretical material but have different practical approach and robotic platforms. Teacher support and training courses are provided by two university-private institution groups which are working together.

Level I Introduction of robotics

Descriptions: First-level course is designed for students who haven't had any contact with technology and robotics. The chapters are easy to read and explain core principles in abstract level. This level is suitable for middle and high school. In the practical part, students have a choice of selecting task that fits their skills. There are 2-5 practical tasks in each section with an increasing level of difficulty. They solve the tasks with LEGO robots as in this case they do not have to worry about incompatibility of hardware and they can concentrate on programming and designing.

Level II Robotics & mechatronics

Descriptions: The second level of robotics is designed for gymnasium and vocational school to offer more professional level of robotics. When pupils are introduced to robotics by LEGO based platforms and everything has been fun and playful, then the robotics moves on to more difficult level by introducing the microcontroller platforms, industrial sensor technology and programming languages. Learners can build flexible small robotic system with real components and develop systems which are very close to market oriented products. However, most of the practical work is still carried out in playful and fun style by developing different robots for robot competitions or simulating some industrial systems in smaller scale.
This level is mainly supported by Robotic HomeLab kit hardware but can also be supported by Arduino, Raspberry Pi and others, when teachers pass training courses, get teaching materials and other relevant support.

Prerequisite: Firt level passed or technology oriented class or strong interest in robotics
Platform: Robotic HomeLab kit, Arduino, Raspberry Pi or other controller based platform
Online available materials: http://home.roboticlab.eu

Published books in local language:

1. Microcontrollers and Practical Robotics, Raivo Sell, Mikk Leini, Peeter Salong,2010
2. Mechatronic and Robotic Learning Situations, Ed. Raivo Sell, 2013
3. AVR Microcontrollers and Practical Robotics, Raivo Sell, Mikk Leini, Rain Ellermaa, 2015

Development and support:

- Tallinn University of Technology, Estonian Engineering Pedagogy Center
- ITT Group OÜ, Robolabor.ee

Teacher trainings and collaboration

Teacher training in Estonia is divided into two levels based on hardware platform and the experience of the target group. Both levels have inner structure where some of the materials are common and some different.

In addition to standard courses, special summer schools are organized every year with the support from HITSA. Summer schools usually take place during August, when teachers are getting back from their vacations, but are not overbooked with school activities yet. Summer schools are very much recommended because it gives a chance to communicate in an open environment. The training last up to two days. It is targeted for teachers that are new or have little experience in educational robotics, although this is not a rule. It is always useful to share experience and knowledge among teachers.

Following schematics presents an overview of teacher training concepts applied in Estonia and supported by HITSA, meaning that all courses are free and, in some cases, even obligatory for robotic teachers in general schools and vocational schools.

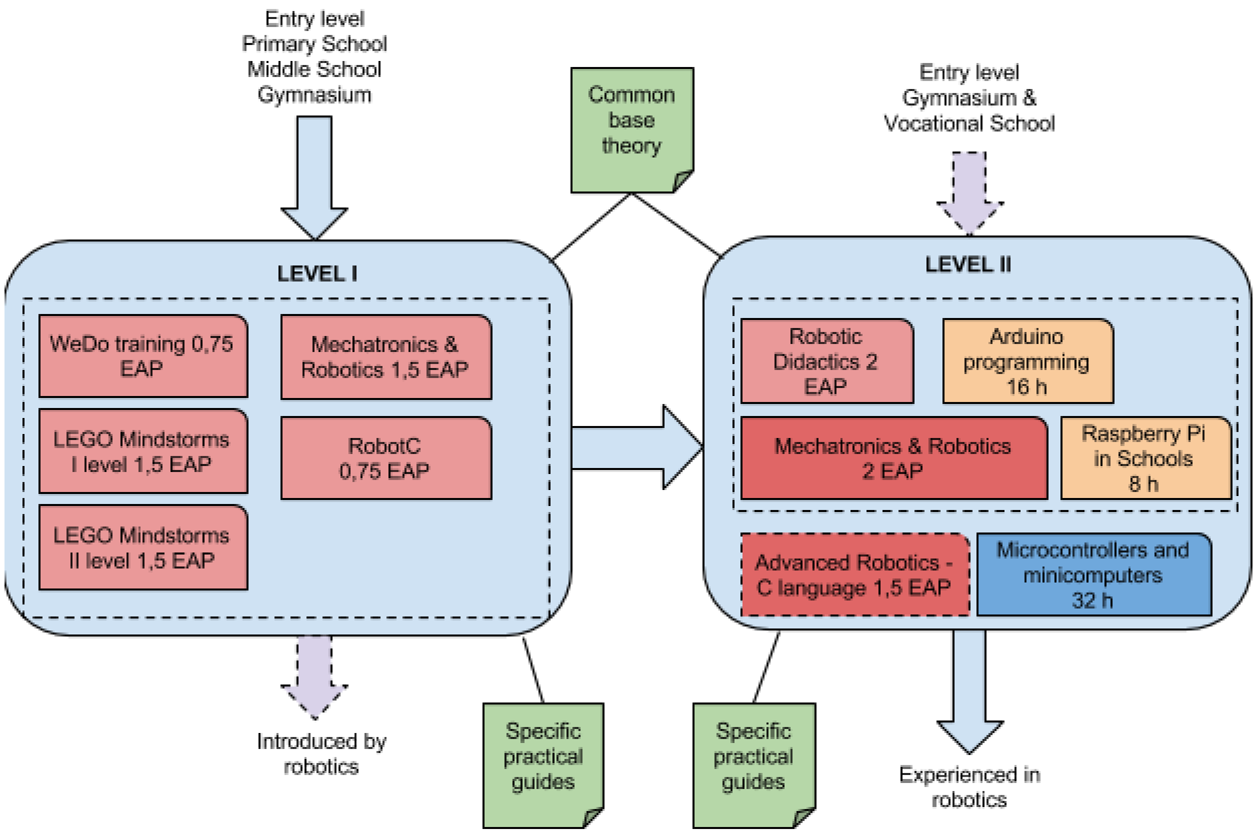

Figure 12. Robotic teacher training concepts applied in Estonia

Level I

WeDo: this one-day training is oriented to kindergarten and elementary teachers to show opportunities and ways of how to teach math, logic and develop sequential skills with this robotic kit. As WeDo is a very simple hardware (one motor, two sensors), it does not take long to understand the programming logic. More important than the hardware, is the methodology teachers learn.

I level Mindstorms: this two-day training is for new teachers that have no experience in robotics. Teachers need to have basic computer skills. After the training, teachers know how to use LEGO Mindstorms programming environment and understand the basic programming logic with block programming. Teachers are also presented methods of using kits in extracurricular activities. Teachers work in pairs just as it is recommended to do in classroom setting.

II level Mindstorms: this two-day training is targeted to teachers that have at least one-year experience with robots and students. Extra opportunities of programming environment (data logging, analysis) and sensors from third parties are presented in the second-level training. History has shown that not all teachers feel need to take part in second-level training and some teachers come back to first-level trainings.

Mechatronics and robotics course: this four-day training is targeted to experienced teachers and is divided between LEGO Mindstorms and Robotic HomeLab kit. The purpose is to introduce materials of the course and get a hands-on experience in level, manageable by teacher's personal aspect. It means that every lesson has a number of assignments that have different difficulty levels. Teachers have to do one task, but they can choose appropriate level according to their skills. It assures that they can receive help from the trainees and still learn something.
FIRST LEGO League (FLL) coaches' training: this one-day training is for teachers that are interested in taking part in FLL (www.firstlegoleague.org) program. It includes basic values of the program, methodology of guiding kids, robot game introduction and making an eligible project research.
Programming in C: this training is oriented to teachers who feel that they and their students want to learn more about programming.

Level II

Robotic Didactics/ Microcontrollers and practical robotics
A four-day training session based on RTLC and Robotic HomeLab kit

- Didactics of Robotics
- Robotic Teaching and Learning concept (RTLC)
- Microcontrollers and robotics - an overview
- Algorithms & Crash course of C programming
- Robotic HomeLab kit hardware platform
- Analogous and digital signals
- User interface - practical work
- Sensors and motors - practical work
- System development
- Practical robot building and competition

Arduino programming
A two-day training session for teachers who wish to use Arduino microcontroller platform for their robotic course.

- Introduction to robotics
- Digital i/o
- Analogous and digital sensors
- Motors
- Arduino hardware - microcontrollers and shields
- Arduino programming language and IDE
- Practical work
- Wired and wireless communication
- Building an Arduino robot

Raspberry Pi for teachers

- Overview of Raspberry Pi and its functionality
- Desktop solution
- Mediacenter
- Server (LAMP & video)
- Wiring up the Raspberry Pi and installing op. system
- Raspberry Pi general purpose input/output ports
- Python programming language
- Practical application
- Simple security system as practical work

Microcontrollers and minicomputers

- Overview of minicomputers and microcontrollers
- Functionality and comparison of minicomputers
- Application examples in school environment of minicomputers
- An overview of minicomputers and microcontrollers
- Functionality and comparison of microcomputers
- Application examples in school environment of microcontrollers
- Practical work with minicomputers
    - Mathematica and Wolfram language
    - Sonic Pi
    - Scratch + GPIO
- Practical work with microcontrollers
    - Programming environments
    - Algorithms and programming in C
- Robotics with microcontrollers
    - Robotic HomeLab kit
    - Arduino platform

In addition to directly robotics-related courses there are several teacher training courses which support Robotics.

The role of projects to support School Robotics in Estonia

A lot of educational robotics has been supported by different projects. From a positive side, it gives more freedom to choose activities and there are more sources for financing. On the other hand, negative aspects are that it does not create sustainability - reporting and writing applications takes a lot of time. Another issue is finding a self-financing part, it is not very easy.
Robotics has been a way to introduce science and technology and engage students in learning STEM subjects. This has been a national priority and robotics gives an opportunity to do it.
There is a list of programs that have been supporting educational robotics in Estonia such as TEEME and TEAME. During these projects, there are:

- held competitions

- developed e-course for secondary school level
- developed robotics gateway for students www.robootika.ee
- developed extracurricular and curricular materials
- teacher trainings

Finances

Robotics is a hands-on type of course and there is always hardware involved. Hardware is in most cases expensive and needs special attention. In Estonia there are two preferred hardware platforms although schools are free to choose and apply to grants for co-financing.
Co-financing grants can be applied from sponsors, local authorities, school's roof organizations or governmental organizations. The last one is used the most in Estonia, through the special foundation dedicated to promote and support ICT and engineering fields in Estonia.

Supporting the purchase of robotic hardware was firstly initiated by Tiger Leap foundation in 2008.
Schools and vocational schools were able to apply grants for co-foundation in the amount of 50%.
During the depression year the support was raised up to 80%. Currently, after restructuring of governmental foundation, the support is managed by HITSA (Information Technology Foundation for Education) and schools can apply once or twice a year for 60% of co-funding the purchase of the robotic hardware kit. The co-finance is currently managed under ProgeTiger sub-programme in HITSA.
When applications are selected and co-funding granted, applicant schools agree to send teachers to training sessions (also financed by the same organization) to ensure effective use of hardware and establishing robotic course.

Conclusions

In this ePublication, Estonian experience and the basics of educational robotics was described. There are two main robotic platforms that are used in schools: LEGO MINDSTORMS and Kodulabor. Both offer support in the form of teacher trainings and materials starting from year 2008. From Estonian point of experience, there is not much of a difference of what robotic platform school decides to use, as long as it is designed for the right age. Materials are equally important and development should be a continuous process. That is why using new platforms in schools should be carefully considered - not all of them have high level of help and user guides. The ideas that teachers could use in their lessons are very much needed. During the project, within this ePublication was created, universal materials for lessons were developed. The materials are teacher-friendly and based on real-life robotic assignments called RoboQuests.
The result will be public for everybody in English, Estonian, Swedish and Finnish.

Multimedia

Video & Animation references

- Remote Lab Portal demonstration: https://www.youtube.com/watch?v=sU5aBKzF_3g
- Robotic HomeLab kit demonstration: https://www.youtube.com/watch?v=Ua3E-vQhSNU
- Teacher training on II level of mechatronics in Estonia: https://www.youtube.com/watch?v=1s9FNAZMHM0
- FIRST LEGO League competition in Estonia: https://www.youtube.com/watch?v=sruRIJU0628
- Competition with multiple disciplines: https://www.youtube.com/watch?v=dpsRbc0L7Qk
- LEGO MINDSTORMS EV3 tutorials: https://www.youtube.com/watch?v=2r-ZsRBcLSk&list=PL_1XYe297U5IwOnaDRg2wzJsnn0UHUWRW

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9. National course curriculum https://www.robootika.ee/?page_id=195
10. Presentation about educational robotics in Estonia https://www.robootika.ee/wp-content/uploads/2015/09/ICT_Heilo.pdf
11. Official gymnasium state curriculum, https://www.riigiteataja.ee/akt/114012011002
12. State curriculum Annex 4 https://www.riigiteataja.ee/aktilisa/1290/8201/4021/2m_lisa4.pdf