Exploring Creativity and Sociability with an Accessible Educational Robotic Kit

Silvia S. C. Botelho, Lilian G. Braz and Ricardo N. Rodrigues
Center for Computational Science
Federal University of Rio Grande
Rio Grande, RS, Brazil
`http://www.silviacb.c3.furg.br`

***Abstract*—This paper presents a pedagogical proposal for Robotic in Education. The approach explores the creative aspects and social consequences of the collective project of robotic devices. A set of steps that compose the proposed methodology was applied to Brazilian schools. A robotic kit available is also presented, allowing its implementation even in schools with low budget.**

I. Introduction

New technologies have a big impact in the way modern societies live. For example, the way people communicate is everyday more centered around the internet. Online services like instant messaging, social networks, video streaming, etc have not only allowed for a reinvention of traditional ways of communication but have also created totally new ways of socializing. In a similar way, the education of children in schools has been directly influenced by new technologies. For example, online searches have substituted the traditional encyclopedia researches; projectors and smart boards have taken the place of blackboards; educational video-games have been used to stimulate creativity and curiosity, etc. The use of these technological tools in schools can improve the quality of education and help to prepare students to a technological society.

Another technology that has been used in education is robotics. Robotics is the science that studies the creation and programming of machines that perceive and interact with its environment. It is a naturally interdisciplinary field, involving concepts from mathematics, physics, mechanics, electronics, informatics, engineering and psychology. The use of Robotics in Education (RiE) allows students to learn a broad range of concepts through the construction and/or manipulation of robots. It has been successfully applied in several schools worldwide, being used from small kids education [16], [7] to graduate level classes [14]. Kids, in special, tend to show a big interest in robots, making it an excellent motivational tool for low grades education.

RiE has a great potential to improve education, but there are some open issues that still need to be addressed. In this paper we focus on two main issues: first, as new technologies bring new benefits to our society, it raises an issue of democratic and equal access to these technologies. High costs can make the implementation of RiE in some schools inviable, specially in poor countries, where economical resources for education may be scarce. As education is one of the main factors that can change this reality, it is important to adapt educational technologies to be as accessible as possible, so they can become viable to a broad range of schools. However, most implementations of RiE make use of educational robotic kits developed by private companies, which can be too expensive for some schools, limiting their access to this technology.

The second main issue with RiE is that traditional pedagogical methodologies may not be appropriate to maximize the benefits of RiE. Schools and educators may have to reformulate their existing pedagogical methodologies or create new ones that can explore the full potential of RiE. This change represents a big challenge for educators since it is still not clear which practices are effective to its implementation, managing and evaluation.

In this paper, we present two main contributions to the field of Robotics in Education that are directly related to the issues described above. First, we present an open source robotics kit that can be constructed from simple objects and scrap material, making it accessible to a broad range of schools. Next, we propose a new RiE pedagogical methodology that focus on students socialization and creativity through the design and construction of robotic structures.

The rest of the paper is organized as follows: in section II we present an introduction to the field of RiE and analyze the main concepts that are important to our work like accessibility, pedagogical methodologies and design in RiE; in section III we propose the construction of an open-source accessible robotic kit that can substitute private companies robotic kits; in section IV we describe a detailed pedagogical method for RiE; in section V we report and analyze some workshops that have been conducted to evaluate the proposed robotic kit and methodology; finally in section VI we present our final analysis, conclusions and future works.

II. Robotics in Education

Robotics in Education (RiE) has been proposed since the 80s and has been successfully implemented by several schools worldwide. The work of Papert [11], with his pioneer LEGO/LOGO project, is considered a precursor of several works involving RiE. It is strongly based on the constructivist educational theory, which support that most learning is achieved when ideas and thoughts are materialized in the construction of something concrete.

Most pedagogical methodologies for RiE make use of standardized robotics kits, which consists of sets of hardware pieces and tools. Some robotics kits, as well as their pedagogical methodologies (when available), are summarized bellow:

- **GoGo Board**[15] Library of open source electronic devices. Can have multiple use. Students can construct their own projects or start with available projects. Different programming languages are supported. Does not provide a specific pedagogical methodology.
- **Topobo**[12] Robotic toy consisting of building blocks where some components have kinetic memory, which can record a sequence of movements from an initial hand-moved example. This simplify robots programming, removing the need for a computer-based programming interface and allowing for a slow transition between static building blocks to moving robots. Several teaching methodologies are possible: free play, robotic puppeteering, collaborative group construction, problem guided project, etc.
- **LEGO**[2], [13] Educational assembly kit composed of static and moving parts. Several versions are commercially available. For example the NXT 9797 kit is composed by 431 pieces like blocks, beams, axels, wheels, gears and pulleys. The electronic components are composed by sensors, motors and the NXT programmable microcontroller, which support three motors and up to four sensors. The programming is done trough a sequence of icons in a visual programming interface, called Mindstorm. Several teaching projects are suggested in the LegoZoom magazine following a specific pedagogical methodology.
- **VEX**[4] Provides software, hardware and classroom resources bundles for construction of advanced robotics systems. Provides standard curriculums with focus on science and engineering learning. Strongly support robotics competitions between students as a motivational tool.

The acquisition cost of these kits is one of the main factors that restrict the implementation of RiE in some schools. With exception to the GoGo Board, all kits above are from private companies. [5] presents a comparison between some private kits, including a cost estimation. In order to make RiE more accessible, some researchers have proposed the development of cheap open source robotic tools. For example, Miranda [9] proposes a low value robotic kit called RoboFacil and a visual programming interface, called ProgrameFacil. In the same line, Gonçalves [6] proposes a low cost robot reusing electronic scrap, what reduces costs and gives support to an environmental education.

Many robotic kits, including the ones proposed by Miranda and Gonçalves, tend to have a bias toward technical education, focusing on the science and engineering aspects of robotics. According to O'Malley [10], children show interest to these aspects only if they are already motivated by science and engineering activities. We believe that independently of the robotic kit, the pedagogical methodology should explore the kit at its maximum, supporting the key aspects of learning without focusing only on technical aspects. However, very few robotics kits provide a suggestion for a pedagogical methodology that can guide educators on how to explore it efficiently.

One of the most popular robotics kits is Lego, and is accompanied by a suggested pedagogical methodology. Due to its popularity and relative maturity we adopt this methodology as a baseline to evaluate our proposed methodology. The Lego pedagogical methodology starts with the presentation by the professor of a theme/problem to be solved by students in groups. The projects show a specific intention that vary in each activity. Each student within a group assume a specific functions among the following: presenter, organizer, constructor or programmer. The projects themes are suggested in a periodic magazine, which contains thematic introduction to the problem, a step-by-step assembly/programming guide and suggestion for further questioning and project extension. A teacher's version of this magazine also includes further details and classroom strategies suggestions, such as debates, interviews, internet researches, etc.

Note that the main educational focus in the Lego methodology is in the proposed theme/problem. In other words, all activities revolve around the main theme; the robotic kit is mainly used as a tool for teaching the concepts related to the theme. The focus is not in the technical aspects of robotics, which (for the intended purpose) is the ideal situation. However, the design process of the robotic devices is also hidden (since a step-by-step solution to the problem is given), so all the creative thinking and deep reasoning involving the design of a robotic device is not worked with this methodology.

According to Lopes [8], design is a fundamental part of RiE. New concepts are not learned by simply copying a project that is already constructed and does not require creative thinking [8]. By giving students a practical activity that merely reproduce something that has already been built and tested, reducing their action to assembly and testing of a pre-defined prototype, the RiE looses its reflection, investigation and transformation characteristics. Lopes proposes that, given a theme/problem, students creativity be explored trough an initial drawing of what is intended to be constructed, indicating the parts and explaining its functionalities. However, Lopes does not provide a detailed methodology, with explicit practices and procedures, only recommendations, which are used as foundations for our proposed pedagogical methodology.

III. Accessible Robotic Kit

We emphasize that low buying-power should not impede schools from implementing technological education projects. So to make RiE more accessible, we describe in this section the construction of a robotic kit using scrap material and low cost components. The kit is divided in three main parts: the building blocks, which are the components used in robot assembly; the electronic hardware board, which is used to

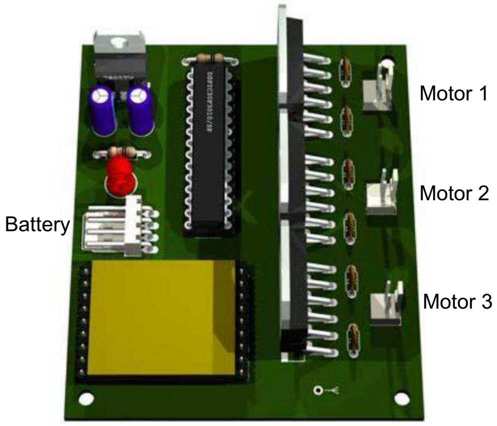

Fig. 2. Electronic board used to control the robot.

Fig. 3. Programming interface used to program the robot.

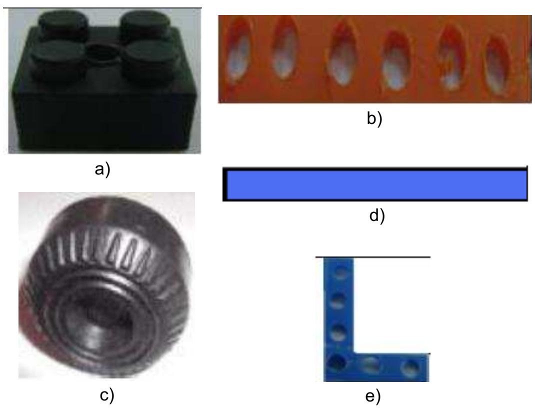

Fig. 1. Basic blocks that compose our robotic kit.

control the robot; and the programming interface, which is used to program the robot.

A. Building Blocks

Figure 1 depicts the main building blocks in our kit. Other components can be freely introduced into the kit as needed, however we identify these components as the basic structures necessary to most projects. In order of appearance we have: a) block, which can be purchased in toy stores, used in basic structures assembly; b) beam, made from wood sticks (ice-cream sticks, wood scrap) with carved holes, allows for connection between parts; c) tires, can be purchased in toy stores or adapted from bottles cap, buttons, etc; d) axel, made from wood sticks, allows for transmission of forces between engines and gears; e) angled beam, made from pieces of wood, used in projects that require angular change.

We suggest the components be available in different sizes and that a color scheme be adopted to represent components of different sizes. Beside these building blocks, the kit also includes tape, small electric engines, rubber bands and other tools (scissors, glue, etc).

B. Hardware

We have developed an electronic board to control up to three motors. The hardware design is open source and is available for download at http://www.nautec.c3.furg.br/SABERLANDIA. The board stores a sequence of actions programmed by the user and then reproduce these actions at a latter time without the need of a computer. The upload of instructions (program) into the board controller is done through serial port and the power alimentation tension is 110V or 220V. Figure 2 depicts the electronic board.

C. Programming Interface

Figure 3 shows the open source programming interface we have developed. Using the graphical user interface buttons, students can create a sequence of commands (movements) that will be sent to the robot. The interface is intuitive, simple and does not require the knowledge of any programming language, allowing students to focus only on the development of logical and algorithmic thinking. The program and its Java source code can be downloaded from http://www.nautec.c3.furg.br/SABERLANDIA.

IV. A Detailed Pedagogical Methodology for RiE

In this section, we describe a new pedagogical methodology that explores students creativity and socialization skills by focusing on robotics design. Similarly to the Lego methodology, our proposal follows a constructivist approach, where students learn by implementing a concrete project. However, in our proposal, neither the project solution nor the steps necessary for its implementation are well defined in the beginning, as we argue that these steps contain key aspects to stimulate creativity and logical thinking.

The project starts from a main theme, which can be suggested by the professor or students. This theme should allow for the construction of some robotic device to solve a proposed problem. The pedagogical methodology consists of five main steps:

First Step - Virtual Sketch. The objective of this step is to stimulate the curiosity, interests and doubts related with the main theme. Students should individually draw a first proposal with their ideas about the solution to the problem. After this, students gather in groups and share their individual ideas. Each group should discuss, exchanging and improving their ideas, and then present a final collective proposal, which can be a refinement of some student proposal or a novel proposal. Note that this step has a strong social component, where each student should defend their ideas and listen to others.

Second Step - Functional Sketch. The virtual sketch proposed by the students usually lack details and do not include mechanical (engines, gears) nor logical components. Therefore, in this step the groups are asked to refine their proposals, thinking and expressing the needs and the operating characteristics of the virtual sketch.

Third Step - Concrete Sketch. First, the available technological resources (educational kits, alternative material, scrap, etc) are presented to the students. The groups should identify the main components that will be used in the construction of their projects, taking into consideration the available resources. Using this information, students may modify or/and adapt the functional sketch, creating a concrete sketch, so it can be built in practice. This step is based on the construction of knowledge through a concrete idea, as defended by Papert [11]: "Better learning will not come from finding better ways for the teacher to instruct, but from giving the learner better opportunities to construct."

Fourth Step - Prototype construction. The groups should collectively implement their solutions as drawn in the concrete sketch, working out creative solutions to eventual problems that may appear. The constructivist learning methodology is directly applied in this step, where children can finally put in practice the ideas they have been working. This follows Papert's idea, that states that learning is improved if students can construct something concrete, like for example, a scale model, a software, something that can be seen and analyzed.

Fifth Step - Presentation. We suggest the groups prepare a final report showing the final robotic system as well as the project evolution process, pointing out strengths and weaknesses in the project.

V. Evaluation

We present a set of four workshops developed to evaluate the proposed educational kit and methodology. The workshops main themes were: trash compactor, tower, claw and mascot. As mentioned before, we use the Lego methodology together with the LEGO-MindStorms robotic kit as a baseline for comparisons. The workshops qualitative analysis presented here is based on a large collection of data consisting of on site observations, pictures, video recording and students reports. A total of 60 projects were analyzed. All parts involved in these workshops (students, student's legal responsible, teachers and school) have been properly informed on the research scope and have signed the appropriate release forms.

A. Workshop 1 - Trash Compactor

In this workshop, we follow the project from Legozoom magazine, year 6, volume 4, where the main objective was to build a trash compactor. The class named fifth grade "A", composed of 24 students (8 boys and 16 girls), has been oriented following the suggestion in the magazine. Meanwhile, the class named fifth grade "B", composed of 27 students (14 boys and 13 girls) has been oriented following our proposed methodology. In this workshop, both classes have used the Lego/Mindstorm robotic kit so only the pedagogical methodologies will be compared.

Analyzing the behavior and results of class "A", which followed the Lego pedagogical methodology, we observe the following:

- The students within a group have worked collaboratively, helping each other in several tasks. This observation is in agreement with Bonals' affirmation [3]: "students can learn more and better if they are allowed to face the learning processes together, specially when they can reach a specific objective and work as a team".
- All eight groups have successfully constructed the robot as suggested in the magazine. However, only one group have extended the project to solve the challenge proposed in the magazine (this challenge would require students to change the project and create a new solution without having access to a step-by-step guide). Moreover, seven groups have reported to successfully completed the project, ignoring the suggested challenge. This situation relates to [1], where the students follow the manual in a mechanical way, without attention to the underlying concepts, making the extrapolation of these concepts difficult.
- All teams where very conservative in their programming approach, strictly following the suggestions given by the teacher (as indicated in the LegoZoom magazine) without risking a different approach. Once again, we observe that when students are given a "straight line" to the solution they tend to focus on this path without thinking alternative solutions. The steps trough this line become their target and not the search for the best path.

On the other hand, analyzing the behavior and results of class "B", which followed the proposed methodology, we observe the following:

- The same level of collaboratively work as in class "A" has been observed.
- There has been a big variation in the project solutions. For example, figure 4 and 5 show all the phases of two distinct groups. In the first group, the idea was to have two rotating gears that would compress the trash. On the other group, the idea was to have a weight based compressor. Other ideas included a hammer like smasher and a jaw like compressor.
- Most groups had difficulties in making the electric motors work as intended, so many demonstrated their projects by manually moving gears or parts. When some students were questioned why they had difficulties, once they had been in contact with the Lego kit for 3 years, they

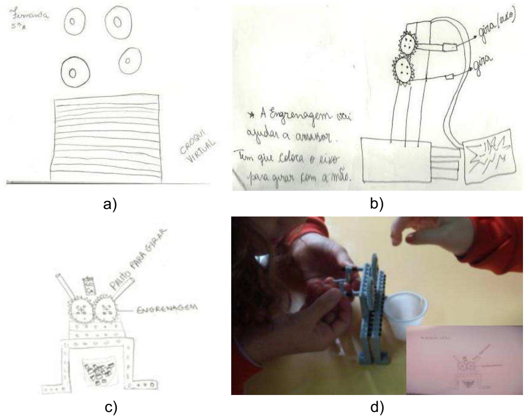

Fig. 4. Group 1 project. a) Virtual sketch; b)Functional sketch; c)Concrete sketch; d)Prototype.

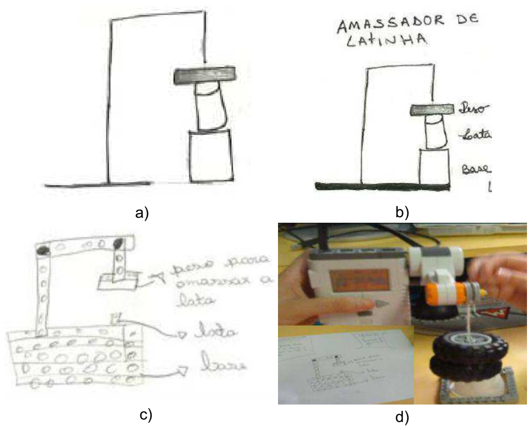

Fig. 5. Group 2 project. a) Virtual sketch; b)Functional sketch; c)Concrete sketch; d)Prototype.

answered: "it was hard to construct without the assembly manual. We do not know how to use the pieces". From a constructivist point of view, a "mistake" is seen as a opportunity for learning, so educators should make clear to students that this is acceptable, avoiding unnecessary frustration.

B. Workshop 2 - Tower

In this workshop, we follow the project theme from Legozoom magazine, year 9, volume 3, where the objective was to build a tower. The class named eight grade "A", composed of 27 students (14 boys and 13 girls) followed the magazine suggestion. Meanwhile, class named eight grade "B", composed of 27 students (14 boys and 13 girls) followed our proposed methodology. We observe that while class "A" had to build a tower as described in the magazine (with the challenge to make it higher), class "B" had no restrictions to which form or functionalities the tower should have and students were motivated to create novel towers. Both classes were lectured with a introductory presentation on the subject showing examples of towers (e.g. Eiffel tower) and describing their functional utility and symbolic value as sign of a new era. Class "B" could use the Lego kit as well as our proposed accessible kit.

Analyzing the results of both classes, we observe some similarities with the first workshop:

- All groups have worked collaboratively.
- All groups in class "A" have strictly followed the guide and most have not completed the challenge. After teacher insistence, most groups presented a solution that consisted on stacking up more pieces on top of the tower, without taking into consideration any significant structural change.
- The proposed towers in class "B" where vastly distinct, containing creative and interesting ideas. Some examples of towers are: a tower with a energy consumption indicator on top, a spinning tower, a finger like tower with an spinning basketball on a top.
- Overall, students found the accessible kit easier to use than the Lego kit. However, some had difficulty in coupling structural parts with the hot glue, mainly because pieces do not dock so perfectly as in the Lego kit.

Even following the guide, students from class "A" have reported that it was challenging to construct the tower. We also observed that the Lego activity required a great level of organization, discipline and concentration, which can be perceived as a positive aspect of Lego methodology.

C. Workshop 3 - Arm with claw

This workshop was an adaptation of a project proposed in Legozoom magazine, year 9, volume 2. The objective was to construct a robotic arm that could pick an object and move it to the other side. Class named seventh grade "A" (30 students, 20 boys and 10 girls) used the Lego methodology, while class named seventh grade "B" (25 students, 12 boys and 13 girls) followed our methodology.

This workshop was atypical as none group (in both classes) were able to successfully complete the task. The main difficulty was programming the movements that would allow the claw to grab the object, move to the other side and open it to release the object. However, we have observed that all groups were motivated in solving this problem.

D. Workshop 4 - Mascot

Students were asked to create a mascot to represent the school. No restriction on the form or movements were imposed. In this workshop, only our proposed methodology was evaluated. The groups could choose between using the Lego kit or the accessible kit.

Overall, students gave the accessible kit a positive evaluation. They seemed to have no troubles in creating and sending commands to the electronic board. Once again, some students had difficulties in managing the hot glue. Some examples of what was said: "The electronic board is just like the NXT, it sends and receives instructions", "the programming was different, but it was easy", "we had difficulties in using the hot glue, but after we got it, it was cool".

VI. Conclusion

We have presented a new methodology for using robotics in education (RiE) along with an accessible robotics kit. The key aspect of our methodology is that it allows students to freely create robots in groups without following a strict step by step guide. We argue that this is an important aspect to engage students, strength creativity and improve social skills. Several workshops where carried out and lead to a positive evaluation on our method.

The proposed accessible robotics kit was also positively accepted by students as being as good as a commercial kit (Lego). Students reported that the kit was simple to use, including the programming environment composed by the computer interface and electronic board. The only complain was related with the use of hot glue to connect the pieces (in commercial kits parts usually snap together). This suggest a possible improvement that will be left for future works.

References

[1] D. P. Ausubel. *Educational psychology: a cognitive view*. Holt, Rinehart and Winston: New York, 1968.

[2] Dave Baum. *Definitive Guide to Lego Mindstorms*. APress L. P., 2nd edition, 2003.

[3] Joan Bonals. *El Trabajo en pequeños grupos en el aula*. Barcelona, España : Graó, 2000.

[4] VEX Education. Retrieved on november 16, 2011, from http://www.vexrobotics.com/education.

[5] D.U. Ekong. Resources for using robotics to inspire interest in engineering. In *Southeastcon, 2009. SOUTHEASTCON '09. IEEE*, pages 273 –277, march 2009.

[6] P. C. Gonçalves. Protótipo de um robô móvel de baixo custo para uso educacional. Available on http://pt.wikilingue.com/es/Lego_Mindstorms, Retrieved on February 18, 2009.

[7] Frank Klassner. A case study of LEGO Mindstorms^{TM} suitability for artificial intelligence and robotics courses at the college level. *SIGCSE Bull.*, 34:8–12, February 2002.

[8] D. Q. Lopes. *A exploração de modelos e os níveis de abstração nas construções criativas com robótica educacional.* PhD thesis, Universidade Federal do Rio Grande do Sul- URGS, Porto Alegre, 2008.

[9] G. L. Miranda. Limites e possibilidades das tic na educação. In *Revista de Ciências da Educação*, number 3, pages p. 41–50, Lisboa, May 2007.

[10] C. O'Malley and D. Stanton Fraser. Literature review in learning with tangible technologies. Discussion Paper 0-9548594-2-1, NESTA, 2004. Report 12.

[11] Seymour Papert. *The Children's Machine: Rethinking School In The Age Of The Computer*. Basic Books, New York, 1993.

[12] Hayes Solos Raffle, Amanda J. Parkes, and Hiroshi Ishii. Topobo: a constructive assembly system with kinetic memory. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, CHI '04, pages 647–654, New York, NY, USA, 2004. ACM.

[13] M. Resnick and S. Ocko. LEGO/Logo: Learning Through and About Design. In I. Harel and S. Papert, editors, *Constructionism*, pages 141–150. Ablex, Norwood, NJ, 1991.

[14] R. Rocha. Utilização da robótica pedagógica no processo de ensino-aprendizagem de programação de computadores. Master's thesis, Centro Federal de Educação Tecn. De Minas Gerais, 2006.

[15] Arnan Sipitakiat, Paulo Blikstein, and David P. Cavallo. Gogo board: augmenting programmable bricks for economically challenged audiences. In *Proceedings of the 6th international conference on Learning sciences*, ICLS '04, pages 481–488. International Society of the Learning Sciences, 2004.

[16] S. Zilli. A robótica educacional no ensino fundamental: Perpectivas e práticas. Master's thesis, Universidade Federal de Santa Catarina, 2004.