Robotics in Elementary School using the BIT microcontroller

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Abstract. Primary education is the first stage of compulsory education and aims to create equal opportunities for all children to achieve a balanced cognitive, emotional and psychomotor development tailored to individual needs. The paper presents informal activities implemented for elementary school students to familiarize them with simple sensors, actuators and BIT microcontrollers that can be programmed with simple software. The activities were carried out in four working groups, organized in the classrooms, the participants being pupils in the third grade. Activities began with a description of the term “robotics” and a short film showing the importance of educational robots. After the introduction into the world of robotics, high school students, member of NanoTech Robotics Club, implemented interactive activities for elementary school students using Micro: Bit microcontroller and simple sensors.

Keywords: elementary education, BBC Micro:Bit, creativity, robotics.

1. Introduction
Because technology cannot be excluded from the modern education of the child, however, it is required at least moderate relationship with it. The question "When should we begin talking to children about robots, taking into account the fact they are already present in theirs and our lives?" should be summarized to "How can we introduce robotic concepts to children in a beneficial and educational way?"

Robotics offers a unique way of studying science, technology, engineering and mathematics, while inspiring students to pursue a career in these fields. Learning with and for Robotics allows the development of students’ creativity, critical thinking, innovation, and accumulation of experience in several scientific fields and technologies [2].

Integrated approaches to STEM (science, technology, engineering, and mathematics) education are increasingly popular, but remain challenging and elusive. There is much hope that integrated approaches to STEM education can help the next generation of students to solve real-world problems by applying concepts that cut across disciplines as well as capacities of critical thinking, collaboration, and creativity [3].

Implementing Robotics in elementary school has seen a rapid increase in recent years in many developed countries. In Romania, such activities are not in the curriculum and the majority of the initiatives are local or regional, and is done by volunteers not by trained teachers. The robotics became more accessible to the teachers and students due to the robot kits available on the market. The LEGO company educational products have greatly contributed to the development of excellent activities bringing children into STEM's mysteries since early age [4].
According to a Euractive study, 17 countries in the European Union have already introduced programming courses in schools (Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Ireland, Lithuania, Malta, United Kingdom, Poland, Portugal, Spain, Slovakia, and Hungary). Of these states, Belgium, Estonia, Finland, France, Great Britain, Portugal, Poland, Spain, and Slovakia have decided that these courses should be included in the primary cycle. Another 12 states will introduce these courses in high school as beginner courses (for students that didn’t study it in primary school) or as the continuation of the courses from the primary classes. The purpose of these courses is not to influence children and adolescents to choose a career in programming, but rather to give them the opportunity to develop their logical thinking, to learn to find the right solutions as quickly as possible, in any situation, and to lay the foundations for a skill required in almost every job - the efficient use of a computer (digital competency) [5].

In the US, legislation regulates education so that all states have adopted or are to adopt computer science courses in schools. In September 2017, in 44 of the 50 states already is taught in schools the basics of computer science and programming, and the other 6 states are adopting and adapting the legislation. Depending on the state regulation, children learn the basics of “programming using objects at primary school level or familiarize with programming using different languages at high school level [6].

In Romania, secondary school students take a compulsory course in IT and ICT that sustains digital literacy efforts and recon consider this concept from the perspective of new socio-professional requirements offering a relevant curriculum in order to form a set of digital skills, which each student can use during their school years and in their active life [7]. All high-school students take a compulsory ICT (Information Technology and Communication) course that ensures the acquisition of computer usage skills and knowledge and of computer programs with applicability in the professional introduction environment targeted by graduates that took up studies in this field; also in technical education high schools there are professional qualifications such as Mechatronic Technician, Operator Technician in industrial robots, Processing numerically controlled machines Technician. These professional qualifications contain technical subjects that highlight the programming of sensors, actuators and robots. Developing modern skills of using sensors and actuators, as well as implementing the programming skills of sensors, actuators and robots could be also achieved through informal activities such as robotics clubs, electronic circles. Examples of such informal activities in our country are: Logiscool Romania, the programming and robotics club for kids and teens (in Bucharest, Alba Iulia, Cluj-Napoca, Craiova, Pitești, Ploiești, Râmnicu Vâlcea and Timișoara), robotics workshops and programs based on modern learning methods (Academy of Robotics, Invent Academy.ro etc.), Another Future programs launched by Microsoft Romania which is among the most important projects for students created by a private company in our country [8]. These activities use Lego Mindstorms kits (NXT, EV3) and the Arduino IDE development environment. There are also many schools that succeeded with a financial effort from the parents to promote robotics among students by creating robotics clubs. In these clubs’ activity there are used the Arduino IDE development environment and Lego Mindstorms EV3 robotics kits.

2. NanoTechFun robotics club activities for elementary school students

To support and encourage students’ passion for electronics at "Saint John de la Salle" Technological High School of Pidcesti, we decided to set up a club, the Robotics Club - NanoTechFun. The main objective of the club is to introduce and implement for high school students, vocational trained in Electronics activities with and for new technologies based on sensors, transducers, actuators, microcontrollers, and robots. The initiative was discussed in details with stakeholders and experts in the field of STEM education before to survey the motivation, needs and expectation of students using a special designed questionnaire [9]. The analysis of pupils’ responses demonstrate that students have low general and specific knowledge about sensors, actuators and robots. The collected data about previous experience of students on acting in clubs was decided to organize the club by settling with students’ help the statute, rules and plan for activities. In the instructors, volunteers and experts refined the documents and helped with implementation.
Since it has been created, the club has had a wide area of activities, participating with its products at several contests and it took every opportunity to present its activities to stakeholders and public at large. Among the works can be mention: “Color sorter Robot” [10], "Air quality spy” [11], “LED propeller display with Arduino” [12], “Robo mission” [13], “Arduino speedometer” [14] A series of Lasallian NanoTechFun club as “Reaction time” [15] and “Für Elise on Arduino” [16] were presented during the open door weekend school event and in the Romanian – American Lasallian exchange programme.

The LEARNING BY DOING practical activities of the NanoTechFun robotics club use the ARDUINO platform, a development board specific to robotic systems, to familiarize the vocational high school students with sensors and actuators world, the basic elements in automation and the development of intelligent machines. The Lego Mindstorms EV3 educational set that allows the construction of robots with different execution and learning structures is also used. The BBC Micro:Bit microcontroller that can be encoded in Microsoft MakeCode (blocks), Javascript, Python, Scratch, and more languages became a last venue in club activities.

The club’s members of NanoTechFun Robotics at the St. John of La Salle Technological High School Pildesti Romania decided to develop a series of attractive and interactive activities for elementary school students using the BBC microcontroller (Micro: Bit) in order to promote Mechatronics and Robotics to the youngers. Some schools in the region were the target for after school informal sessions designed for elementary and middle schools students.

3. Programming and playing with BBC MICRO:BIT
The BBC MICRO:BIT device is a powerful, fully programmable computer with a GO MB158 GO microcontroller with 32-bit ARM Cortex-M0 architecture, equipped with 5 x 5 LED array, a magnetometer, an accelerometer, and temperature sensor, digital / analog and power pins, Bluetooth and USB connectivity, two programmable buttons and can be powered either via USB or an external battery pack. It can be encoded from any web browser in Blocks (Microsoft MakeCode), Javascript, Python, Scratch, and more [8].

The activity was based on simple, block-based programming projects using Microsoft MakeCode based on workbooks (Micro: Bit, Bit on Micro: Bit and Smiley and Micro: Bit Bit) by primary school pupils with the help of club members. The elementary school students became aware that the microcontroller “can to control and to do many things.”

4. Activities design and implementation
The purpose of the informal activities was to familiarize elementary school pupils with the concepts of sensor, actuator and microcontroller, measuring and taking decision with the main aim to stimulate their curiosity in the field of robotics. Increasing the quality of education offered to the pupils through out-of-school and extracurricular activities, giving them the opportunity to work in a team, to assume responsibilities within the group is beneficial and contributes to the increase confidence and motivation for STEM.

Educational objectives of the activity were: (i) to familiarize pupils with the basic concept of temperature sensor, actuator, microcontroller and artificial intelligence programed by humans making decision; (ii) to train pupils skills related to the programming of microcontrollers “through blocks by scratching the screen” as an easy way to “communicate with artificial intelligence”; (iii) to develop communication and team working skills; (iv) to improve logical and critical thinking and proactive attitude for innovation.

The warming up activities began with basic understanding of what is meaning a "robot" and imagining the robots world. Short movies describing the impact of the robots on our present and future world were project to challenge the child in entering in the robotics scenario. The children warmed up at high level of expectation were involved in different groups’ activities based on Micro: Bit microcontroller facilities.

The feedback of the 3rd grade (age 9 years) on the activities was collected by a questionnaire and received from 21 the pupils in the 3rd grade (age 9 year).
4.1. Reaction Time

Educational approach: the activity aims at students acquiring the concept of the electrical circuit as an assembly consisting of an electrical source (battery), wires (crocodile wires), consumer and switch. Through this activity students will be able to create a closed electrical circuit using their body as a switch. The human body is a good conductor for the electric current when touching the aluminium foil between the two poles of the battery that will allow the passage of the electric current. The processor of the Micro: bit device is attached to the circuit and can be compared with a touch screen, feeling the difference of the charge and treating it as a signal, as a command [17].

The project uses the Micro: bit to measure the pupils’ reaction times in switch off a circuit. On a cardboard stand, the students built an electric circuit made of a pin that represents the table and two pins linking our cardboard to the Micro: Bit. Pupils have to test their speed by pressing the simultaneously GND pin and the connecting pin, thus closing a circuit. Figure 1 a) shows experimental device layout, and figure 1 b) shows activity pictures.

![Figure 1. a) Reaction Time board, b) Photo taken during “Reaction Time” the activity](image)

4.2. Milk Monster

Educational approach: the activity aims to familiarize elementary school with the basics of actuator as "muscles" of mechatronic systems. The actuators execute instructions (most often receive electrical signal) and produce changes in the physical system through the generation of force, movement, heat, etc. Within the activity elementary school students became able to identify an actuator (an electric motor, a servomotor) as a basic element in the construction of robots whose purpose is to “move” or “start the robot working”. Thus, students will be able to differentiate between a motor and a servomotor by following the robot's motions. Unlike motors, which produce a continuous rotation as long as they are connected to a voltage source, servo motors are used to obtain partial, stable and controlled rotations in order to perform small amplitude but high precision operations: actuation mechanism of closing-opening, positioning sensors, performing gestures, and more [18].

Milk Monster is a small robot built from a milk box, an actuator and a Micro: Bit board. The board is programmed in Microsoft MakeCode so that when it sends a beam of light on the robot it opens its mouth, and when the beam of light is removed the robot closes its mouth. Figure 2 a) shows experimental device layout, and in Figure 2 b) shows activity pictures.
Figure 2. a) Milk Monster device; b) Photo taken during “Milk Monster” activity

4.3. MOVE buggyRobot for the BBCMicro: Bit
Educational approach: the activity aims to clarify elementary school students’ understanding of the concept of microcontroller as the “brain and control center” of the robot. Within the activity students can follow the pathway of robot decision and realize how the robot executes the instructions received by the microcontroller through a program. Students will thus be able to assign to the microcontroller role of the "brain" to the robot, because it is capable to process, show on different types of displays, and store the data [20].

The MOVE buggyRobot is a two-wheeled robot that can be controlled remotely via the Bluetooth application or by using a second BBC Micro:Bit as a controller via the radio function of them crocontroller. The MOVE mini robot is powered by two continuous rotary actuators. For the activity with elementary school students the robot was programmed to draw a circle. Figure 3 a) shows the robot drawing and in Figure3 b) is presented a photo taken during the activity.

Figure 3. a) MOVE buggyRobot; b) Photo taken during “MOVE buggyRobot” activity

4.4. Organizing group activities
After warm-up of elementary school class by presenting robots and NanoTechFun club activities group activities were implemented. The class was divided into five groups of 5 pupils and under the guidance of club members the following activities were carried out:

- *Scroll Message on Micro:Bit*: during this activity, pupils were taught how to scroll through a message on the Micro: Bit screen.
- *The Heart "beats" on Micro:Bit*: during this activity, pupils were taught how to use Microsoft MakeCode animations, while changing the luminous intensity of animations.
- Smiley and sad Micro:Bit: the purpose of this activity was to teach pupils how to use two animations that appear when the two Micro Buttons are pressed in turn on.
- Banana Keyboard: during this activity, pupils had a banana, an orange, and crocodile, clips and they had to try to play a sound that was heard in a mini speaker when closing a circuit (a circuit made of a banana, an orange, and Micro: Bit).

In figure 4 are displayed photos taken during the activity and in figure 5 it is shown an example of coding in Microsoft MakeCode facility.

5. Feedback on Activities
We designed a short questionnaire to which elementary school students responded to the following questions: 1) What did you enjoy most? 2) What didn't you like? 3) Would you like to participate in such activities? If YES, why? If NOT, why? 4) List three feelings you had during the activities.

The analysis of the answers was deduced that the students were very pleased with the activity carried out, 100% wanting to participate in such activities, because: "I want to become a programmer"; "It was interesting"; "I want to learn how to command robots"; "Robots are interesting"; "It's fun"; "I learn new things"; "Robots are cute when you know how to command them"; "It's fun and smart". The main feelings they lived during their robotic activity were of joy, happiness, interest, pride and fun.

The most important result of these activities was that the pupils participated with much enthusiasm, learned by playing, experimented new feelings by discovering, and thinking. They had the opportunity to get information about how new gadgets work, they were able to get a better understanding of how programmers think, and they could feel like little inventors.

6. Conclusions
The education in schools can no longer be done using only blackboard and chalk. Animations, experiments, didactic films, interactive games, educational software, robotics, represent the future of up-to-date education. Thus, activities of introducing students, from an early age, into the beautiful world of new technologies should be a priority for future generation education.

The robotics activity carried out by the students working in the robotics club NanoTechFun has succeeded to arouse the curiosity of elementary school students. The high school students members of the Robotics club were pleased by the active participation of the elementary schools students in these activities, they consider them successful and there is a desire to repeat such events for pupils. Other and more exciting projects are in the club activities list for the future years.

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