Development of activities to promote the interest in science and technology in elementary and middle school students

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ABSTRACT

Innovation through science and technology will be essential to solve important challenges humanity will have to face in the years to come, regarding clean energies, food quality, medicine, communications, etc. To deal with these important issues, it is necessary to promote STEM (Science, Technology, Engineering and Mathematics) education in children. In this work, we present the results of the strategies that we have implemented to increase the elementary and middle school students interest in science and technology by means of activities that allow them to use and develop their creativity, team work, critical thinking, and the use of the scientific method and the engineering design process.

Keywords: science, technology, children, teenagers, outreach.

1. INTRODUCTION

Year after year, science and technology are having a growing importance in our life, impacting the way we communicate, we produce and distribute food, water, energy and other important supplies, etc. The generation and the use of knowledge will be crucial to attain a sustainable progress, to improve the quality of life, and the means that will allow innovators to deal with global problems such as providing high quality food, efficient transportation, clean energy, health care, communications, waste management, etc.

In order to find creative solutions to these challenges, developing countries need to have more scientist and engineers. In 2009, UNESCO reported that countries like Finland, Japan and South Korea had 20, 13 and 12 scientist per thousand labor force, while Mexico had less than 2 [1]. To reduce this difference, the interest in science and technology need to be encouraged among children and teenagers by using engaging methods and tools. Fortunately, there are software [2] and hardware [3] that make easy and fun the creation of technology by means of electronics, microcontrollers, sensors, actuators, programming of mobile devices, etc.

In this work, we present a set of activities that we have proposed and implemented for elementary and middle school students as their first approach to the scientific method [4], the engineering design process [5, 6] and the process of technology creation in a fun way. By means of these activities, we want to help children and teenagers to gain knowledge, skills and confidence to allow them to stop being only technology users, and to become technology creators based in their needs and interests.

Most of these activities can be easily adapted and implemented by teachers in their classrooms.

2. METHODS

The set of activities described in this work are part of an introductory level (Level 1) that make what we have called the "Science and Technology Workshop for Children and Teens". The contents of Level 1 comprise:

- The scientific method.
- The engineering design process.

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- Electricity.
- Electric current, resistance and voltage.
- Switches.
- Resistors.
- LEDs.
- Basic electric circuits.
- The use of the protoboard.
- The multimeter.
- DC motors.
- Servomotors.
- Microcontrollers and the Arduino Uno platform [7].
- Sensors and actuators.
- Basics of programming [8].
- Arduino programming.
- Bluetooth communication between Arduino and mobile devices.
- 3D modeling [9] and printing.
- Solar cells and solar energy applications.

Groups of 12 students participated in Level 1, which had a duration of 30 hours distributed in 10 sessions of 3 hours with a 30 minutes break. In order to promote teamwork and communication, the participants worked in 4 groups of 3 students, and a minimum of 4 personal computers (one for every team) with an internet connection were needed to do the programming, for 3D modeling and to search information on Google.

Every session started with a fun experiment intended to promote in the students the use of one or more steps of the scientific method and to think critically. Some of the experiments were:

- Vinegar and baking soda chemical reaction inside a soda bottle covered with the neck of a balloon (Figure 1).
- Drawing simple working electric circuits with a battery an LED and a pencil.
- A solar motor made of plastic bottles and black insulating tape.
- Splitting the colors of light sources, including LEDs, with a diffraction grating or a CD.
- Image formation with a magnifying lens, a white paper (the screen) and a compact fluorescent light.

Figure 1: Students making an experiment intended to promote in them the use of scientific processes and critical thinking.

The age of the students for Level 1 was chosen based on our own experience working with children and teenagers, and also on Jean Piaget's studies, from where he concluded, among other things, that at the age of 12, children have the ability to formulate and to test abstract hypothesis [10]. For these reasons, we consider that Level 1 is suited to students from 12 to 15 years old. Younger students have often more difficulties programming with Arduino, but it depends on their skills, motivation and previous knowledge. On the other hand, older students often make progress faster, and can get bored or distracted because younger students take more time to complete the tasks.
At the end of the first session, we presented the following challenge to the students: to design and to build a little car capable of moving when exposed to direct sunlight. The car should be made of inexpensive materials found at home, preferentially. Every team used brainstorming to design their car, thought about the main components of a solar vehicle and how could it be implemented. The purpose of the challenge strategy was to make them use their creativity and to start thinking as engineers.

The main car parts needed to complete the challenge were:

- A chassis.
- Wheels.
- Two axles for the wheels.
- A motor to move the car.
- A solar panel.
- A transmission to link the motor to the rear axle.

From the second session on, they started to work in their projects. The car structure was made of cardboard by most teams, the wheels were made out of plastic caps from milk and yogurt bottles, and the axles were made with wood sticks and plastic straws that were attached to the chassis with adhesive tape. The transmission was a little bit tricky. Together we concluded that the power of the DC motor could be transferred to the rear axle of the car by means of a rubber band and two pulleys. A smaller plastic cap was used as a pulley for the rear axle, and was fixed between the wheel and the chassis. For the second pulley we decided to choose another solution: even though some DC motors come with a pulley attached to the shaft, we decided to use the lack of this element as an opportunity to introduce them to the fascinating world of 3D modeling and printing. Students learned how to model a simple pulley with a free and easy to learn software, suitable for students from 10 to 18 years old [9].

In the third session, and after some trials, the cars designed by the students moved under the sun, what made them very happy, proud and motivated. Once their first working car was completed, they were asked to think about what else would they like to add to their car to make it better. In that way, the new concepts and tools needed to improve their basic design were presented to the students throughout the remaining sessions of Level 1.

3. RESULTS

At the end of Level 1, the students were able to build their car, which was improved in every session. The car steering was implemented with a servomotor controlled with Arduino and an HC-05 Bluetooth module. Figure 2 shows some students testing their first prototype.

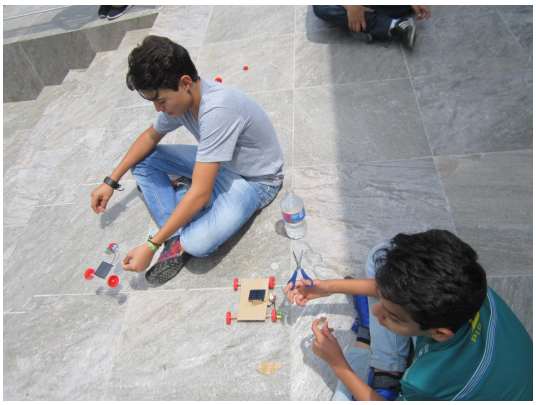

Figure 2. Building their first car that moved when exposed to direct sunlight.

Figure 3 shows the students learning the basics of programming with the help of "The hour of code" [8].

Figure 3. Students learning the basics concepts of computer programming.

Figure 4 shows some students programming a mobile app to control the steering system of their car wirelessly with their smartphones via Bluetooth.

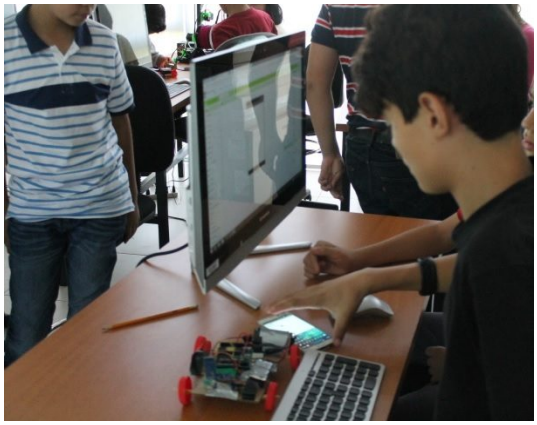

Figure 4. Students programming mobile devices to control their cars.

Figure 5 shows one of the cars finished and ready to go.

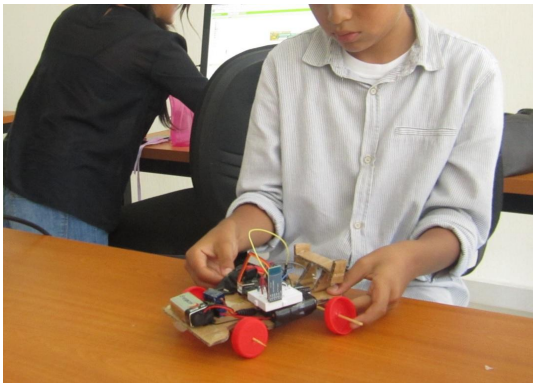

Figure 5. Students completing their final version of the car.

The last session, the students showed their cars to their families, teachers and also answered questions. They were very happy and surprised they were able to do all that.

Among the skills that were promoted in students during Level 1, we can list:

- Novel and adaptive thinking.
- Programming.
- Problem solving.
- Critical thinking.
- Communication.
- Collaboration.

These skills are very valuable and, according to some organizations, will be very demanded by the job market in the next years [11].

Throughout the sessions, we encouraged students to persevere and not to give up at the first difficulty. We let them know that making mistakes is a part of making science and technology [12], that we need to learn from our mistakes and that all the devices and technology we use in our everyday life are the result of constant improvements and innovations.

At the end of Level 1, students and their parents were requested to complete a survey, and the results showed us that they were very satisfied. Parents noticed excitement and engagement in their children during the sessions, and students asked for a Level 2 to keep learning and creating.

CONCLUSION

By means of the activities described in this work, we were able to motivate and engage elementary and middle school students in science and engineering. In order to offer them more to learn, we are developing Level 2 and 3, in which they will improve their knowledge on topics learned in Level 1, they will use more sensors and actuators, and will make experiments to learn more about the importance of light and light based technologies in our everyday life. Moreover, we are preparing another workshop specifically for children between 10 and 11 years old in which they will use LEGO robotic kits. Once they finish this level, they will have the basic knowledge and skills to participate in Level 1. We are also preparing a Teacher's guide and a kit with basic components that elementary and middle school teachers could use to

introduce their students in the fascinating subject of the creation of technology, and to contribute in this way in the early preparation of the next generation of scientists and engineers our society will need.

All over the world, people and institutions are making efforts to promote the participation of boys and girls equally. That is also one of our goals. It is necessary to change the stereotype that certain scientific and technological fields are not for women, and it can be done more easily at an early age.

Finally, we consider that, in the case these activities don't make some students get interested in a scientific or technological career, the skills developed will be very valuable to all of them, independently of the careers they will choose later in their lives. Furthermore, their perception of the benefits and the importance of science and technology will increase.

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