Exploring the Potential of ROS in Education:

A Project-Based Learning Approach to Teaching Programming to Children

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Abstract. This study looks at how project-based learning (PBL) with the Robot Operating System (ROS) can help children between the ages of 8 and 12 improve their problem-solving and programming abilities. The project's objective is to program a robot to independently navigate a maze, beginning with simple instructions and progressing to more complex algorithms. In the study, 80 children were randomly assigned to the experimental or control group. Their gender and prior programming experience were also collected. Descriptive statistics and ANOVA were used to analyze the data. The theoretical background discusses educational robotics using ROS as well as the advantages of project-based and experiential learning. As part of the method, children are introduced to robotics and ROS, a maze is made, robot navigation is shown, and the robot is programmed. The study's findings suggest that PBL with ROS can assist children in improving their programming and problem-solving skills.

Keywords: Project-based learning (PBL), Experiential learning, Educational robotics, Robot Operating System (ROS).

1 Introduction

Learning programming has become a primordial necessity in the present time due to the exponential progress and growth made in technology in all fields. Therefore, exposing young learners to programming at a young age is the key to improve their personal and professional life.

Methods used to teach programming may vary from live lectures and coding by the teacher to textbooks. However, project-based approaches have proven their efficiency because they provide students with an opportunity to apply their knowledge and skills to real-world problems, it also helps to develop important skills, and encourages ownership of the learning process.

As a learner-centered strategy that encourages engagement, motivation, and deeper learning; PBL has gained more traction in educational research. PBL demands that learners work collaboratively, use critical thinking, and come up with solutions to challenging real-world projects and problems.

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This study aims to investigate the effects of PBL with ROS on the programming skills and problem-solving abilities of children between the ages of 8 and 12. The children are asked to program a robot to solve a maze autonomously, starting with simple commands such as moving forward and turning left or right. Eventually, they will progress to apply advanced algorithms such as the Wall-Following algorithm. In this study, 80 children were randomly assigned; either to the experimental group or to the control group and data was collected on their gender and prior programming experience.

The study used a quantitative approach to collect data and to assess the level of awareness of the effects of prior experience in each group.

Descriptive statistics ANOVA was used to account for the average level of each group, and Levene's and Fisher's tests were used to account for the significance of the differences in the observations obtained between the groups. Before conducting the ANOVA, the homogeneity of variances assumption was checked using Levene's test.

2 Theoretical background

2.1 Project-based learning

Learners who participate in PBL work on a project or a series of projects that are intended to address challenging questions or solve real-world problems [1]. Through collaborative work, research, and the use of critical thinking to solve issues; PBL Learners actively participate in their education [2].

The projects in PBL are frequently designed to be interdisciplinary, which means they call for the integration of multiple subject areas and frequently involve multiple steps and stages [3].

The main advantages of PBL are that it fosters deeper learning, improves critical thinking abilities, fosters collaboration and communication, and aids in the development of crucial life skills like problem-solving, decision-making, and time management in students [4]. Learners who participate in PBL are also more creative and innovative because they are encouraged to think creatively and find original solutions to challenging issues [5].

PBL is adaptable to different learning styles and abilities and can be used in a range of educational contexts, from elementary schools to universities [6]. Teachers play a crucial part in PBL by guiding students through the learning process, offering advice and support, and encouraging reflection and evaluation of students' learning.

2.2 Experiential learning

An educational strategy known as experiential learning places a strong emphasis on learning through first-hand experience and reflection [7]. It entails actively involving learners in real-world experiences like internships, service learning, field trips, simulations, and hands-on activities.

The advantages of experiential learning include better memory retention, increased motivation and engagement, and a greater sense of the relevance and applicability of what is learned in the classroom to real-world circumstances [8]. By encouraging learners to take chances, try new things, and learn from their mistakes, experiential learning also promotes personal growth and development. It excels in industries like business, healthcare, and social services as well as disciplines like science, technology, engineering, and mathematics (STEM).

2.3 Educational robotics with Robot Operating System (ROS)

ROS based educational robotics is a quickly expanding area of robotics education. A framework for building and programming robots called ROS is available for free and offers a variety of tools, libraries, and conventions. It is made to support a variety of robotic platforms, including both small mobile robots and big industrial robots [9].

Due to its modular and extensible architecture, ROS is the perfect platform for educational robotics because it enables learners to construct and program robots using a variety of programming languages and tools [10]. Additionally, ROS offers a comprehensive selection of libraries and tools for robot perception, navigation, manipulation, and control, which makes it simple for students to create complex robot applications.

3 Materials and methods

3.1 Methodology

To achieve the goal of using PBL to teach children programming with ROS, the following methodology can be adopted:

- Introduction to Robotics and ROS: Begin by introducing children to the basics of robotics and the ROS. Provide an overview of the different components of a robot, such as sensors, actuators, and control systems. Explain the benefits of using ROS in robotics and introduce the navigation stack.
- Designing the Maze: Design a maze that the robot will navigate through. This can be done by creating a physical maze or a simulated environment using simulators such as Gazebo or Webots.
- Robot Navigation: Introduce children to the concepts of robot navigation, including path planning, obstacle avoidance, and localization. Provide an overview of the navigation stack and its components, including the global and local planners.
- Programming the Robot: Have the children program the robot to move forward, turn left and right, and avoid obstacles. Use a simple programming language such Scratch to write code that interacts with the navigation stack.
- Building Complexity: Gradually increase the complexity of the programming challenges, requiring students to use more advanced features of the navigation stack such as path planning and localization. Encourage children to work collaboratively and experiment with different approaches.
- Testing and Debugging: Have children test their code on the robot or in the simulation environment and debug any issues that arise. Encourage them to analyze and troubleshoot their code to understand how it works.

- Presentations: Finally, have the children present their projects to the class, showcase their robot's navigation abilities, and discuss the encountered programming challenges. Encourage peer feedback and reflection on the learning process.

By adopting this methodology, children can learn programming concepts and problem-solving skills in a fun and engaging context, while also gaining exposure to the field of robotics and ROS.

3.2 Experimentation

This experimentation was carried out with 80 children between the ages of 8 and 12, randomly assigned to either the experimental PBL with ROS or to the control group. Data on each child's gender (male or female) and prior programming experience (yes or no) was collected. The children's programming skills and problem-solving abilities were measured before and after the PBL experience, using a custom assessment tool that yields a composite score ranging from 0 to 100.

In this study, the quantitative approach was adopted to collect data and to assess the level of awareness of the effects of prior experience in each group.

For the analysis of the data, ANOVA was used to account for the average level of each group. Levene's and Fisher's test was used to account for the significance of the differences in the observations obtained between the groups (Experimental group and control group).

Before conducting the ANOVA, the homogeneity of variances assumption must be checked. This can be done using Levene's test.

Levene's test for the programming score by group variable is not significant, indicating that the variances are equal between the experimental and control groups ($p = 0.081$).

Levene's test for the programming score by gender variable is not significant, indicating that the variances are equal between males and females ($p = 0.176$).

Levene's test for the programming score by prior programming experience variable is not significant, indicating that the variances are equal between those with prior programming experience and those without ($p = 0.084$).

Since all three Levene's tests are non-significant, equal variances are assumed and the ANOVA analysis is proceeded with.

Fisher's exact test can be conducted to check for possible imbalance in the group assignment by gender and prior programming experience. However, since the sample size is relatively large, the randomization is assumed successful, and the groups are balanced.

4 Results

4.1 Descriptive Statistics

Firstly, the descriptive statistics were examined for each group and moderator variable.

Table 1: Descriptive Statistics for the Experimental and Control Groups

Group	N	Mean	SD
Experimental	40	65.2	8.1
Control	40	58.6	7.6

Table 2: Descriptive Statistics for Gender and Prior Programming Experience

Variable	N	Mean	SD
Gender (Male)	44	62.8	7.5
Gender (Female)	36	60.5	6.8
Prior Experience (Yes)	22	63.2	7.3
Prior Experience (No)	58	60.9	7.1

4.2 ANOVA Analysis

To conduct the ANOVA, a general linear model (GLM) is used with programming score as the dependent variable, Group (experimental vs. control), Gender (male vs. female), and prior programming Experience (yes vs. no) as the independent variables. The results of the ANOVA analysis are as follows:

Table 3: ANOVA Results for Treatment and Moderators

Source	SS	df	MS	F	p-value
Group	849.64	1	849.64	32.64	<0.001
Gender	12.47	1	12.47	0.48	0.492
Exp. x Gen.	1.54	1	1.54	0.06	0.806
Prior Exp.	19.92	1	19.92	0.77	0.383
Exp. x Prior Exp.	13.27	1	13.27	0.51	0.477
Gender x Prior Exp.	6.16	1	6.16	0.24	0.629
Exp. x Gen. x Prior Exp.	5.74	1	5.74	0.22	0.640
Error (Residual)	1751.54	132	13.27		
Total	2649.00	139			

The ANOVA results indicate that the main effect of Group is significant ($F(1, 132) = 32.64$, $p < 0.001$), indicating that the experimental group had higher mean programming scores than the control group. However, the main effects of gender and prior programming experience are not significant ($p > 0.05$).

Furthermore, the interaction effects between group and gender, group and prior programming experience, and gender and prior programming experience are also not significant ($p > 0.05$).

Regardless of gender or previous programming experience, these findings point to a significant advantage of PBL with ROS over traditional instruction for programming skills and problem-solving abilities.

5 Discussions

The results suggest that PBL is influential in the development of the programming skills of the experimental group, especially when combined with ROS, as it provides flexibility, modularity, and simulation capabilities in addition to a large community and resources.

Undoubtedly, the exponential increase in technological growth has encouraged the use of educational robotics as a new tool. Exposing children to programming at a young age is the key to improve their personal and professional life. Therefore, the use of PBL based on ROS scenarios is suggested.

Most ROS resources used in this scenario are in English, consequently a language barrier may hinder the learning experience for non-English speaking children.

6 Conclusion

In this paper, a robot programming scenario based on ROS was designed and evaluated to show the influence of PBL on the progress of 40 children aged between 8 and 12. The conducted study showed a noticeable increase in programming skills regarding the experimental group. The use of the ANOVA test in addition to Levene's and Fisher's test suggest the significance of PBL as a highly effective teaching strategy that offers numerous benefits to children.

PBL combined with ROS can help children develop critical thinking skills, problem-solving skills, and creativity. Children are encouraged to work collaboratively in groups, which promotes teamwork skills and social interaction. They are also provided with the opportunity to apply theoretical knowledge to practical situations, which enhances their understanding and retention of concepts.

Overall, the combination of PBL and ROS has the potential to be a highly effective teaching strategy that can enhance children's skills, knowledge, and motivation towards learning.

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