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Science Club activity at Székely Mikó High School

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Abstract. The aim of the Science Club is to organize workshops that improve the technical and IT competence and skills of students. These transcurricular activities are based on STEM topics, Arduino applications, robotics and space research, which are not included in the school curricula. Through these activities, students are acquainted with the latest results of science and technology, which they can apply in practical workshops. The achievements of the Science Club (Arduino controlled meteorological station, minisatellite, rescue and fire robot, etc.) show that these activities can motivate students to participate more effectively at classroom activities in order to learn theoretical subjects and later choose a career in this field.

1. Introduction

In addition to the rapid development of technology, the renewal of education is becoming increasingly important. In order to achieve this one needs to use challenging methods that reveal the creativity and innovative ideas of students. The Science Club's Robotics class provides the students with the opportunity to apply theoretical knowledge through inquiry (IBL) and project-based methods (PBL) to create autonomous and controllable devices.

Therefore, at the start of the Science Club program (at the beginning of the school year), a preliminary assessment of the students background knowledge has to be made in order to explore their interests on what they would like to learn about the proposed subject. The applied questionnaire could be divided into 3 parts with 3 questions each. The first group consists of questions about the prior knowledge of the students in terms of microcontrollers, self-controlled devices (what a sensor is, how microchips are used, measuring principles in electronics, and operating systems). The second set of questions relates to the background knowledge of electricity (voltage, power, resistors, capacitors, semiconductors); and the last section examines the ideas students have related to the topic of robotics (intelligent-brick, Wi-Fi communication, controllable sensors). The pre-test results show that students are very curious (62%) but they lack the sufficient knowledge in the field of smart bricks, microcontrollers or Arduino platform. Almost two-thirds of the respondents (71%) do not know how to apply the learned physics laws (resistors or capacitors network, Ohm law, etc.) in building a robot. Based on the conclusion of the survey special activities for the robotics group is organized. To accomplish these goals problem and project-based method are used. The activities are not directly related to any school subject but they are transcurricular and challenging for learners. Applying the project-based method the main objective is to build an autonomous robot, which is able to carry out a pre-programmed mission without any human intervention or design measuring devices to carry out scientific research with them.

The students are divided in small groups, 4-6 people each (8-10th grade) lead by a mentor student (11-12th grade). During the project, the following steps were taken by each group in order to accomplish their tasks:
- Formulate the problem that has to be investigated and to be solved using the robot, or formulate a question, which has to be explored with the measuring robot; brainstorming.
- Gathering the necessary information about the topic: they acquire basic knowledge about electrical circuits, measuring principle, Arduino microcontroller, sensors, data collection and analyzing procedures, programming languages and mechanics of the movements. This is an intense learning phase, where their theoretical content knowledge (Ohm laws, active and passive circuit elements, dynamics and movement laws, atmospheric physics, etc.) is applied in a concrete practical situation. Simple circuits are designed and built by the students using few elements: power supply units, a variety of resistor networks, switches and measuring instruments with suitable accuracy. The outcome of this process is that the learned theories are fixed and, in the meantime, are enriched with practical skills.
- Planning, designing the robot circuit, the mechanical structure and the algorithm for the commanding software.
- Robot building phase consists in drawing the circuit and selecting the appropriate sensors (using the datasheets and technical characteristics) then soldering the elements, finishing and uploading the software and finally verifying its operation.
- Testing the robot; the students have to perform the first measurements or the proposed tasks (avoiding obstacles follow a colored line, extinct fire, move or collect color balls throughout the track, move heavy objects, measure air parameters, etc.). If it is necessary, the robots could be improved, some elements could be changed, the software could be refined to make measurements that are more accurate.
- The finished robots can strictly measure and process the collected data. A considerable step in data processing is the graphic representation, interpretation and tracking the data over a long period. As a result, the conclusions are much precise and could be verified, combined with the knowledge learned at physics, biology, chemistry or geography classes.

2. Science Club and Arduino controlled robots

The mentor students have been already working with Arduino and Redboard for 4 years. The younger students (14-15 years old) are starting their work with the learning phase, led by the mentors. In the introductory lessons the basic theory of electrical circuits, microcontrollers (without internal structures description, semiconductors, and microchip theory), and sensors are explained. Youngsters are also taught how the datasheets are used for active electric components to design new measuring or dynamic devices. The students from upper secondary school also learn about the internal structure of the Arduino board, communication protocols between microcontrollers, the operation of the sensors and the development of the software for their robots.

Figure 1. The Arduino Uno board.

The most used electronic element in our project is an Arduino Uno board (figure 1), which is a microcontroller, based on the Atmega328 processor. The Arduino is an open source electronics

platform with easy-to-use hardware and software that can be adapted in a variety of interactive school projects, while helping to understand semiconductor physics.
Over the last school years, we have built a variety of controlled devices, successfully using active learning methods that have benefitted the students. In this paper, we would like to present some of these devices, especially those that helped the students to acquire new knowledge and hands-on skills to develop these devices.
The first of these devices is a mini satellite (CanSat, figure 2), which performs a scientific task while modeling the operation of a real satellite. This is a device that is fit in a 330ml soda can and flown at 1km altitude, where measures the basic atmospheric parameters. The most challenging task for students was to design a flying device, which could be launched on a specified altitude with an intruder rocket, and to send the measured data back to the ground station and return safely on the surface of the Earth. The unit was designed for modular construction, each unit performing a well-defined task at the command of a proper control software.

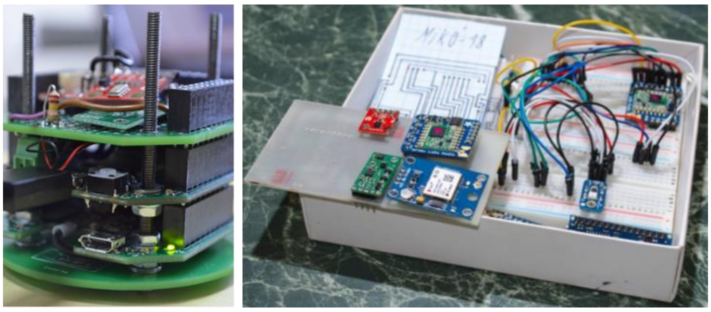

Figure 2. The CanSat (designing and building a minisatellite).

We used the knowledge gained by the construction of the satellite and the ESA CanSat contest to build a mini weather station (figure 3). The task for one of the groups was to build such a station that can be fixed on the top of the gym of the school and provide continuous measurements.

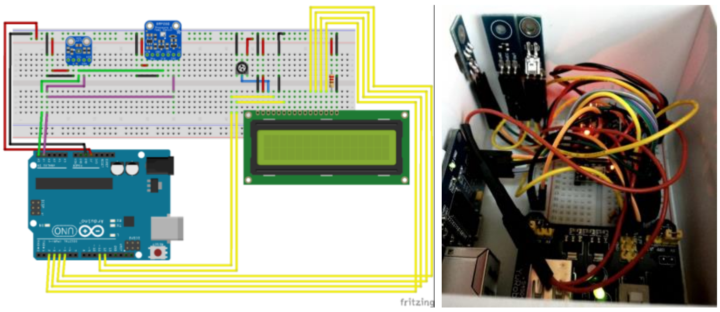

Figure 3. Mini weather station (from design to final product).

The sensors built in the weather station is acquiring and sending measurements of relative humidity, pressure, temperature, solid pollution, and UV index for the ground station, which is located in the physics lab of the school. For developing the controlling software the Arduino environment with wiring library was using. This is based on C/C++ language. The software, written by the mentors, has the task to run all the data collecting and analyzing processes. With this control program, the primary sensors can be activated and it sends the gathered data to the computer and also the dedicated webpage (figure 4). The collected atmospheric data is analyzed and used for classroom activity at Chemistry, Biology, Geography classes and/or several other school activities, which help to understand the thermodynamic processes in the atmosphere and the influencing factors of the weather.

Figure 4. Air pressure and temperature diagram on mini weather station webpage. (http://globalweather.000webhostapp.com/index.php)

One of the first self-designed robots was the line-follower robot (figure 5), which was built by the students for RoboChallenge International Robotics competition. This project used the mechanical skills of the students to create a controllable electronic car.

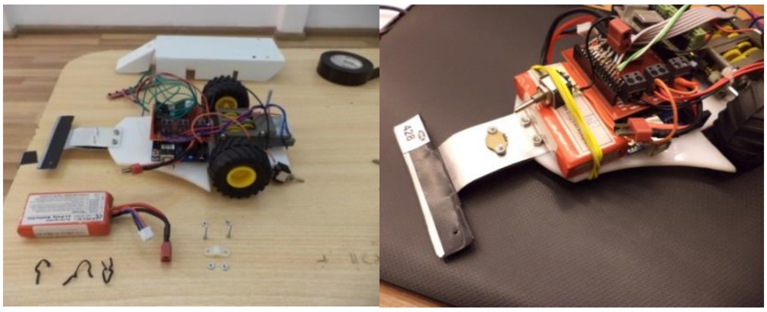

Figure 5. Line follower robot.

During the design and build phase students have met a real challenge: how choose the leading engine and the wheels to get the highest speed to complete the race. Meanwhile, the vehicle travelled steadily following the black (or red) line: it did not leave the track neither in sharp bends. Another issue was that the color and distance sensors had to measure the path precisely and control them so that the robot does not stop under any lighting conditions.
The most complex robot we have built is a life-rescue robot that won the second prize at the International Youth Innovation Competition (figure 6). This robot was designed to help rescue teams by exploring disaster-stricken and difficult-to-reach areas. The robot-mounted sensors send information about the detected terrain (position of obstacles, presence of smoke and toxic/flammable gases, temperature) and on the other hand about the status and position of the robot (water level, battery charge level, gyroscope and vibration sensor).

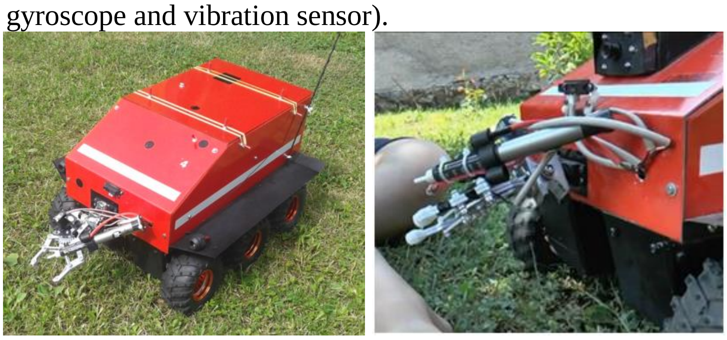

Figure 6. The Lifebot (made by R Krecht).
The Lifebot also has a wireless IP camera that sends live footage about the examined area and the potentially injured people. When the vehicle is launched, the camera turns on and transfers the images

to the command computer via a wireless router. The router is connected to the control unit where the collected information is displayed in the browser window by the control software developed using C# Windows Form: pulse and body temperature of victim, position. If it is necessary, the medical unit can decide about the emergency intervention. It is also possible to activate the robot-arm mounted on the front section of the robot in order to administer an analgesic injection.
In addition to the Arduino robots we have built and programmed Lego robots with lower year secondary students. For them the aim was to learn the use of smart bricks since they already know the world of Lego-games. First of all, the young students gained practical skills by participating in a project-based learning process as they acquired new knowledge while solving a task with the built-in tool.

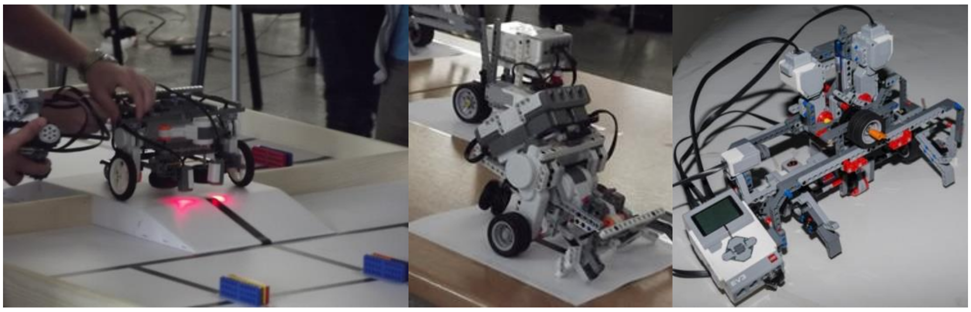

Figure 7. Discoverer, loader, drawing Lego-robots.

The smart brick programming is based on functional objects, which facilitates the learning process because it combines the task to be accomplished with the programming element.
The smart brick programming is based on functional objects that facilitate the learning process because it combines the task to be accomplished with the programming element. During the construction of a Lego rover students had to learn how to choose the best suitable tools for they purpose; set up the control programs after deciding what task should the robot perform and what strategy to use for it. It is essential to teach them that developing the right strategy is only possible if the task, which has to be performed, is defined precisely. The building process will guide step-by-step them from setting up the problem to the solution. Successful completion of the task means that they have found the solutions, which effectively combines theoretical knowledge with practical and engineering skills.

3. Conclusion
This creative STEM process performed with students involved in the Science Club helped them to deepen their understanding of the internal connection between the theory taught at physics and IT classes and those practical, technical applications. The students enjoy these activities because they participate actively and innovatively in every phase of the project. The results of the project-closing test (which repeats the questions of the initial one) shows that completing at least one of the projects provide students with serious practical and theoretical knowledge. The answers given to the questionnaire show that most of the students (78%) have learned the basics of microcontrollers and those easy applications; and they are more confident in using the theory to solve practical tasks.
During these projects, they have learned:

- Research and time management – how to carry out a scientific project from planning through design, to final product;
- Problem-solving and communication skills;
- Designing and building a robot;
- Teamwork, collaboration abilities and self-management.
- Manual work skills (soldering, drawing a circuit diagram, drilling, molding, etc.);

- More physics content: mechanics, atmospheric physics, electronics, electricity;
- IT skills and different programming languages: Arduino software, C++, icon-based software, C#.

The students take part unconstrained in these activities with strong motivation, because this is a funny and pleasurable opportunity of learning.

4. Acknowledgements

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