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ROBOTICS IN THE TEACHING OF PHYSICS: A PROJECT BASED APPROACH

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Abstract

This paper aims to propose a procedure for the use of robotics in physics teaching based on a model of project-based learning (PBL). The procedure was applied during one semester to high school students of two public schools in Guaratinguetá, in the Valley of the Paraíba - SP. The methodological approach employed was Action Research, with the involvement of Physics teachers from the partner schools, working together with teachers and students from São Paulo State University (UNESP) – Guaratinguetá Campus. The motivation for the development of the project is the lack of both laboratories and materials for experimental activities observed in Brazilian public schools. In this context, considering the recommendation of the National Curricular Parameters for Secondary Education for the use of technology in the classroom, we have opted for the insertion of educational robotics through the development of a mobile robot in the form of a teaching project. Educational Robotics, besides being a current and relevant technology, allows the student to interact with the learning object, which contributes to the construction of his knowledge. The robot design was done using Arduino platform. Regarding the use of the PBL model, in the planning stage first we established the objective of designing an automated vehicle that would then be used to determine the physical quantities of its movement (displacement and average velocity). Then we established a road map for the development of the action in the form of activities carried out in workshops in the schools, with the participation of the students, teachers and the tutors of UNESP. The application of the procedure indicated as results, among other aspects, a greater motivation and also a greater involvement of the students in the activities developed in the classroom. The students participated in the development of the robot in all activities, acting both in the assembly of the circuits and in actions related to its programming.

Keywords: *Active learning, educational robotics, mobile robot, teaching physics, teaching projects.*

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1. Introduction

This article aims to present a procedure used to work with Robotics in Physics Teaching, based on a Project Based Learning (PBL) model. The actions were carried out in two public high schools, and were developed in the context of a proposal that focused on the use of experimental activities as a means to assist in the understanding of Physics concepts. The motivation underlying the proposal is the lack, observed in Brazilian public secondary schools, of laboratories and resources for conducting experimental activities.

The main action in the schools was the development of a teaching project of a mobile robot, to be used in the demonstration and study of Physics concepts related to its movement. This action was initially discussed with the teachers, and the corresponding activities were developed by the students in the classroom, supervised in each of the schools by the Physics teacher and by teachers and students of the São Paulo State University (UNESP). One of the objectives was to investigate, among other aspects, strategies for using the PBL model in a traditional teaching context.

The paper is organized as follows. Section 2 presents a brief discussion of the main characteristics of the methods and model used in the joint work with the schools. Section 3 describes the development of the robot project in the schools. Some results of the action performed are presented in section 4. Section 5 is intended to present some conclusions from the work.

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2. Methods

As the work should be developed in partnership with the teachers of the schools involved, the methodological focus of the research was based, fundamentally, on action research. The action research has as one of its characteristics the fact of being participative, differentiating itself in this way from routine practice (individual) and scientific research (team/collegiate) (Tripp, 2005). Thiollent (1997) emphasizes that this type of research is not only limited to a diagnosis and description of a situation, but also must be able, in certain cases, to generate transformations that allow evolution of the group or organization involved. Franco (2005), with respect to the use of this type of research in Brazil, presents a classification of action research in three modalities, one of them being the strategic action research, in which the need for transformation is planned previously by researchers without participation of the subjects of the group.

Project Based Learning is a teaching strategy in which problems are used to emphasize, among other aspects, critical thinking and the development of skills for its resolution, leading to a student-centered teaching and learning style in which students work collaboratively and teachers act more like mediators or facilitators in the process of knowledge construction (Sena, Fiscarelli, & Akamatsu, 2008). The PBL model adopted in the project was proposed by the BIE Institute (Buck Institute for Education, www.pblworks.org). This model emphasizes, among other aspects, a teaching method that involves investigations by students about authentic and complex issues related to the accomplishment of well-planned assignments and products (Mergendoller, Markham, Ravitz, & Larmer, 2005).

The model is focused on standards, which presuppose the organization of a project according to the principles described briefly in the sequel. *Begin with the end in mind*: definition, among other aspects, of content standards, of the key skills and mental habits that will constitute the project results. *Formulate the guiding question*: proposing a relevant and meaningful question that leads to the students' involvement with the project. *Plan the evaluation*: specification of the expected project outputs and how they will be evaluated. *Map the project*: it includes, among other aspects, the presentation of the project, the organization of the tasks and activities to be developed and the elaboration of a visual script (for example, a schedule). *Manage the process*: description of tools and strategies to assist in the management of the project development (Markham, Larmer, & Ravitz, 2008).

Markham et al. (2008) present several tools that can be used both in planning and during project development. This more pragmatic aspect of the model makes it easier to work with PBL in the classroom. Taking advantage of those tools, the use of the guidelines of the model aimed to subsidize the teacher in the insertion of experimental activities in his pedagogical practice, through the development of a teaching project, together with his students.

According to Zilli (2004), the use of Robotics in the classroom is a proposal that meets various educational theories such as, for example, Piaget's Constructivism and Papert's Constructionism. For Maxwell (2006), Papert and Piaget were adept of the idea that the child builds his knowledge from his interactions with the learning object. However, for Papert the learning process would be more effective if the student constructed a significant product after his interactions with the object.

In the literature one can find several works related to the use of Robotics in the teaching of Physics. For example, Souza and Duarte (2015) discuss strategies that can be used in Physics teaching (secondary education) through a Robotics show, which included, among other actions, demonstration of prototypes and Robotics projects. Kubínová and Šlégr (2015) discuss the possibility of using the Arduino board for demonstrations of values obtained from measuring instruments such as thermometers, manometers and voltmeters. Bouquet et al. (2016) describe a laboratory approach to physics, in the form of projects, carried out with university students, based on low cost and open source devices: Arduino and compatible sensors.

3. Development

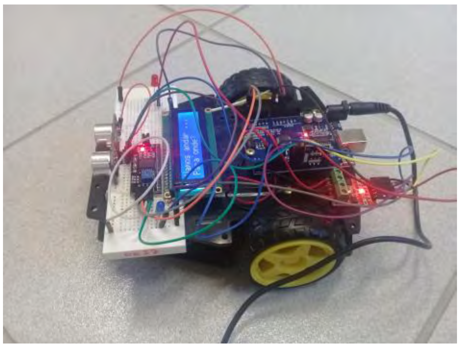
The action in the schools aimed at the development of an automated vehicle and its use in determining the physical magnitudes of its movement. As mentioned, the development of the mobile robot project should be based on the guidelines of the PBL model of Institute BIE. In this sense, we initially worked on the project proposal according to the project planning form of the model. This tool contains sections for each project principle of the model. The most relevant aspects of the planning and accomplishment of the proposal are presented below.

With regard to what was expected to achieve with the project, the form requires the specification of content standards, skills and mental habits. With respect to the content, concepts of mechanics related to URM (Uniform Rectilinear Motion) and some basic concepts of Electricity (voltage and current) were specified. In terms of skills, emphasis was placed on teamwork, adaptation to complex situations and commitment. In relation to mental habits, the persistence and application of previous knowledge to new situations were emphasized.

In the following, one must specify a guiding question for the project. The following question was proposed: "How to build a mobile robot that can be used to demonstrate URM concepts?". The next stage of planning refers to the evaluation, where project products must be specified, which should be aligned with the expected results. The final product of the project was the automated vehicle, from which the values of physical quantities related to its movement should be determined. However, during project development, some intermediate "products" were generated, such as the assembly of a circuit for determining distances with the ultrasonic sensor. Teaching by projects generally involves a performance assessment, and the model provides specific tools that can be used for this purpose (Markham et al., 2008). For the application described here, it was up to the Physics teachers to evaluate the performance of the teams, which occurred at certain moments during project development, as well as at the end of the action.

The next step is project mapping, which involves pooling the required resources, organizing tasks and activities, and starting the project. In the project launching class, a mounted mobile robot was introduced to the students (Fig. 1 below), and a general explanation was given about what was expected from them in order to build and automate a robot as the one shown.

Figure 1. Mobile Robot.



The necessary materials, such as the car's structure with motors, electronic components and computing resources, would be provided by the University team for use during project development. As for the organization of the tasks, they were planned in the form of activities to be carried out in 8 workshops in each school, each corresponding to two Physics classes. In the workshops, the electronic components necessary for a basic understanding of Robotics with Arduino and the assembly of the mobile robot were presented. Thus, students could work, among other components, with resistors, LEDs, ultrasonic sensor, LCD display and remote control (RC). Parallel to the presentation of the components, some concepts and other elements related to their use were discussed, such as Arduino board, Arduino IDE, serial monitor, PWM input/output, voltage and current, among others.

With regard to the management of the process, the activities were organized in the form of scripts that included three sections: conceptualization, experimentation and challenges. In the first section were presented concepts related to the components that would be worked in the workshop. In the second, elements of both the assembly and the programming to be carried out by the group were presented. And in the third, it was proposed a task that corresponded to extensions of the accomplished work.

In the last two workshops, after both the assembly of the robot and the loading the program, tests were started to determine the magnitudes of its movement. As the goal was to study the URM, a straight track was mounted using PVC gutters. The robot should move from the actuation of its motors through a RC until approaching an obstacle at the end of the track, when it should stop automatically.

Each group moved the robot on the track, measuring the distance traveled and timing the time elapsed from the beginning of the movement to its stop. The group then recorded the measured values (distance and time) and those presented by the program on the LCD (distance, time and average speed). The groups were instructed to repeat the experiment several times, to calculate, from the measured amounts, the values of average velocity, and to compare the calculated and measured values with those provided by the program. The UNESP team accompanied the groups in this process, assisting them in the interpretation of the obtained results.

4. Results

At the end of the project development, an evaluation instrument (questionnaire) was applied, containing questions grouped into four parts:

- Part I: Content questions (on the content worked on the activities).
- Part II: Questions about the robot control program (regarding program commands and functionalities).
- Part III: Questions on the activity development (general statements about the expected results and expectations from the development of the activities, to assess students' degree of agreement with the statements, according to a 5-point Likert scale, ranging from 1 = strongly disagree to 5 = strongly agree).
- Part IV: Open questions (for students to express their opinion on various aspects of the project).

It was possible to observe, from the analysis of the data, that the results of the action were very satisfactory. Following, a brief summary of some of the obtained results in each part is presented. The percentages were calculated considering the total number of students who answered the questions.

Part I consisted of questions of multiple choice and of association between elements in two columns. Those referred to the Robotics contents (components) worked on the activities, and to the areas of Physics emphasized in the action. The objective was to verify the students' perception regarding the elements involved in the mountings as well as the areas of Physics to which the activities were related. It could be verified that the students in both schools had a good perception regarding the elements used in the mountings, as well as with respect to the areas of Physics involved in the activities.

The questions in Part II referred to the code of the mobile robot control program. This part consisted of two sections, and in the first the students should identify in the code the connecting pins of some components. The questions in this section were relatively simple and the rate of correct answers, in terms of the average of those who responded, was 89%. In the second section, students should identify instructions for specific actions such as "verifying that the remote control key 1 was pressed", "calculating the distance from the ultrasonic sensor to an obstacle", among others. The students had more difficulties with the questions in this section because, due to time constraints for the development of the project, it was sought, with regard to the programming aspect, only give them an overview of its importance in the context of a Robotics application. Nevertheless, among the 10 questions proposed, 7 had percentages of accuracy ranging from 61% to 100%.

For Part III, 12 statements were listed for which the students' degree of agreement was checked. As exemplification, some of these statements are listed in the sequel: a) Robotics activities have made physics classes more creative, dynamic and motivating; b) The contact with Robotics contributed to increase my interest in Physics; and c) The contents worked in the practical classes were related with the theory given in the Physics classes.

It was observed that, in one of the schools, most of the students agreed with all the statements, with percentages varying between 84% and 100%. In this analysis the responses to the "agree" and "strongly agree" options were considered. At the other school, most students agreed with 11 of the statements, with percentages ranging from 63% to 100%. For operational reasons, there were more respondents in the first school, compared to the second. On the other hand, it was observed that there were students who disagreed with several of the statements. As exemplification, this fact occurred in one of the schools in 8 questions, with percentages of 5% for 6 questions and 16% for 2 questions. At this school, for instance, there was disagreement with respect to statements (a) and (c) above.

In relation to part IV, it included open questions, in which students could express themselves on various aspects like what they liked the most and what they liked the least during the development of the project, situations in which Robotics could be used on a daily basis, and the final goal of the activities developed, among others. Some points observed on the students' responses are presented in the following. With regard to what they liked most, most of the students expressed that they liked the mounting of the robot, but especially when they managed to put it on the move. Regarding what they least liked, what was highlighted by most of the students was the reduced number of didactic kits, considering the amount of students in the class. There were also manifestations regarding the insufficient time for the development of the activities and regarding difficulties with the programming part.

5. Conclusion

As it could be seen from the evaluation data, the results of the action in the schools were quite satisfactory in all the aspects emphasized in the evaluation. In particular, in the part regarding the evaluation of the degree of agreement of students with general statements about the expectations and expected results from the development of the activities, it could be observed that the majority answered by agreeing to a greater or lesser degree with the assertions. The results were also good in relation to the students' perception of the contents presented, in particular with respect to the components and mountings of Robotics. Nevertheless, there were manifestations of disagreement, of some students regarding several of the affirmations. This fact meets one of the points raised in a meeting with the staff of one of the schools, that some students showed their preference for the traditional teaching model.

Several difficulties were observed during the development of the activities and some were pointed out by the students themselves in the final evaluation. One complaint from students was with respect to the reduced number of Robotics kits available. As the classes were relatively large, it was necessary to work with groups with an average of 6 students. Even though there was a division of tasks into the groups, there were times when some of the participants showed themselves scattered. Another difficulty pointed out and observed was related to the time required to carry out the activities. Thus the scripts had to be well planned and objectives and also it was not possible to give a detailed treatment to all the elements involved in an activity. In this particular aspect, the programming part was only intended to give an overview of its importance in the context of a Robotics application, without requiring students to learn in depth the basic structures used in the construction of programs. These difficulties should subsidize the realization of adjustments in the materials and methods prior to the implementation of new interventions in Brazilian public schools, with a view to improving the quality of Physics teaching.

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