

# An Experimental Study on the Use of Robotics as an Educational Tool

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***Abstract.** This paper discusses the use of robotics as a tool for leading primary school students toward an effective understanding of educational skills such as Logics and Physics principles. In order, the use of robotics is not completely acceptable as a teaching resource, so that it is important the development of researches that can evaluate this new process and propose approaches for a better use of robotics in education. In this current experiment, students have used special kits to deal with a search problem, so that we describe the lessons learned in terms of designing the robots and learning aspects that have emerged from the students' experiences in building and programming robots.*

***Resumo.** Este artigo discute o uso da robótica como uma ferramenta de auxílio ao aprendizado de alunos do ensino fundamental em aspectos como raciocínio lógico e noções da física. De fato, o uso da robótica não é completamente aceito como uma ferramenta educacional, de modo que é importante o desenvolvimento de pesquisas que avaliem este novo processo de aprendizagem e proponham métodos para o melhor uso da robótica na educação. No experimento discutido neste artigo, estudantes utilizam kits especiais para lidar com problemas de busca, de modo que descrevemos as lições que podem ser aprendidas em termos do projeto dos robôs e da aprendizagem que emerge da experiência dos estudantes em construir e programar tais robôs.*

## 1. Introduction

Educators are using robots increasingly across the curriculum. The use of robots in the classroom at the primary school level has the advantage of evolving students' problem solving skills and interest in science. Examples of this practice can be seen in some public primary schools, where local government programs have sponsored the use of robot kits as an auxiliary educational tool. In fact, some initial researches present the use of robotics as a powerful learning tool. However, the educational robotics is still a recent activity in schools and there are several open questions about the valid of developing works of such kind with students of the fundamental and secondary schools.

This work argues that robotics has a considerable potential to education, once it stimulates creativity, logical reasoning and interaction. During the robots programming, students must orderly and logically think about what they are doing. Every command must be associated with a goal action and the programming is carried out according to

the needs of the own student in finding a solution to a problem detected by him/herself. In this way, during the process of building and rebuilding a robot and its control program, we can observe that students are elaborating a very singular neural connection network, once they must predict actions, plan, codify and test the whole implementation.

To support this affirmation, this paper discusses an experimental study performed with 12 students, who were confronted against a typical problem of robotics that mainly requires skills of Logics and Physics. Our conclusions were collected from the observations and interviews conducted with these 12 students. Together with other efforts [Weinberg *et al.* 2007; Goldweber *et al.* 2001; Johnson 2003; Mataric 2004], this work tries to stress the advantages of the use of robotics. Note that motivating and engaging students in active learning is challenging, even for the most experienced teachers, due to students' different learning styles, cultural and ethnic backgrounds. The use of a unique approach does not necessarily lead all of them towards high standards achievements. Therefore, the primary role of teaching is not to lecture, explain, or otherwise attempt to transfer knowledge, but to create situations for students that will enable mental constructions. We believe that robotic can properly create such situations.

The remainder of this paper is structured as follows: Section 2 presents the educational properties of robotics, stressing its relation with logical reasoning, creativity and Physics. Section 3 discusses the methodology of our experimental study, where are presented the robotic stuff, proposed problem and issues about the team of students. Section 4 discusses the experiment and learned lessons of this process. Finally, Section 5 concludes this work, stressing the necessity for methodologies regarding the use of robotics in specific niche of education.

## **2. Robotics and its Educational Properties**

This section discusses the relation between robotics and important learning theories, mainly represented by the works of Piaget. Furthermore, the section also details the main educational niches [Castilho 2002] that can take advantages of the educational robotics.

### **2.1. Piaget Learning Theory and Robotics**

According to the Piaget learning theory [Piaget *et al.* 1985], the cognitive development of young students is associated with four factors: biological maturation, experience with the physical environment, experience with the social environment, and equilibration. Equilibration refers to the biological drive to produce an optimal state of equilibrium between people's cognitive structures and their environment [Duncan 1995]. Equilibration is an attempt to bring about a state of equilibrium between the first three factors and the reality associated with one's external environment. This state must be present for cognitive development to take place. Equilibration involves both assimilation and accommodation. During each stage of development, people conduct themselves with certain logical internal mental structures that allow them to adequately make sense of the world. When external reality does not match with the logical internal mental structures (disequilibria), equilibration occurs as an effort to bring balance between assimilation and accommodation as the person adapts more sophisticated internal mental structures. Human beings continually attempt to make sense of the world

around them by assimilating new information into pre-existing mental schemes and accommodating thought processes as necessary. This effort to maintain a balance, denoted by equilibration, allows for cognitive development and effective thought processes. The educational robotics supports the development of world models where students can manipulate, create and to encode objects so that via such practices they develop their logic reasoning. Then, using logic reasoning, students are able to infer, assimilate and accommodate new concepts in a more natural and fast way.

Some negative experiences with the use of robotics are associated with the incorrect use of this approach. In this case of the logic reasoning development, there are reported cases where educators suggest the problem and indicate the steps, features and functions that should be used to resolve such a problem. According to the basic idea of the educational robotics, this kind of approach is not appropriate once the problem must challenge students so that they should think by themselves about solutions and project decisions. For example, a classic robotic problem is to design and build a *Line Following Robot*, which is able to complete a circuit defined by a black line on a white background (Figure 1). The arena can have lots of turns, including sharp ones, together with breaks and multipaths, so that the robot has to make decisions and navigate along the entire path.



**Figure 1. The Line Following robot arena**

In this problem, each student should develop its own robot and if such a robot is able to follow the black line and complete the track, then the robot design is considered correct. In a first moment, the design decisions, such as algorithms and qualification parameters (e.g., time to complete the resource) are not important. Such issues could be worked in a latter moment, if they are important in the context proposed by the educator.

However students can design robots that do not work. In other words, this means that students can try a hypothesis, such as a specific algorithm, that does not produce the expected effect. Considering the learning process, this is not a bad result, once such scenario leads students to reflect about their actions and the reasons about their failures. The process of thinking logically is essential in any situation, even if this situation is related to a failure. The use of robotics immediately enables that bad solutions can be redesigned and applied again. In some cases, this process can be carried out in cycles, where solutions are refined and evaluated in an evolutionary process. Thus, robotics supports the concepts of assimilation and accommodation discussed in the Piaget work

about equilibrium. The learning process, which is normally carried out in a long term period, can be carried out in a shorter time interval using robotics. This fact enables that the reflexive reasoning, which is developed in classes of mathematics, physics, chemistry and other; can be developed in a more relaxed and motivating environment created by the educational robotics.

## **2.2. Creativity Development**

For each new hypothesis that students create to deal with a problem, they become learning agents of their own knowledge, so that students build a complete process of learning. Based on situation-problems, which are created by the own students from the interaction with the reality presented by educators, students search for solutions and evaluate such solutions so that they reflect and know if their actions were correct. Thus, students learn to learn and this reflective logic reasoning becomes as more efficient as much it is used.

This new practice brings a different reality to the education, where students are the center of the process and account for applying their creative imagination to modify the environment. In this process, students are not limited to provide operational answers about the environment. Rather, they can actively act on the environment, so that the experience has a new meaning. In this way, students sense the environment and they can act via the building and rebuilding of a robot, using pieces that require and, usually, should be adapted to the process because such pieces are not exactly what was planned at the beginning.

During this process of sensing the environment and the parts required to develop a robot, a student initially creates in his/her mind several alternatives of actions. In educational robotics, it is important to always confront students with new problems, so that it can produce innovative solutions, rather than just copying past solutions. In this way, students will be able to develop their abilities, talents and creativity.

## **2.3. Physics Foundations**

Physics education is one of the educational areas that can mostly take advantages of robotics. During the activities of building a functional structure, students require knowledge about several physical fundamentals. For example, if the project is about a mechanical arm, students must prioritize strength in their structures rather than velocity. However, if the idea is to build a fast vehicle, then a structure that enables velocity is the most important requirement.

According to some works in learning [Piaget 1971] the physical experience essentially supposes the intervention of actions, because “the subject cannot know the objects without acting on them”. Based on this idea, students could easily understand the physical effects during their actions on objects and the observation of the consequences of such actions. For example, to obtain the required relation between strength and velocity, students can play with the engines, so that the motor rotation can be reduced or increased. Thus, students are working with physical parameters and relations between them. In this scenario, questions, such as “Why the association of two engines of different diameters and connected for a belt can increase or decrease the velocity of a machine?”, will certainly appear and the answer will come out via the

students' observations of their own actions. This experiment brings the comprehension of a particular physical property in such way that students will correctly apply this property in other projects and they will also be able to explain the physical reasons that controls this property.

### 3. Methodology

#### 3.1 The Problem

The motivational problem to this experiment is related to a search operation. Consider that after an earthquake, there is a building in a bad state, so that this building can fall down at any moment. Consequently, search and rescue teams cannot be sent to check if there are injured civilians inside this building. Then a robot could be sent to each building floor to search for possible civilians.

Using this motivational scenario, a simple reduced model of a building floor was specified with an area of 6 m<sup>2</sup> and light points were used to simulate injured civilians (Figure 2). This idea was based on the *Robocup Rescue competition* [Kitano *et al.* 1999]. Then, robots have 5 minutes to find so much as possible humans (lights) in this scenario. The positions of the lights are not previously available to the teams.

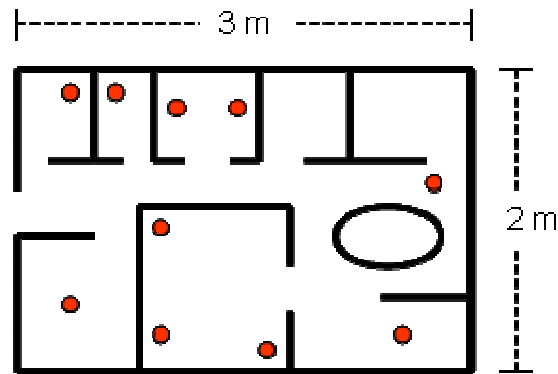


Figure 2. Emulation of a scenario for the search problem

#### 3.2 Resources

The LEGO Mindstorms Robotics Invention System consists of a bunch of LEGO pieces and a RCX (Robotics command System) unit (Figure 3a). The RCX unit is a programmable microcomputer, which uses a Hitachi H8/3932 microcontroller.

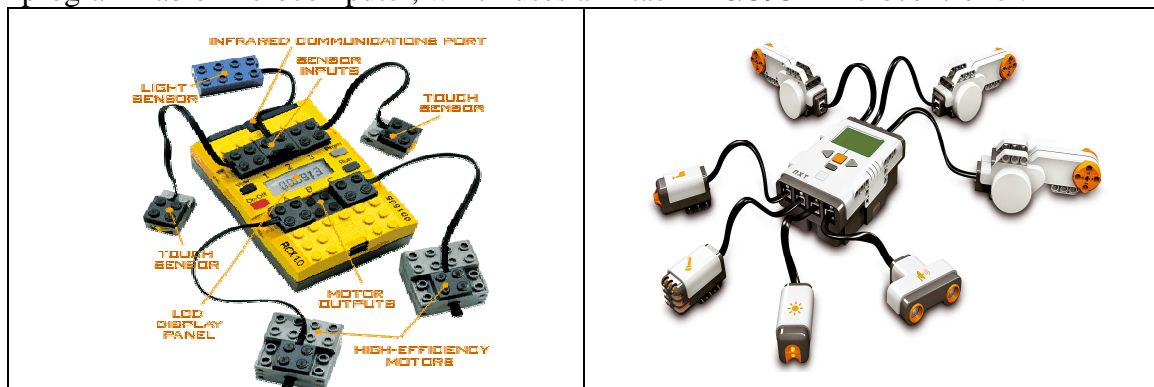


Figure 3. The RCX (a) and NXT 2.0 (b) Lego programmable microcomputers

The RCX brick can be used to control actuators, like a sound generator, lights, and motors, and read input from various sensors, such as light sensors, pressure sensors, rotation sensors, and temperature sensors. The RCX brick also has an LCD display (useful for printing information) and an IR-transceiver (for downloading programs and communicating with other bricks). Currently there is a new version for the RCX unit, called NXT 2.0 (Figure 3b), which brings several improvements such as three new sensors to use: the sound sensor, the ultrasonic sensor and the built-in rotation sensor.

Students build models and robots using the RCX as the brain. They then use the ROBOLAB software to write a program and download it to the RCX via the Infrared Tower. After being programmed, the robots are fully autonomous, acting on their own with any support from the computer. Robots take action, interact with their environment and make decisions based on input from their surroundings via sensors. Two RCX bricks can even communicate with each other using their infrared eyes.

### 3.3 The Teams

A good approach for this experiment is to form small teams, whose members have different abilities. In this way, each member has the opportunity to learn or improve other abilities with their partners. Teams with three members enable the development of collaborative and communication skills. The reason to avoid bigger teams is the nature of the problem, which does not demand so many students involved in its resolution. A resource that can be used to form the teams is the own academic evaluation of the students in related subjects. Examples of subjects are Physics, Mathematics and Logic. For example, consider the table below (Table 1).

**Table 1. Example of Evaluation of six students in three different subjects**

	Physics	Mathematics	Logic
Student-1	High	Low	Low
Student-2	Low	High	Medium
Student-3	Medium	Low	High
Student-4	High	High	Medium
Student-5	Low	Medium	Low
Student-6	Low	Low	Low

The most natural strategy to form equilibrate 3-members teams, in this scenario, is to allocate one student with high ability in each different subject. For example, a team  $\alpha$  could be composed by Student-1, Student-2 and Student-3. However, using the remainder students, we cannot form a second team with the same features. The problem is more complex because we should avoid the formation of teams with students in very different levels. For example, if we form a team with the three last students (Student-4, Student-5 and Student-6), then the Student-4 may lose the motivation in collaborating because the others are not helping so much. Several experiments could be carried out on this issue, so that theories about the best approaches to create collaborative learning teams could be defined.

#### **4. Results and Discussion**

The principal goal of this experiment was to observe aspects associated with the learning process of students. The main observations were related to initiative, motivation, concentration, teamwork and attitudes toward technology.

Initiative can be defined as a personal behavior related to the ability and tendency to start an action, including coming up with a proposal and giving or helping without first being requested to do so. This behavior could be observed when students have spent further hours of working in laboratory or at home. This means that they have organized some meetings, apart the normal classes, on their own initiative.

Motivation is defined as the activation or “energization” of goal-orientated behavior. We observe motivation in students, for example, when they informally ask for more information from their teachers. An interesting feature of motivation is its source, which is classified as intrinsic (comes from within the individual) and extrinsic (comes from outside of the individual). Certainly students have an extrinsic motivation, once they are looking for a good grade. Furthermore, competition could also be considered an extrinsic motivation. However we are interested in observing the intrinsic motivation, which is lead by an interest or enjoyment in the task itself, and exists within the individual rather than relying on any external pressure. In fact, this intrinsic motivation could be observed in some students’ activities, such as extensive web searches on robot issues and the analysis of the design of opponents to improve their own design, once they were carried out in a funny and relaxed way.

Concentration can be defined as the cognitive process of selectively focusing on one thing while ignoring others. It is easy to observe this cognitive process during robotics experiments, once students keep themselves deeply involved in the solution of problems. Conversations about other themes are rarely observed and students spend long times continually discussing about the project techniques, sharing/comparing programming codes and showing different robot designs.

Teamwork means people working together cooperatively. It involves several other ideas, such as communication, coordination, mutual support, balance of contributions and cohesion. Reports of students use to refer to several aspects of teamwork as essential to correct robot designs. The drive to build an appropriate robot had lead students to understand the importance of joint work in facing new challenges, so that progress on engineering and science problems was carried out collaboratively in interdisciplinary teams, rather than by a single individual working in isolation. This is a different systematic approach to learning [Beer at al. 1999].

About attitudes toward technology, we have seen that patience and discipline are essential requisites during the building of robots, as already observed in other works. These works relate that students’ attitude towards technology has changed after their participation in the robotics education programs. In fact, students of primary school generally do not have a strong technological background other than the lessons they have learnt in Physics. After this experiment, we should find students more confident and interested in the engineering field and technological work area.

The principal problem of robotic projects is to ensure that the robot could reliably work along the time. Students often found that their robots would work correctly during some period. However, in some moments the robots do not used to work as designed. Many factors could contribute to the unpredictability of a robot, such as the level of charge of the batteries and the conditions of several robots' analogical components (e.g., sensors, motors). An interesting aspect of this design process was to observe that students were generally able to indentify several physical reasons for this unpredictability.

Other research directions in educational robotics try to configure the role of affection between robots and users during the educational process. According to such works, empathic interaction with synthetic characters enables users to build and maintain an emotional involvement that can result in stimulating novel interactions. Details can be seen in [Bickmore 2003; Hall et al. 2005].

## 5. Conclusion

This paper discusses an initial experiment that can be used to validate the efficiency of robotics as an educational tool. In particular, robotics shows advantages when it is used to improve the students abilities in subjects such as Physics, Mathematics and Logic. Furthermore, it is also important to evolve personal features such as initiative, motivation, concentration, teamwork and attitudes toward technology. The observations of this experiment have demonstrated that in fact the educational robotics can support other learning methods, so that it has the potential to become an important educational tool in the future. However, the lack of related literature and case studies stress the need for more researches in the area to better characterize this use of robotics.

A particular problem, in this context, is the lack of methodologies. For example, we do not know which could be the best experiments for specific problems, how to apply such experiments, the appropriate level of participation of educators during the robots development, how to form the students teams and so on. In fact, the available know-how in educational robotics is largely under development and experimentation. There are several possible actions to support this development. For example: to make available low cost robots and associated software in as many schools as possible; to bring up awareness about the potential of robots inside the educational community, and incorporating robotics in vocational and academic education. If robotics testifies its education potential, then it could be essential its explicit integration in the national curriculum.

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