Fostering Science and Technology Interest in Chilean Children with Educational Robot Kits

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***Abstract*— These days stand on a digital era, where science and technology are two key concepts for understanding the fundamentals of devices people cope daily. In order to increase the population size of at least, technology-friendly users, fostering the algorithmic thinking process on children is a crucial step and has taken more relevance every year.**

This document presents the experience of a group of students highly-committed to present to children the exciting underlying concepts found on robotics, through practical sessions whose ending is marked by a national competition for school children, where the acquired solving problems skills using robotics can be tested. These courses have been extended both on impact and physical locations: some children are taken to compete at RoboCup Junior, and there has been an increasing interest of attend to these free courses on several places from all over the country.

I. Introduction

Robotics presents a novel and attractive approach for allowing children to identify some key principles on physics, math and disciplines having direct relationship with this area, such as mechanical design or electronics and programming. In order to incorporate robotics into the school curriculum for optimizing its benefits through a more formal education, teachers themselves would have to take classes in the area for becoming more confident and knowledgeable to teach children [15], but support material would be needed and its cost still remains unaffordable for many schools in the country.

On the other hand, some places are already taking educational robotics as part of its school curriculum. For instance, as highlighted on [**?**], some schools in some regions of Russia have included courses in educational robotics as optional or elective subjects, in the context of the recently launched *Complex program of educational robotics development and continuous IT-education in the Russian Federation* (2014-2020), taking this area outside the sphere of extracurricular activities. In many other schools, this approach is being introduced as an innovative learning environment where students can solve complex problems by means of enhancing their thinking skills and abilities [6].

Although practical classes are useful for acquiring the basic notions of a given topic, competitions represents an excellent scenario for encouraging students to go further on their knowledge [5], propitiating an adequate context for struggle between children on the same group and motivating an equal participation for each one of them. In this scenario, RoboCup Junior [17] provides a worldwide competition for school children, allowing them to have their first experience at international events while getting them closer and motivating them to participate in the future at the Senior leagues of this robot soccer world cup.

A key difference between RoboCup Junior and other robotics competitions is the motivating factor for students, allowing them to continuously develop their solutions while expanding their knowledge and skills [9], given that the goals of its games remains almost the same from year to year, improving the rules for enhancing the whole learning experience for participating students. Also, first attempts to find out the long-term impact of this competition on the career decisions of participants has been reported in [16].

As highlighted on [2], there are still several open issues in the research and practice of educational robotics, such as refuting the perception that robotics is hard to grasp and not inviting for most students, or the fact that most uses of robotics nowadays do not support scientific reasoning, problem solving, creativity, teamwork and communication skills. This document presents the experience coming from university students organization, dedicated to introduce school children into this exciting area while addressing both of the aforementioned problems, and motivating them to obtain more profound knowledge through a national competition (which is completely independent from the challenges of RoboCup Junior).

The remainder of this article is organized as follows: Section II presents the motivation of the problem being solved through the application of educational robotics in children, by first presenting an appropriate and brief description of the educational scheme on our country. Then, Section III describes the different courses offered and supported by our respective affiliations, as well as an analysis of the interest of children on taking these courses and how we intend to push them further and taking some of them to compete at RoboCup Junior. Finally, Section IV draws some final conclusions.

II. Problem Definition

Science and technology are directly related to the economical growth of a country. In this context, many economists consider the largest world-wide growth and development over at least the last decade as a consequence of acceleration in the diffusion of technology and world-wide access to codified knowledge [3]. Moreover, increases in science and

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technology produces a cycle of growing development, considering that countries tend to acquire international technology more readily when domestic firms have R&D programs, or there are domestic research laboratories and universities [20].

It has been emphasized that bridging the gap between developing and developed countries depends very largely on the import and transfer of technology and knowledge [10], [27]. The main challenge in a developing country is related to the establishment of industrial technological competitiveness through more traditional industrial science and technology policies including the support for engineering and design skills [11]. This issue, including the interest in science careers and the transfer of common sense using new technologies for problem solving, has been addressed from the educational robotics context in many countries [13], [14], [23], [28].

The current educational model in Chile is based in an educational reform implemented in 1965, and corresponds to a K-12 education. It starts with a not mandatory preschool level with children below 6 years old, to continue with the basic school level (K1 to K8 levels) with children between 6 and 14 years old. The scholar period ends with the K9 to K12 levels, which conform a high school level with teenagers between 13 to 18 years old. To satisfy the needs of covering subjects outside the national standard educational program, extracurricular activities were included as an important educational complement.

In 1984 with a new ordinance, extracurricular activities reached a fuller conception and definition including the establishment of appropriate norms. This ordinance defined the extracurricular activities as a complementary basic element in the educational development of children and teenagers, and that corresponds to the group of educational-recreational leisure actions that originates from the oriented and organized practice of sport, artistic, scientific, social activities, and in general to all practices that, considering the aims and goals of the national education, contributes to the development of the individual through a permanent process of creation and recreation.

Taking into account the highly economical resources necessaries for performing a national attempt to include robotics in the Chilean educational program as a standard subject, the extracurricular context is the most common approach for providing the benefits of educational robotics during the scholar period. This approach can be divided in two common implementations: while private educational institutions can afford commercial robots developed as educational kits for its own use, cultural and educational institutions as universities and non-profit foundations perform free open courses in order to reach a wider audience without considering social and economical status of the receptor students (e.g., [21]). The latter is the case of study in this document, free introductory courses on robotics for scholar students whose first implementation was in 2005, resulting in a evolved program resuming more than 10 years of robotics knowledge transference experience.

III. Robotics Courses

This section presents the methodology and a more in-depth description of the different free introductory courses on robotics offered by our affiliations. Although all of this classes have no admission fee, an initial application is required due to the limited capacity and human resources available at the time and the high number of school students willing to participate at this practical sessions.

Applicant school courses must be ranging between K7-K11, and two commitments letters have to be submitted: the first specifies a commitment to attend all the eight sessions this workshop last, and the other letter states that the applicant will assist to the national annual competition if qualified by a previous regional participation.

A. Lego Mindstorms NXT

The successful toy manufacturer brand called Lego started in the early 1930s with its founder and his son, by constructing wooden toys among other home-made objects, turning into plastic interlocking building bricks by the late 1950s [26]. Then three decades later, a collaboration between this popular brand and Media Lab from Massachusetts Institute of Technology allowed students to move their plastic creations using motors, a connection cable and a computer with the appropriate software, which rapidly evolved into the first version of a small battery-powered computer known as the RCX programmable brick.

One of the main advantages that the RCX brick presented corresponds to the infrared communication between the computer and this programmable piece, allowing this brick to store and execute the routines in remote mode, without requiring a direct computer connection. The success of this educational kit led to the next generation of programmable bricks, called NXT, with collaboration of the well-known company National Instruments and entering into the market in 2006 [8]. Finally, the current version of this programmable brick is called EV3 [25], which features a full Linux operating system on board and five new sensors, including a gyro sensor for measuring angle orientation or angular velocity.

Table I shows comparative information about the hardware specifications of the programmable device on the last three models, obtained from [8]. The reader can note its processing capabilities improvement through the models, which is a major difference beyond the number of analog or digital (A/D) input-output ports, but not necessarily plays a major role in the design of the experiences given that it is out of the scope. The objective of these classes is to help school children develop an algorithmic manner to think, while encouraging them to pursue science and technology university careers, contributing as a long-term consequence to the development of the country.

Although the first evidence of workshops for school students with Lego robots has been reported on by Martin [19], many other studies related with this platform and education can be found in literature. For instance, Church et al. [7] presents multiple example projects for teaching physics, helping students to develop conceptual understanding of

	RCX	NXT	EV3
Processor	Hitachi H8/300	Atmel 32Bit ARM 48MHz	ARM9 300MHz
RAM Memory	32 KB	64 KB	64 MB
Inputs (A/D)	3	4	4
Outputs	3	3 (motors w/encoders)	4 (motors w/encoders)
PC Connection	RF Tower	USB 2.0 (12 Mb/s)	USB 2.0 (480 Mb/s)
Rechargeable Battery	•	Lithium-ion	Lithium-ion

TABLE I
COMPARATIVE INFORMATION ABOUT LEGO MINDSTORMS KITS

(a) Course at 2005

(b) Course at 2015

Fig. 1. Lego-based courses

physics principles through the process of investigation, data analysis, engineering design and construction by specifically targeting the topics of speed, acceleration, simple harmonic motion and sound waves.

The first workshop at 2005 started with one undergraduate student willing to share its Lego programming experience with other university students, using the RCX programmable brick and NQC as programming language [24]. Then, the next semester the course increased its extent to high school professors and students, which later some of them enrolled in this university and wanted to help the organization and teaching committee. Last year, 564 school students were taught to program the NXT platform all over the country, with a group of 45 undergraduate students doing organization and mentoring labors, but most importantly leading under the same first organization ideal: a group of students that changes over time but its objectives and projections remains the same. Figure 1 shows a typical session of this course at 2005 and 2015.

This course consists on eight practical sessions, whose direct learning objectives can be summarized as follows:

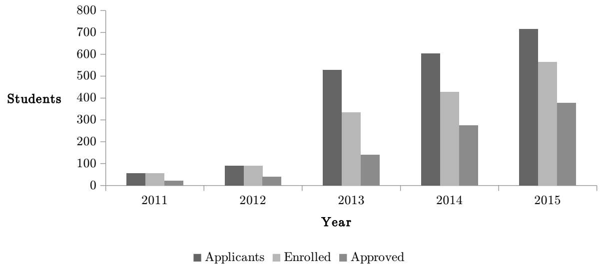
- Recognize different elements that compose the field of robotics, appreciating its results as a consequence of the interaction between other academic areas.
- Formulate a methodology to code on a given language (currently NXC [12]).
- Program a robot for allowing it to navigate with basic movements, including line trajectory tracking and obstacle avoidance.

In order to achieve the expected learning results at the end of the course, the eight sessions involves the following practical experiences:

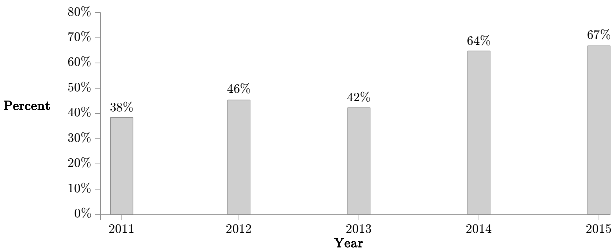
1) This session is meant to introduce and motivate children in robotics, by themselves programming basic movements using NXC. A previously constructed Lego robot is expected to move from one site to another, by performing basic movements without obtaining feedback from the environment.
2) On this second session, notion of variables and conditional sentences are introduced. The Lego robot has to follow a trajectory given by some black marks over the surface, and at the end of this path the robot choose randomly between make turns or continue straight ahead for a fixed amount of time, depending on the value of the respective variable.
3) This class explains the difference between analog and digital sensors. Students have to program a robot capable of following a line path on the surface and detect an obstacle by using touch sensors.
4) *While* loop is introduced in this class, and more sensors are presented. The robot has to be programmed such that while tracking a line trajectory, have to detect up to three randomly located obstacles of different size.
5) This session corresponds to an intermediate challenge and implies a qualification grade depending on the obtained performance. The robot is supposed to track a black-line trajectory and identify two different obstacles, where depending on this object it would have to be moved to the right or to the left side of the path. Sonar, touch and light sensors are allowed for this challenge.
6) This class presents a practical experience such that an output has to be switched between two constants, introducing the hysteresis concept.
7) This seventh session introduces the *until* sentence, for repeating a task until a predefined condition is met. In this experience the robot starts at a green-coloured surface and has to perform a line following task until getting into a bifurcation, choosing its path depending on whether the right or left touch sensor has been pressed.
8) This eighth class corresponds to a final challenge, and serves as a qualification phase for the national competition for school students. This national contest is held

once a year, and represents the first opportunity to have a robotics competition experience for many children on our country.

Every year there are more children interested in taking this course. Figure 2 shows the quantitative information of the increasing interest on applying over the last five years, as well as the improvements on teaching this course, reflected on the percentage of approved students, highlighting that the explosive increase on 2013 has been possible thanks to the support of one of our affiliations, being immersed into the Robotics program of Fundación Mustakis.



(a) Applicants, enrolled and approved students



(b) Approval percentage

Fig. 2. Evolution of the course over the last five years

B. Arduino

Arduino platform is composed both from a development environment and an electronic board, and the idea of this platform was to create inexpensive and simple tools for non-engineers to create digital projects [4]. There exists several models of this board depending on the processing capabilities or the number of digital-analog input-output ports, as well as number of ports supporting PWM generation. A brief comparative analysis between two popular Arduino models is shown in Table II.

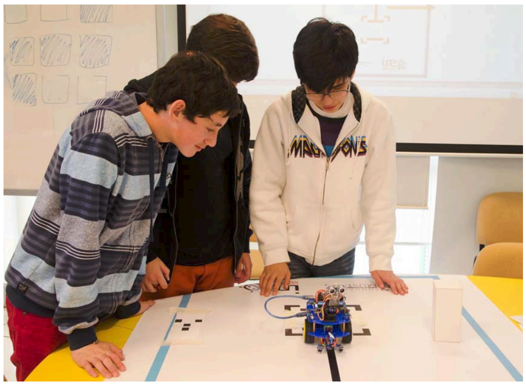
	Uno	Leonardo
Microcontroller	ATmega 328	ATmega 32u4
RAM Memory	2 KB	2.5 KB
Digital I/O	14	20
Analog I/O	6	12
PWM Ports	2	7
Flash Memory	32 KB	32 KB

TABLE II

COMPARISON BETWEEN ARDUINO UNO AND ARDUINO LEONARDO

Arduino Uno was chosen because of its size, cost and appropriate processing capabilities. This board is a popular

(a) Iroh robot



(b) First course on 2015

Fig. 3. Intermediate course using Arduino

choice for several applications, such as work by Mynderse [22], where Arduino Uno is used for teaching a mechatronics course in Senior/Graduate level and consists on six lab assignments with topics ranging from state machine design and implementation to sensor and DC motor integration with a microcontroller.

It can be found several other works in literature using this board for educational purposes, such as Albrecht et al. [1] that incorporates Arduino into a computer science undergraduate curriculum, or Kornuta et al. [18] which uses this development board for providing an open-loop control of a digital peristaltic pump in order to study lymphatic biomechanics in vitro.

This course starts on 2015 because of the increasing interest of children in acquiring more experience in programming robots and participating in these activities. Then, children approving this intermediate course have the possibility to continue participating with the principal mentors of this initiative in order to prepare themselves for RoboCup Junior.

The robot used on this course, shown on Figure 3, is called *Iroh*, and features a 2WD mobile platform compatible with Arduino Uno, with a sensor shield using sonar for obstacle detection, infrared sensors and a capacitive touch sensor.

This course also consists on eight practical sessions, whose direct learning objectives can be summarized as follows:

- Interact more precisely with some of the already identified elements that compose the field of robotics, like facing hardware difficulties when doing a sensor calibration, or debugging a given code when it does not work as expected.
- Formulate a methodology to code multiple tasks in the Arduino development environment.
- Program a robot for allowing it to navigate through a line trajectory path by using three infrared sensors, while avoiding obstacles.

In order to achieve the expected learning results at the end of the course, the eight sessions involves the following practical experiences:

1) The student is supposed to be able to code already on this first session because of the previously approved basic course, so the Arduino development environment is presented. The robot has to track a line trajectory and avoid obstacles detected with an infrared sensor. Obstacles have to be removed from the path using a servo as a lever.
2) The second session introduce the different kinds of sensors and its corresponding configuration mode, emphasizing the calibration steps required to operate under certain circumstances. The robot has to track a line trajectory and read a barcode on the surface for deciding which path should take next between three possibilities.
3) This class presents different debugging options through a LCD screen or an USB serial port. The activity remains the same as in the previous session, but this time students have to incorporate debugging routines and show on the LCD screen the path chosen after reading the barcode.
4) Session 4 introduce the notion of counters, and a line trajectory following strategy using three infrared sensors. Then, the practical experience consists on reading the barcode and following the line trajectory using this three sensors, noting that variables and counters must be used.
5) This fifth class intends to put all together before the intermediate challenge. Students have to program the robot in order to read a barcode, follow a line trajectory whose path depends on the previous code, by using three infrared sensors and defining functions with debugging routines shown on the LCD screen.
6) This sessions corresponds to an intermediate challenge related to follow a line trajectory and taking decisions according to the patterns found on the surface.
7) This second to last session introduce additional difficulties on the line trajectory following task, adding bifurcations and crossings for choosing the correct path. Also, gaps are randomly introduced on the line trajectory and there is a double barcode.
8) This eighth session corresponds to a final challenge, and serves as a qualification phase for the national competition for school students. This national contest is held once a year, and children on this level do not compete with those on the Lego course.

C. *RoboCup Junior*

Both of the previous courses end up with a robotics school competition each semester, where performance of participating teams ensures them a place on the national robotics school tournament. Despite this fact, students who have won any of these competitions not necessarily participates into the RoboCup Junior team.

Attending children who have taken the basic and intermediate course, and still have more curiosity and want to push further their knowledge in robotics are invited to participate at our RoboCup Junior team, called *Mustabot*. Given that more advanced mentors are needed in order to accomplish this task, there is needed an special preparation of classes, and also there is limited vacancy so other children are invited to attend other courses.

At 2014 Mustabot team won the Best Presentation and Electronic Innovation Award, while last year the team shown on Figure 4, composed by different students won the Best Integration System Award, both on the Rescue League. Far beyond the happiness of children for competing and being awarded, they all presented an enormous satisfaction feeling because of the experience obtained and improvement on their technical and communicational abilities.

Fig. 4. Mustabot team at 2015

IV. Conclusions

Authors have described the activities taking place on their affiliations, concerning to practical robotics courses for K7 - K11 children, developed since 2005. The goal of these activities is to foster the interest on children in science and technology, by developing extracurricular school activities related to these two areas.

More than 500 school students enrolled into the basic course just in the last year, with children from all over the country. Since data presented shows a growing behavior of the number of applicants each year, the space and equipment capacity is expected to continue evolving as well.

A more in-depth analysis about the long-term impact of these courses remains as future work, and we are currently collecting data in order to study the real impact of this experience into students decisions for choosing a technology-related university career.

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