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# MBOT ROBOT AS PART OF PROJECT-BASED LEARNING IN STEM

## *ROBÔ MBOT COMO PARTE DA APRENDIZAGEM BASEADA EM PROJETOS EM STEM*

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**Abstract.** Students of modern times are learning fast and passionately. They love the interactivity and are very interested in science. Robotics can be safely assigned as engineering for students. This is the first step toward disciplines such as programming, mathematics, science, and algorithms. Thus, the objective of the study is to investigate the feasibility of implementing robotics in our educational system to develop learning in STEM subjects. Therefore, the main purpose of this study was to investigate the effect of mBot robot activities in STEM subjects as part of project-based learning, to determine their satisfaction and perceptions of the project carried out. The methodology used for this research is the descriptive study model, which combines qualitative and quantitative research methods. The selected sample of 14 students was a purposive sample, since the participants were the students who had implemented the robotics competition project. Quantitative data is collected from questionnaires, while qualitative data is generated from open-ended survey questions. From the results of this study, it has been shown that the integration of the mBot robot into the educational system will undoubtedly increase the effectiveness of teaching and learning STEM education. Also, it was found that the level of students' creativity, attitude, and motivation increased with the inclusion of the mBot robot during project-based learning in STEM.

**Keywords:** Education, mBot, Project-based Learning, robot, and STEM.

**Resumo.** Os estudantes dos tempos modernos estão aprendendo com rapidez e paixão. Eles adoram a interatividade e se interessam muito por ciências. A robótica pode ser designada com segurança como engenharia para estudantes. Este é o primeiro passo em direção a disciplinas como programação, matemática, ciências e algoritmos. Assim, o objetivo do estudo é investigar a viabilidade de implementação da robótica em nosso sistema educacional para desenvolver a aprendizagem em disciplinas STEM. O objetivo principal deste estudo foi investigar o efeito das atividades do robô mBot em disciplinas STEM como parte da aprendizagem baseada em projetos, para determinar sua satisfação e percepções do projeto realizado. A metodologia utilizada para esta pesquisa é o modelo de estudo descritivo, que combina métodos de pesquisa qualitativos e quantitativos. A amostra selecionada de 14 alunos foi uma amostra proposital, uma vez que os participantes foram os alunos que implementaram o projeto de competição de robótica. Os dados quantitativos são recolhidos a partir de questionários, enquanto os dados qualitativos são gerados a partir de perguntas abertas do inquérito. A partir dos resultados deste estudo, foi demonstrado que a integração do robô mBot no sistema educacional aumentará, sem dúvida, a eficácia do ensino e da aprendizagem da educação STEM. Além disso, constatou-se que o nível de criatividade, atitude e motivação dos alunos aumentou com a inclusão do robô mBot durante a aprendizagem baseada em projetos em STEM.

**Palavras-chave:** Educação, mBot, Aprendizagem Baseada em Projetos, robô, STEM.

## INTRODUCTION

Across the globe, innovative educational programs are preparing students to enter the fields of science, technology, engineering, and mathematics. These subjects, commonly called STEM, can open up new passions for students to succeed in developing 21st-century skills and abilities in students.

Programming brings out the advantages of logical thinking, mathematics, and creativity. Teaching approaches such as project-based learning, problem-based learning, and cooperative learning strategies can be applied to allow greater autonomy and active learning experiences, to promote uncertainty and active learning methodologies student-centered (Grant, 2011). Based on these learner-centered learning strategies, thinking can be applied through a logical analysis of data, abstractions, and problem-solving. All these practices in an educational context allow students to develop skills to solve complex problems (Johnson, Adams, Estrada, & Freeman, 2014). Recent years have seen a growing interest in the development of apps and games oriented toward learning programming, due to the many advantages and opportunities they offer, as well as the opportunities they offer in today`s and future world of work.

From these essential bases, some authors proposed a methodological strategy focused on project-based learning (Jonassen, 1977), with educational activities oriented to solving problems in real contexts with learning opportunities. This approach is based on inquiry, to ensure that learning occurs when the subject actively discovers and solves situations. According to these foundations, learning by doing involves an active approach to teaching and learning as the student seeks to acquire knowledge and skills through the

educational process. These approaches encourage the development of activities that involve skills and logical thinking.

The mBot robot has a big advantage in that you can work with an intuitive visual language with the 'mBlock' app, which includes a category called 'robot'. The mBot consists of an Arduino board (see Fig. 1), so all the materials, resources, and advantages of working with this board are actively in use when working with this robot. Its resources include: Brightness sensor; Proximity sensor; Sensor that follows lines; 2 RGB LEDs with a choice of color; Allows a user to play musical notes (buzzer); A button on the plate (Sáez-López, 2019).

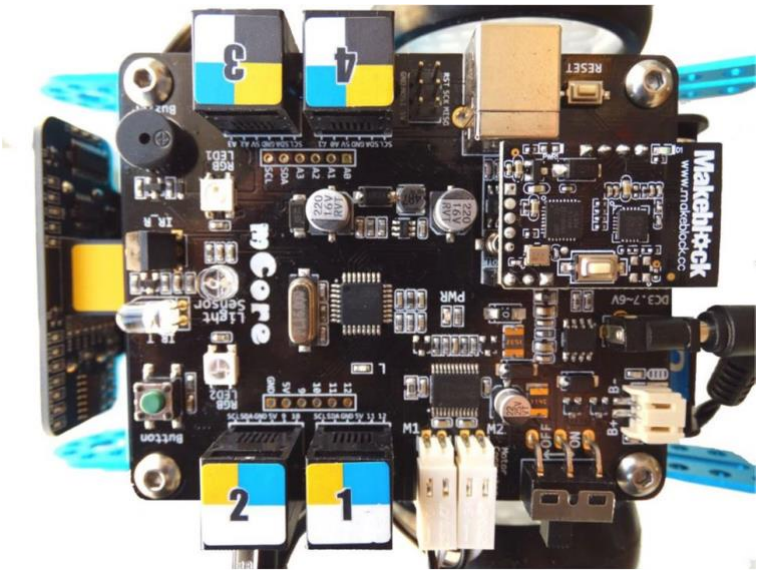


**Figure 1.** mBot, Arduino board details (Sáez-López, 2019)

In these contexts, visual programming can be used to solve problems and enable coding to be taught in lower secondary schools. When students manipulate pieces to fit them together, this visual block system avoids the programmer error messages that commonly appear in programming languages. Coding with such apps is easier than using traditional programming languages because students can play and interact with colored blocks to create scripts.

Computer programming is based on processes, methods, and logical models that enable problem-solving and the design of systems that we cannot do autonomously. Therefore, it is about programming a computer to solve a series of tasks through problem representation, prediction, and abstraction. The importance of teaching thinking skills from an early age is a key element that has attracted students' attention. Programming is not only a fundamental computer science skill and a key tool to support the cognitive tasks involved in computational thinking but also a demonstration of logical competence.

Coding has become a new modern language to express ideas and inspire originality in students, helping to develop logical thinking. mBlock, the software used to program the mBot is a programming software consisting of colorful and modularized drag-and-drop graphical blocks. Students feel fulfilled when they can easily program mBot without writing difficult codes and languages. mBlock is inspired by Scratch 2.0 which makes it easy to program the robot and undertake creative interactions. Programming is also easy to master as building blocks. By dragging the blocks into the editing area, you can easily create funny games, stories, and animations. The program interacts with mBot's main control board, allowing users to easily create interactive smart applications.

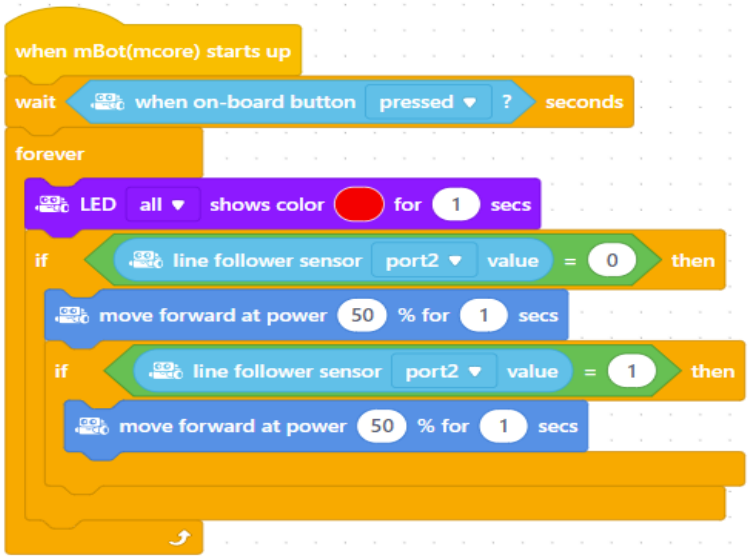


**Figure 2.** mBlock Code (Orhani, 2023)

On the other hand, project-based learning (PBL) is an instructional methodology that encourages students to learn by applying knowledge and skills through an engaging experience. PBL presents opportunities for deeper learning in context and for developing important peer-related and career-readiness skills. Projects require students to engage in research, solution construction, and product construction to help address the issue or challenge presented. As students do the work, they often use content knowledge and skills from multiple academic areas to successfully complete the project (O'Brien, 2022).

Therefore, this study provides students with the opportunity through project-based learning of mBot robot programming to engage them in real-world learning. This project was arguably the greatest opportunity to engage students in authentic projects or perform tasks related to careers and real-world experiences. The students in this project worked for a long period time, in the first four rounds of qualification in the robotics competition organized by "Bonevet", who were engaged in solving some problems required for this project. "Bonevet" is an educational institution in Kosovo that encourages children, youth and adults to identify talents and develop skills.

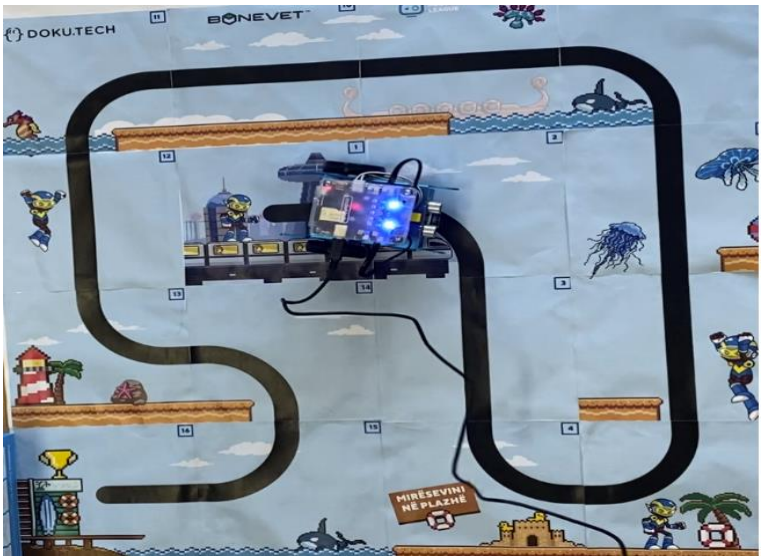


**Figure 3.** The project was realized with mBot robot (Orhani, 2023)

## BACKGROUND

A motivated student will perform better than an unmotivated student. In this respect, motivation is an important component of teaching. Recently, researchers have shown a growing interest in the effect of robotics activities on student motivation in science lessons. Studies that investigated the relations between

the environment and students' motivation to engage with science have typically looked at the state of students' motivation at a given time and its relations with the environment (Fortus & Touitou, 2021). Robotics in education is of particular importance in today's digital society where students need to know how to deal with technology. However, the use of robot components in science lessons has emerged as an innovative and effective teaching tool in educational processes. Applications of robotics in education are mostly used in the STEM field and science lessons (Yolcu & Demirer, 2017). A series of educational resources and robots can be programmed and manipulated through visual block programming (Tickle, Blocky, Scratch, M block, etc.), and can foster easy experimentation in elementary education settings due to the intuitive nature of this type of programming.

Rusk et al. (2008) define robotics as programmable devices that perform actions depending on sensor inputs (Rusk, Resnick, Berg, & Granlund, 2008). Programming can be defined as providing the solution to a specific problem, in which the problem must first be understood and analyzed; finally, the solution algorithm is translated into code (Oddie, Hazlewood, Blakeway, & Whitfield, 2010). Empirical evidence suggests the effectiveness of robotics as a supplemental learning tool (Mazzoni & Benvenuti, 2015). Various studies on robot assisted learning have proven them to be effective tools for language education because robots are remarkably successful in eliminating the affective filter. This study demonstrates ROBOSEM with class content for sustaining long-term interaction with students in English classes of elementary schools as a teaching assistant, not a teacher (Park, Han, & Kang, 2011). Robots can be helpful teaching tools in the school, as evidenced by the results and pertinent literature, but it is unlikely that they will ever completely replace teachers. Robots, however, are a flexible solution for the educational system and are appropriate for some forms of assistance (Orhani, 2023). Robotics technologies are seen as a suitable tool for science education because they motivate students to participate in learning and facilitate the implementation of active learning strategies (Khanlari, 2013). Robotics can be applied as a pedagogical tool for science education using different teaching approaches, such as inquiry learning, problem-solving (Altin & Pedaste, 2013), and project-based learning (Karahoca, Karahoca, & Uzunboylu, 2011).

In project-based learning, students are first presented with real-world problems or projects, and these problems or projects become the focus of mentor-led teaching and learning. Students begin to learn specific subjects and achieve general skills to solve problems or make projects. Project-based learning provides students with general professional skills such as problem-solving skills, team skills and adaptability to change, communication skills, self-directed learning, and self-assessment skills (Bada, Laamanen, & Miiro, 2013).

Many researchers-based robotics on constructivism theory, which believes that teaching is expected to be an indirect process and students' conceptual changes result from immersion in real-world situations and interaction with learning resources and events through personal experiences. Through this perspective, learning enhances students' understanding of natural and complex environmental systems. This is achieved through promoting student interest, motivation, and engagement, especially when they are assigned to a collaborative learning environment (Kiaie & Khanlari, 2015).

**Purpose of the Study**

The project organized by "Bonevet" focused on robotics competitions to enhance the intellectual development of primary and lower secondary school students, which produce positive results across the globe. Today is the right time for educators to think about implementing project-based learning through robotics in educational systems to facilitate the learning of scientific phenomena and the engineering application of environmental sustainability. Thus, the objective of the study is to investigate the feasibility of implementing robotics in our educational system to develop learning in STEM subjects.

Despite the many advantages offered by the use of robotics activities in science education, there have not been enough studies in our country on the integration of robotics activities directly into science lessons. Therefore, this study highlights the importance of an educational design that incorporates robotics and programming through a visual programming language as a means of enabling students to significantly improve their understanding of the elements of logic. Thus, the main purpose of this study was to investigate the effect of mBot robot activities in STEM subjects as part of project-based learning, to determine their satisfaction and perceptions of the project carried out.

**Research Questions**

In this regard, we pose several research questions:

1. How important is it to apply programming as part of project-based learning in junior high schools?

2. What role does the integration of robotics have in pedagogical practice for motivation, engagement, participation, and critical thinking?
3. How do students perceive the inclusion of the mBot robot as part of project-based learning in STEM?

**Hypothesis**

Hypothesis 1: Students feel satisfaction and are motivated for lessons when their activities include projects realized with the mBot robot.

Hypothesis 2: Project-based learning through mBot programming positively affects student engagement in STEM.

Hypothesis 3: There is a statistically significant relationship between mBot implementation and project-based learning in STEM.

## METHODS

The methodology used for this research is the descriptive study model, which combines qualitative and quantitative research methods. A descriptive survey involves gathering information from students who are related to the education process (Borg & Gall, 2007). Orodho (2012) also opines that descriptive survey designs are used for exploratory studies to provide scope for sampling the attitudes, views, practices, and social issues of individuals (Orodho, 2012). Therefore, the choice of the descriptive model was suitable for this research, to understand the students' attitudes about the implementation of project-based learning through the mBot robot in STEM. The lessons developed during the research were projects based on programming topics, where students integrated programming through blocks to create scripts.

**Participants**

The sample of the study consists of 14 students of the lower secondary school "Heronjte e Lumës" in Vërmicë/Prizren, the lower secondary school "Xhevat Berisha" in Prizren, and the lower secondary school "Lidhja e Prizrenit" in Prizren from Kosovo that was part of a robotics competition organized by "Bonevet" at the Kosovo level. The selected sample is a purposive sample, since the participants were the students who had implemented the robotics competition project. The study was carried out for about 4 months, as long as the qualification procedure of the competition until the final.

Participating students were equal by gender, where half were male and the other half female. Regarding the age, 7.1% of the students were 12 years old, 14.3% were 13 years old, 64.3% were 14 years old, and 14.3% were 15 years old. Whereas based on technological knowledge, 21.4% of students had a basic knowledge of technology use, 71.4% had average knowledge, and only 7.1% advanced knowledge of technology use.

The Alpha Cronbach of the questionnaire was .651, indicating adequate internal consistency for the effect of mBot robot activities in STEM subjects as part of project-based learning.

**Data Collection and Analysis**

Quantitative data is collected from questionnaires, while qualitative data is generated from open-ended survey questions. The questionnaire in this research was used since the students were participants in the lessons elaborated by means of the mBot robot. In the parallel design, qualitative and quantitative data of equal importance were collected simultaneously, combined, and used together to answer the questions and hypotheses posed. In this study, qualitative and quantitative data were collected together and then analyzed in a holistic manner. The questionnaire includes 8 closed questions and 2 open questions. Closed questions are presented in a Likert scale format with five response options (5 = Strongly agree, 4 = Agree, 3 = Neutral, 2 = Disagree, 1 = Strongly disagree). On the other hand, open questions require the students' deepest opinion on the studied topic. In the analysis of the quantitative data, the software for social sciences SPSS was used, while in the analysis of the qualitative data for the open questions, the qualitative content analysis method was used.

Descriptive statistics such as frequency distributions and cross-tabulations were used to analyze and visualize all ordinal data from the Likert scale questions. After confirming normality, the t-test was used for comparisons within variables to account for unequal sample sizes in the analyzed subgroups. All statistical tests were performed at a 95% significance level. Also, Chi-Square was used to analyze whether there is a relationship between students' technological knowledge, the inclusion of the mBot robot in STEM, and the

use of project-based learning in STEM lessons. And finally, using Paired Samples Correlations it was seen if there is any significant relationship between the studied variables.

Since the students were of adult age, it was not necessary to obtain parental consent, but only the students voluntarily participated in the research.

## RESULTS

Today, the need for curriculum development that possesses concrete training in STEM education is constantly growing. Improving the quality of education in Kosovo's lower secondary schools is becoming necessary to increase competition with modern countries. Now also in our country, various robotics competitions are taking place. In these competitions, students and their teams were challenged to program a mBot robot that defines a mission or accomplishes a specific task to promote STEM education. Therefore, our student`s understanding of their own abilities, including project-based learning, is strongly influencing their perception of STEM education. From all this, we are presenting the results of our research regarding the inclusion of the mBot robot as part of project-based learning in STEM subjects.
Below the crosstabulation tree we are analyzing the results of including the mBot robot in project-based learning:

**Table 1.** mBot robot with project-based learning

| Robot * PBL Crosstabulation | | | | | |
|---|---|---|---|---|---|
| | | | PBL | | |
| | | | Agree | Strongly agree | Total |
| Robot | Agree | Count | 0 | 2 | 2 |
| | | % within PBL | 0,0% | 18,2% | 14,3% |
| | Strongly agree | Count | 3 | 9 | 12 |
| | | % within PBL | 100,0% | 81,8% | 85,7% |
| | Total | Count | 3 | 11 | 14 |
| | | % within PBL | 100,0% | 100,0% | 100,0% |

Research results regarding student motivation by integrating the mBot robot into project-based learning emerge these findings. About 85.7% of students think that the application of robots in learning activities will increase their interest in actively participating in the classroom, and robotics as a learning object motivates classroom students in science, technology, education, and mathematics. Also, the same figures show that project-based learning increases the engagement and motivation of students in the classroom. If we analyze the students' motivation and satisfaction together, the results show that 85.7% of students are motivated and satisfied if the robot is integrated into STEM lessons, while 78.6% agree that they have the additional motivation and greater engagement when STEM lessons are applied based on projects.

Below through the t-test, we are looking at the significance is significant about the inclusion of the mBot robot in project-based learning in STEM:

**Table 2.** t-test results for the mBot robot and project-based learning

| One-Sample Test<br>Test Value = 0 | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | 95% Confidence Interval of the Difference | |
| | t | df | Sig. (2-tailed) | Mean Difference | Lower | Upper |
| Robot | 50,047 | 13 | ,000 | 4,85714 | 4,6475 | 5,0668 |
| PBL | 42,052 | 13 | ,000 | 4,78571 | 4,5399 | 5,0316 |

According to the t-test results, we notice that we have a high mean of 4.65 and a standard deviation of 5.07 for the integration of the mBot robot in STEM, we also have a high mean of 4.79 and a standard deviation of 5.03 for the inclusion of learning project based. For these two variables, we have a significant significance with .000, which is less than .05 which shows that these two variables are with a significant significance.

Below we analyze through the nonparametric test whether there is a correlation between students' technological knowledge, the inclusion of the mBot robot in STEM, and the use of project-based learning in STEM lessons.

**Table 3.** Chi-Square test

| | Technological knowledge: | Robot | PBL |
|---|---|---|---|
| Chi-Square | 9,571a | 7,143b | 4,571b |
| df | 2 | 1 | 1 |
| Asymp. Sig. | ,008 | ,008 | ,033 |

a. 3 cells (100,0%) have expected frequencies less than 5. The minimum expected cell frequency is 4,7.
b. 0 cells (0,0%) have expected frequencies less than 5. The minimum expected cell frequency is 7,0.

Analyzing the results of the Chi-Square table, we notice that the variables of technological knowledge, robotics, and project-based learning are related to each other, because the result is significant since the p-value is less than the level of assigned alpha .05. This value results in .008 for students' technology knowledge, .008 for mBot involvement in STEM, and .033 for use of instruction based on STEM lessons.

Below we analyze via average and histogram whether robotics can be used to teach design, programming, teamwork and science, technology, and math skills:

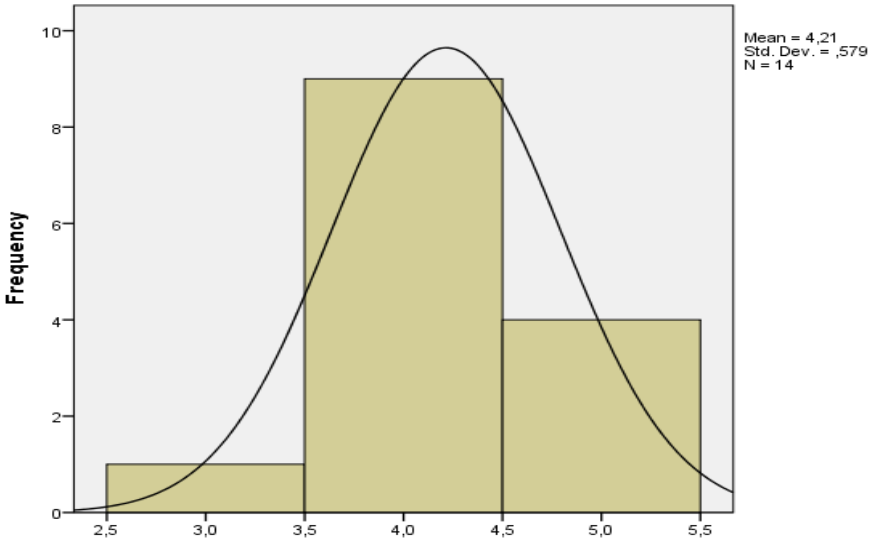


**Figure 4.** Histogram for students' perceptions about the inclusion of programming in STEM

From the results of the histogram presented above, we are noticing that we have a normal distribution where the mean of student perceptions regarding the use of the mBot robot to teach design, programming, teamwork, and science, technology and mathematics skills is 4.21 and a standard deviation of .579. This shows that the students think that the mBot robot is influencing the learning of STEM subjects through programming and thus developing the technological skills of the students, and this is proving to be important as part of project-based learning in low high schools.

Below, through Paired Samples Correlations, we are analyzing the relationships between the implementation of the mBot robot among project-based STEM subjects:

**Table 4.** Paired Samples Correlations

| | | N | Correlation | Sig. |
|---|---|---|---|---|
| Pair 1 | Can the implementation of robots in learning activities increase students' interest in actively participating in the classroom? & Robot | 14 | ,558 | ,038 |
| Pair 2 | Do robotic technologies enable students to learn many necessary skills through practice? & Robot | 14 | ,548 | ,043 |

| | | | | |
|---|---|---|---|---|
| Pair 3 | Did the implementation of project-based learning have an effect on developing our skills, abilities, and group cooperation to successfully finalize the project? & PBL | 14 | ,549 | ,042 |
| Pair 4 | Do I prefer that the lessons of scientific, technological, educational, and mathematical subjects are realized with a research project? & PBL | 14 | ,174 | ,552 |

From the analysis of Paired Samples Correlations from the table above, we notice that we have a significant significance that is smaller than .05 or close to this value. Therefore, we will take as a basis the examination of the correlation between these variables, interpreting the findings of the table. From this, we are noticing that we have a moderate positive correlation with .558 for the implementation of the mBot robot in learning activities on the other hand that affects the increase of students' interest to participate actively in the classroom. Also, another moderate positive correlation with .548 for the opportunity offered to students by robotic technologies to learn many necessary skills through practice. On the other hand, we have a moderate positive correlation with .549 for the impact of the implementation of project-based learning on the development of skills, and group cooperation to successfully finalize the project. However, we have a low positive correlation with .174 for students' preferences for STEM lessons to be carried out with a research project.

From the qualitative research results collected from the open questions of the questionnaire, the following findings emerge. Taking into account the ninth question about what experience the students gained while programming the mBot robot in the implementation of project-based learning, they declare that they had acquired skills on how to work with the robot and how to gain as much knowledge as possible about the technology. Also, another student points out that they had learned the basics of programming and robotics, how to program the robot to walk along a path. They emphasize that they had acquired 21st-century knowledge and skills, awakening curiosity and creativity for STEM subjects. The students' answers show that they had cooperated in groups to carry out the project successfully and had invited a good experience with robotics. From the answers to the last question about what additional comments they have related to the application of the mBot robot in project-based learning, the participating students reflected on their comments. One of the students says that if we have more access to project-based learning, I think we will have an easier time with our work or project. Participants indicate that it was great to integrate the mBot into our lessons and it was very engaging for students and teachers. The students said that it was a very nice competition, and they were trying to complete it successfully. Also, they give additional comments showing that it was a very simple but sometimes difficult task, and it was also a very nice experience. They point out that the mBot robot gives them more interest in technology and was a targeted project.

## DISCUSSIONS

New technologies are changing the way people around the world have an ever-greater impact on society. Our educational institutions are promoting reforms that take this revolution into account, both to take advantage of the educational opportunities opened up by these technologies and to train students in their use. Not only is the content delivered changing, but so is the way the classes themselves are focused. However, there is still much to do. Based on this analysis and our experience in Kosovar schools, an educational proposal has been drawn up and presented on how to introduce robotics into STEM teaching and learning.

From the analyzed results, we notice that we have a high average of 4.21, which shows that programming, design, and teamwork skills are important to be applied as part of project-based learning in lower secondary schools. The results of our qualitative research data are also showing that the program is becoming an activity that involves creating, modifying, and implementing code, and exposing students to computational thinking, and becoming an integral part of today's STEM education. The results of the study by Abesadze and Nozadze (2020) show that during the development of the project with X-grade students learn programming and develop 21st-century skills, while elementary school students programmed by playing and learning at the same time. Learning through programming with game creation is an interesting and innovative method to use in practice (Abesadze & Nozadze, 2020). Therefore, from these findings we can answer the first research question that programming is important to apply as part of project-based

learning in junior high schools, since in addition, students learning programming will be more interested in learning how to program a robot, learn about artificial intelligence, and get involved in other projects.

On the other hand, satisfaction in STEM lessons is related to students' positive feelings towards the developed learning activities, which directly affect students' motivation. Therefore, students' satisfaction with mbot robot activities was also among the topics discussed in our research. The results of our study show that significant improvements were achieved in the lesson and in the acquisition of concepts, based on an active pedagogical practice that aroused motivation, enthusiasm, commitment, fun, and interest in the studied content. Results from the qualitative data indicate that students had acquired 21st-century knowledge, and skills, awakening curiosity and creativity for STEM subjects. Our results are similar to the findings of the study conducted by Talib, Aliyu, Aliyu, and Malik (2020) who point out that robotics helps students transform abstract scientific, engineering, and technological concepts into concrete concepts to understand the real-world environment. , so countries like China, Japan, Russia, and the United States of America organized robotics competitions for high school STEM subjects to cultivate students' intelligence and talent in the next generation (Talib, Aliyu, Aliyu, & Malik, 2020). From our findings and the reviewed literature, we can answer the second question posed, what role does the integration of robotics have in pedagogical practice for motivation, engagement, participation, and critical thinking. So, integrating robotics into pedagogical practice can help improve students' creativity by enabling them to think differently and critically. Through the design and programming process, students can develop thinking skills and other engagements such as digital literacy, as well as active participation in problem-solving. The application of the methodological approach allowed the design of workshops focused on the needs of a specific user and context. In other words, the proposal is a process that can include methodological guidelines to apply a robotics curriculum.

The current research showed active student participation in project-based learning through the inclusion of the mBot robot in STEM, where there was positive acceptance and impact. The study by Cano (2022) states that students' interest and curiosity about a methodological approach that allows educational robotics to develop STEM competencies leads to the development of positive perceptions (Cano, 2022). From the results of our study, we observed that almost all students had positive perceptions regarding the integration of the mBot robot through project-based learning in STEM lessons. According to the analysis of the results in table 1 we are noticing that 81.8% of the participants fully agree that it is necessary to integrate robotics in STEM lessons through project-based learning, and also the rest show that they have positive perceptions regarding this inclusion. Also, from the additional comments of the participants, a positive perception was observed regarding this phenomenon, and they think it was also a very nice experience for them. Therefore, from these results, we can also answer the third question posed for this research, that students positively perceive the inclusion of the mBot robot as part of project-based learning in STEM. So, a project-based learning approach has proven to be successful in teaching with the inclusion of robotics, as it is providing a successful mechanism to help students achieve higher-level learning goals and deal with real activities for the realization of projects.

From the results of our research, we are noticing that 85.7%, respectively 78.6% of students enjoy integrating the mBot robot into project-based learning in STEM, and this percentage also results in higher student motivation during learning activities. Also, from the results, of the qualitative data, it was observed that the participants indicated that they were satisfied with the integration of the mBot robot in our lessons, and it was very engaging for the students and teachers. It was also observed that evaluation results by Bada, Laamanen, and Miiro (2013) show that during project-based learning activities, students developed skills in circuit design, robot programming, problem-solving and collaborative work. (Bada, Laamanen, & Miiro, 2013). From these results we can prove the first hypothesis of the research by emphasizing that the students feel satisfaction and are motivated for the lessons when their activities include the projects realized with the mBot robot. In project-based learning, students are more responsible for their learning, which results in a higher approach to student motivation in the STEM learning environment.

From our findings of the correlation analysis between the impact variables of the student engagement variable and the implementation of project-based learning in STEM subjects, we are noticing that we have a significant significance with a value lower than .05 and a correlation positive moderate between these variables. Also, the findings of the qualitative data are showing that the students cooperated in groups to carry out the project successfully and invited a good experience with robotics, and they reflected their positive comments that project-based learning through programming. The mBot robot is greatly influencing their engagement in STEM subjects. The results of our research are in line with Coşkunserçe's (2021) study which states that robotics activities are used in many different educational environments due

to their positive effects (Coşkunserçe, 2021). Therefore, from the results, we are noticing that we can support the second hypothesis of the research that project-based learning through the programming of the mBot robot has a positive effect on the engagement of students in STEM. Thus, mBot the robot has emerged as a unique learning tool that can provide hands-on, fun activities in a project-based learning environment, nurturing students' interest and curiosity about STEM subjects.

The results of the Chi-Square table show that the p-value is less than the standard alpha value, so we will support our hypothesis that the variables are dependent on each other. Simply put, the result is significant, the findings suggest that the variables robotics and project-based learning are related to each other through the technological knowledge that the students had. Also, from the qualitative data, we are noticing that they emphasize that the mBot robot gives them more interest in technology, and it was a project aimed at STEM. Our findings parallel those of Ghaleb, Aly, and Almalki (2020) who suggested that students with this type of project-based learning for robotics engineering were more active learners and were more likely to view problems as challenges that could be faced with success (Ghaleb, Aly, & Almalki, 2020). In this case, so we would accept the third hypothesis by pointing out that there is a statistically significant relationship between the implementation of the mBot robot and project-based learning in STEM. This shows that the students engage in a creative way, the knowledge and skills they had acquired from the implementation of the mBot robot to solve their projects. Thus, there is a need to promote robotics education in teaching curricula, as project-based learning in STEM with the inclusion of robotics is becoming a basic component in developing students' skills and abilities.

## CONCLUSION

From this study we can draw two important pedagogical implications. Initially, given all the findings discussed above, project-based learning through mBot robot programming can be integrated into STEM subjects. Then, when implementing these projects in the classroom, mentors may face several challenges that they should be aware of: teamwork collaboration, student support and student motivation, amount of time needed to complete the project and the mentor's role as a facilitator in these projects.

From the results of this study and the various literature analyzed, it has been shown that the integration of the mBot robot into the educational system will undoubtedly increase the effectiveness of teaching and learning of STEM education. Also, the findings, show that programming was important to apply as part of project-based learning in lower secondary schools and the integration of robotics in pedagogical practice is helping to develop students' creativity by enabling them to think differently and in a critical way. Among the other findings that we can single out is that students positively perceive the inclusion of the mBot robot as part of project-based learning in STEM. Also, the results show that the students feel satisfaction and are motivated for the lessons when their activities include the projects realized with the mBot robot. And finally, from our findings we can conclude that there is a statistically significant relationship between the implementation of the mBot robot and project-based learning in STEM.

In conclusion, we can say that technology has not come to replace pre-existing teaching methodologies, but has come to strengthen our abilities as human beings. Learning is not likely to be automated as is the case with many industries these days, but it will only change the structure of our work as teachers and help students reach their full potential faster and in a way rollicking (Clarke, 2022).

Although this scientific paper has analyzed the positive impact of mBot robot as part of project-based learning in stem, there are some limitations that should be considered. One of the limitations is that the study is geographically limited to a specific school context. This may make generalization of the findings to different contexts more difficult. Also, this study may be based on a specific time, so changes in time and future technological developments are not addressed in detail.

In addition to limitations, future steps include extending the research to more schools and school contexts to assess whether the results are consistent. Another step could be to use other research methodologies, such as online surveys, to obtain further perspectives of students and teachers.

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