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FUN ROBOTICS TEACHING PROGRAMMING WITH PLAY

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ABSTRACT
The present study examines the effectiveness of gamified robotics as a method of teaching programming to elementary school students. Using a mixed methodological approach, the study compared an experimental group, which participated in a semi-structured leisure flight program, with a control group. The results showed a significant increase in programming knowledge and related skills in the experimental group, with an average improvement of 42% in test results, compared to 12% in the control group. A high level of engagement and intrinsic motivation was observed among participants, with 92% expressing a desire to continue learning the program through this approach. The qualitative analysis revealed improvements in collaboration, communication and problem-solving, as well as a positive change in students' attitudes towards mistakes and challenges. The final projects demonstrated creativity and practical application of the concepts learned. Despite the promising results, the study recognizes limitations in terms of sample size and duration of the intervention, which indicates the need for further studies on a larger scale. It is concluded that fun robotics has significant potential as a method of teaching programming, providing an attractive and effective learning environment that not only teaches technical skills, but also promotes essential skills for the 21st century.

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Revista ARACÊ
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INTRODUCTION

In the contemporary educational scenario, the integration of technology in the teaching-learning process has become increasingly relevant. Among the various innovative approaches, "Fun Robotics" stands out as a promising methodology for teaching programming. This approach combines the principles of educational robotics with playful elements, creating an engaging and stimulating learning environment.

The digital age has brought with it a growing demand for programming skills, making teaching this skill increasingly crucial, especially for younger generations. In this context, educational robotics emerges as a powerful and innovative tool to introduce programming concepts in a playful and engaging way. According to Papert (1980, p. 27), "the child programs the computer and, in doing so, acquires a feeling of mastery over one of the most modern and powerful technological equipment and establishes an intimate contact with some of the deepest ideas of science".

The "Fun Robotics" approach proposes a teaching methodology that combines the principles of game-based learning with the fundamentals of programming and robotics. This fusion creates a stimulating educational environment, where learning occurs in a natural and pleasurable way. As Resnick (2017, p. 14) states, "when children create projects that interest them, they get involved in the creative process, developing themselves as creative thinkers".

The use of programmable robots in educational activities is not just a passing trend, but a response to the need to prepare students for an increasingly technological future. Fun robotics offers a unique platform for developing essential 21st-century skills, including critical thinking, problem-solving, and teamwork.

One of the most notable aspects of fun robotics is its ability to turn abstract programming concepts into tangible, interactive experiences. Through the physical manipulation of robots and the immediate visualization of the results of their codes, students can develop a deeper and more intuitive understanding of programming principles.

In addition, fun robotics has the potential to democratize access to technological knowledge. By presenting programming in an accessible and entertaining way, this approach can appeal to a more diverse range of students, including those who traditionally would not be attracted to the field of technology.

Interdisciplinarity is another key aspect of fun robotics. This approach is not limited to just teaching programming, but naturally integrates concepts from mathematics, physics,

Revista ARACÊ
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design, and even the arts. As Bers (2008, p. 145) observes, "robotics offers a unique path to integrate STEM (Science, Technology, Engineering and Mathematics) into early childhood education in a developmentally appropriate way".

The playful aspect of fun robotics should not be underestimated. The element of fun not only increases student engagement but also reduces the anxiety often associated with learning new tech skills. According to Prensky (2001, p. 5), "game-based learning is an agreement between the teacher and the student where, through the educational process, the student has fun and the teacher teaches".

Collaboration is an integral component of fun robotics. Many activities are designed to be carried out in groups, promoting communication, leadership and teamwork skills. These collaborative experiences reflect the actual work environment in technology, preparing students for future careers in the field.

In addition, fun robotics offers unique opportunities for the development of creativity. Students are often encouraged to create their own projects, solve problems in innovative ways, and express their ideas through robot programming and design. This creative freedom is key to nurturing the next generation of technological innovators.

The assessment of learning in fun robotics also deserves special attention. Unlike traditional assessment methods, this approach allows for continuous, project-based assessment, offering a more complete picture of students' progress and abilities. As Gardner (2006, p. 142) suggests, "assessment should support learning, not just measure it".

Finally, it is important to recognize that the successful implementation of fun robotics requires a paradigm shift in education. Educators need to be adequately trained and supported to effectively integrate this approach into their teaching practices. As Fullan (2007, p. 129) states, "educational change depends on what teachers do and think - it is as simple and as complex as that".

This article aims to explore the potential of fun robotics as a method of teaching programming, analyzing its theoretical bases, practical methodologies and impacts on the learning process. It seeks to understand how this approach can foster not only the development of technical skills, but also promote critical thinking, creativity and problem-solving, preparing students for the challenges of the ever-evolving digital world.

THEORETICAL FRAMEWORK

Fun robotics as a method of teaching programming finds its bases in several educational and psychological theories. One of the most relevant foundations is Seymour Papert's constructionist theory, which proposes learning through the active construction of knowledge. Papert (1993, p. 142) argues that "the best learning occurs when the learner takes charge", emphasizing the importance of autonomy in the educational process.

The game-based learning approach also plays a crucial role in fun robotics. This methodology takes advantage of the engaging elements of games to promote learning. Prensky (2001, p. 106) points out that "games are engaging because, among other things, they are fun, they are a way of playing, they give us goals, they give us feedback, they are adaptive, they have results and status, they give us ego gratification, adrenaline, creativity, social interaction and emotion". These elements, when incorporated into the teaching of programming through robotics, create a highly motivating learning environment.

Howard Gardner's theory of multiple intelligences offers valuable insights for fun robotics. Gardner (1983, p. 8) proposes that "intelligence implies the ability to solve problems or develop products that are important in a given environment or cultural community". Fun robotics, by combining visual, logical, kinesthetic, and interpersonal elements, has the potential to engage different types of intelligence, making learning more inclusive and effective.

Vygotsky's concept of zone of proximal development is particularly relevant in this context. Vygotsky (1978, p. 86) defines this zone as "the distance between the actual level of development, determined by independent problem solving, and the potential level of development, determined by problem solving under adult guidance or in collaboration with more capable peers". Fun robotics creates an environment where students can work collaboratively, supporting each other in the learning process.

Csikszentmihalyi's flow theory offers another important perspective for understanding student engagement in fun robotics. Csikszentmihalyi (1990, p. 4) describes flow as "the state in which people are so engaged in an activity that nothing else seems to matter." Fun robotics, by providing appropriate challenges and immediate feedback, has the potential to create flowing experiences, increasing student engagement and satisfaction in the learning process.

Papert's constructionist approach is complemented by Mitchel Resnick's view of "creative learning." Resnick (2017, p. 3) argues that "success in the future – for individuals,

Revista ARACÊ
ISSN: 2358-2472

for communities, for companies, for nations as a whole – will depend on the ability to think and act creatively". Fun robotics aligns with this vision, providing an environment where students can experiment, create, and innovate.

The concept of "tangible learning" is also central to fun robotics. Zuckerman et al. (2005, p. 859) define tangible interfaces as those that "give physical form to digital information, employing physical artifacts both as representations and as controls for computational media". In fun robotics, students interact with physical objects (robots), making abstract programming concepts more concrete and understandable.

Sweller's cognitive load theory offers insights into how to structure fun robotics activities to maximize learning. Sweller (1988, p. 257) argues that "instruction should be designed to reduce the cognitive load on working memory". Fun robotics, by presenting programming concepts in a visual and interactive way, can help reduce the cognitive load associated with learning abstract concepts.

Problem-based learning (PBL) is another approach that aligns well with fun robotics. Barrows and Tamblyn (1980, p. 1) define PBL as "learning that results from the process of working towards the understanding or resolution of a problem". Fun robotics naturally incorporates elements of PBL, presenting students with concrete challenges that require the application of programming concepts to solve.

The concept of "computational thinking", popularized by Jeannette Wing, is fundamental to understanding the value of fun robotics in programming education. Wing (2006, p. 33) argues that computational thinking "involves solving problems, designing systems, and understanding human behavior, drawing on the fundamental concepts of computer science." Fun robotics offers a concrete means to develop these computational thinking skills.

Finally, Ryan and Deci's theory of self-determination provides a framework for understanding students' motivation in fun robotics. Ryan and Deci (2000, p. 68) argue that "the conditions that support the individual's experience of autonomy, competence, and relationship foster the most volitional and high-quality forms of motivation and engagement for activities." Fun robotics, by providing choices, appropriate challenges and opportunities for collaboration, can satisfy these basic psychological needs, promoting more effective and enjoyable learning.

Revista ARACÊ
ISSN: 2358-2472

METHODOLOGY

To investigate the effectiveness of fun robotics as a method of teaching programming, we adopted a mixed methodological approach, combining qualitative and quantitative methods. This choice allowed us to capture both the richness of individual experiences and measurable data on student performance and engagement.

We began our research with a systematic review of the existing literature on educational robotics, programming teaching, and game-based learning. This step was crucial in establishing a solid theoretical foundation and identifying gaps in current knowledge that our study could address.

We then developed a fun robotics intervention program, designed to be implemented in elementary schools. The program consisted of a series of weekly workshops, each lasting two hours, over the course of an academic semester. The activities were carefully designed to introduce programming concepts in a gradual and playful way, using educational robotics kits appropriate to the age group of the participants.

To select the participants, we adopted a convenience sample, working with schools that showed interest in participating in the study. In total, five schools were selected, representing a diversity of socioeconomic contexts. In each school, two 6th grade classes were randomly chosen: one to participate in the fun robotics program (experimental group) and the other to continue with the regular curriculum (control group).

Data collection was carried out in multiple stages. Before the start of the program, we apply a pre-test to assess students' prior knowledge of basic programming concepts. This test was developed in collaboration with computer education experts and has undergone a validation process to ensure its reliability.

During the implementation of the program, we used participant observation to collect qualitative data on student engagement and interactions. The researchers kept detailed field diaries, recording observations about the students' behavior, challenges faced, and moments of discovery.

In addition, we conducted semi-structured interviews with a random sample of students and faculty throughout the program. These interviews allowed us to gain deeper insights into participants' perceptions of fun robotics and its impact on the learning process.

To capture quantitative data on student engagement, we implemented a digital badge system. Students earned badges for completing challenges, helping classmates, and

Revista ARACÊ
ISSN: 2358-2472

demonstrating creativity in their projects. This system not only provided us with measurable data on participation, but also served as an additional motivating element for students.

At the end of the program, we apply a post-test to assess students' progress in relation to programming concepts. This test was structured in a similar way to the pre-test, allowing a direct comparison of the results. We also asked students to complete a satisfaction questionnaire, using a Likert scale to rate their experiences with the program.

To analyze the qualitative data collected through observations and interviews, we used thematic analysis. This method allowed us to identify recurring patterns and themes in participants' experiences, offering a rich and contextualized understanding of the impact of fun robotics.

Quantitative data, including test results and engagement metrics, were analyzed using appropriate statistical methods. We performed paired t-tests to compare pre- and post-intervention performance, as well as analyses of variance (ANOVA) to examine differences between the experimental and control groups.

It is important to note that throughout the entire research process, we have maintained a strict commitment to ethics. We obtained informed consent from all participants and their guardians, ensured the confidentiality of the data collected, and ensured that participation in the study would not affect the students' regular school assessments.

Finally, we recognize the inherent limitations of our research design. The nature of convenience sampling may limit the generalizability of results, and the relatively short period of intervention may not fully capture the long-term effects of playful robotics. Nonetheless, we believe that our rigorous and multifaceted methodological approach has allowed us to gain valuable insights into the potential of fun robotics as a method of teaching programming.

ANALYSIS OF RESULTS

The results obtained through our research on fun robotics as a method of teaching programming revealed interesting and promising patterns. Initially, the comparison between the pre-tests and post-tests demonstrated a significant increase in programming knowledge among the students in the experimental group. On average, these students showed a 42% improvement in their scores, contrasting with an increase of only 12% in the control group.

Analysis of the semi-structured interviews revealed widespread enthusiasm among participants in the fun robotics program. A 6th grader commented, "I never thought coding could be so much fun. Now, I can't wait for the next class!" This sentiment was echoed by many others, suggesting a high level of engagement and intrinsic motivation.

The data collected through the digital badge system corroborated these qualitative impressions. We observed that 78% of the students in the experimental group earned at least five badges throughout the program, indicating a consistent involvement with the proposed activities. Interestingly, we noticed a gradual increase in obtaining badges related to collaboration and mutual aid throughout the semester, suggesting the development of a learning community among participants.

The thematic analysis of the field observations revealed interesting patterns in the behavior of the students. Notably, we identified a clear progression in the complexity of the projects developed by the students. At the beginning of the program, most students focused on simple tasks, such as making a robot move in a straight line. By the end, many were creating sophisticated designs, including robots that could navigate mazes or respond to environmental stimuli.

The satisfaction questionnaire applied at the end of the program provided valuable insights into the students' perception. An overwhelming majority of 92% of participants indicated that they would like to continue learning programming through fun robotics. One student expressed, "Before, I thought programming was only for nerds, but now I see that it's a way to create amazing things!"

The comparative analysis between the experimental and control groups revealed significant differences not only in programming knowledge, but also in related skills. Students in the fun robotics group demonstrated more marked improvements in problem-solving and logical thinking, as assessed by standardized tests administered before and after the intervention.

Interviews with the teachers involved in the program brought to light unexpected benefits. One educator noted, "I noticed an improvement in collaboration and communication among students, skills that extended to other subjects." This transfer of social and cognitive skills to other educational contexts emerged as a recurring theme in the interviews with the teachers.

The analysis of the final projects developed by the students revealed an impressive diversity of applications. From robots designed to assist with household chores to

Revista ARACÊ
ISSN: 2358-2472

prototypes of assistive devices for people with disabilities, the projects demonstrated not only technical mastery, but also creativity and social awareness.

Quantitative data on student engagement, measured through time spent on activities and frequency of voluntary participation, showed a steady increase throughout the program. Notably, we observed a positive correlation between the level of engagement and performance on programming tests, suggesting that the playful aspect of fun robotics can be a crucial factor for effective learning.

Finally, the analysis of the researchers' field diaries revealed an evolution in the dynamics of the classes. Initially, many students were hesitant and afraid of making mistakes. However, throughout the program, a shift to a more experimental and resilient attitude was observed. As one researcher noted, "Students began to see mistakes not as failures but as learning opportunities, a crucial mindset for development in programming."

DISCUSSION

The results obtained in our research on fun robotics as a method of teaching programming offer valuable insights into the potential of this approach. The significant increase in programming knowledge observed in the experimental group, compared to the control group, suggests that the integration of playful and tangible elements can accelerate the learning of complex concepts. This finding is in line with the constructionist theory of Papert (1993, p. 142), which emphasizes the importance of the active construction of knowledge.

The high level of engagement and intrinsic motivation observed among participants in the fun robotics program is particularly encouraging. The excitement expressed by students and their desire to continue learning programming through this approach suggests that fun robotics can be an effective solution to the problem of lack of interest in STEM (Science, Technology, Engineering, and Mathematics) subjects. As Resnick (2017, p. 14) argues, "when children create projects that interest them, they engage in the creative process, developing as creative thinkers."

The progression observed in the complexity of the projects developed by the students throughout the program is a promising indicator of the development of computational thinking. This evolution reflects the concept of the "creative learning spiral" proposed by Resnick, where students engage in a continuous cycle of imagination, creation, play, sharing, and reflection. The ability of students to create increasingly

Revista ARACÊ
ISSN: 2358-2472

sophisticated projects suggests that fun robotics can be an effective means of cultivating problem-solving and algorithmic thinking skills.

The improvement observed in collaboration and communication skills among the students in the experimental group is a particularly interesting result. This finding resonates with Vygotsky's sociocultural theory, which emphasizes the importance of social interactions in learning. As Vygotsky (1978, p. 86) states, learning occurs in the "zone of proximal development", where students can perform tasks with the help of more capable peers. Fun robotics seems to create an environment conducive to this type of collaborative learning.

The diversity and creativity demonstrated in the students' final projects suggest that playful robotics can be a powerful tool for fostering innovation and critical thinking. By allowing students to apply programming concepts to real-world problems, this approach seems to cultivate a "maker" mentality, aligned with the skills needed for the 21st century. As Martinez and Stager (2013, p. 21) observe, "the act of doing something tangible, whether it is a computer program or a physical object, is a powerful learning exercise."

The observed correlation between the level of engagement and performance in programming tests is a crucial finding. This result suggests that the playful aspect of fun robotics is not just a nice "extra", but a fundamental component for effective learning. This observation aligns with Csikszentmihalyi's (1990, p. 4) theory of flow, which describes the state of total immersion and focus that occurs when an activity is intrinsically rewarding.

The change in attitude towards mistakes, from initial hesitation to a more experimental and resilient approach, is a particularly valuable result. This evolution reflects the development of a "growth mindset", a concept proposed by Dweck (2006, p. 7), who argues that "the passion to stretch oneself and persevere, even (or especially) when things are not going well, is the seal of growth." Fun robotics seems to create an environment where mistakes are seen as learning opportunities, a crucial perspective for development in programming and beyond.

The observed skill transfer, where the competencies developed through playful robotics have extended to other disciplines, is a particularly promising result. This finding suggests that the approach may have educational benefits that go beyond the specific domain of programming. As Wing (2006, p. 33) argues, computational thinking is "a fundamental skill for everyone, not just computer scientists."

However, it is important to recognize the limitations of our study. The relatively small sample size and the limited period of intervention suggest the need for additional research

Revista ARACÊ
ISSN: 2358-2472

on a larger scale and for longer periods. In addition, equity issues and access to the technology needed to implement large-scale fun robotics programs remain important challenges to be addressed.

In conclusion, our results suggest that fun robotics has significant potential as a method of teaching programming. By combining elements of tangible learning, collaboration, and creativity, this approach appears to create a rich and engaging learning environment. As Papert (1993, p. 1) observes, "the best learning will not come from finding better forms of instruction, but from giving the student better opportunities to build." Fun robotics seems to offer precisely this kind of constructive opportunity.

FINAL CONSIDERATIONS

This study sought to investigate about fun robotics as a method of teaching programming, a promising and thought-provoking panorama emerges. The results obtained throughout this study not only corroborate the potential of this innovative approach, but also open new perspectives for the future of technological education.

The significant improvement in the performance of the students in the experimental group, both in terms of programming knowledge and related skills, suggests that fun robotics can be a powerful catalyst for learning. As Seymour Papert (1993, p. 142) states, "the best learning occurs when the learner takes charge". Our research demonstrates that by providing a playful and interactive environment, playful robotics effectively puts students at the center of their own learning process.

The exceptional engagement observed among program participants is particularly encouraging. The transformation of abstract programming concepts into tangible and fun experiences seems to have the power to demystify technology, making it accessible and attractive to a wide range of students. This finding resonates with the view of Mitchel Resnick (2017, p. 3), who argues that "success in the future will depend on the ability to think and act creatively".

In addition to technical learning, the collateral benefits seen in terms of collaboration, communication, and problem-solving are remarkable. These skills, often referred to as "21st century skills", are increasingly valued in the contemporary world. By naturally fostering the development of these skills, fun robotics positions itself as a holistic and future-oriented educational approach.

Revista ARACÊ
ISSN: 2358-2472

The change in attitude towards mistakes and challenges, observed throughout the programme, is a particularly valuable result. Transitioning from a fear-of-failure mindset to an approach of experimentation and resilience is crucial not only for learning to program, but for personal and academic development in general. As Carol Dweck (2006, p. 7) observes, "the passion for stretching oneself and persevering, even when things are not going well, is the seal of growth".

However, it is imperative to recognize the challenges and limitations inherent in the large-scale implementation of fun robotics. Issues of equity and access to the necessary technology remain significant obstacles. It is crucial that as we move forward with this approach, strategies are developed to ensure that all students, regardless of their socio-economic background, can benefit from these educational innovations.

Looking ahead, we see vast potential for further research in this area. Longitudinal studies could explore the long-term effects of exposure to fun robotics, investigating how this experience influences students' academic and career choices. In addition, interdisciplinary research could examine how the principles of fun robotics can be applied in other areas of the school curriculum.

It is important to note that the success of fun robotics lies not only in the technology itself, but in the way it is integrated into the educational environment. The role of educators in this process is crucial. As Paulo Freire (1996, p. 47) states, "teaching is not transferring knowledge, but creating the possibilities for its own production or construction". Therefore, it is essential that teacher education programs incorporate not only the necessary technical skills but also the innovative pedagogies that underpin the fun robotics approach.

As we move into the digital age, the importance of computational thinking and programming skills is only likely to grow. Fun robotics, with its ability to make these concepts accessible and engaging, has the potential to play a crucial role in preparing students for the challenges of the future. As Jeannette Wing (2006, p. 33) observes, computational thinking is "a fundamental skill for everyone, not just computer scientists".

In conclusion, our research on fun robotics as a method of teaching programming reveals a promising path for technological education. By combining tangible learning, collaboration, and creativity, this approach not only teaches programming but cultivates a mindset of innovation and problem-solving. As we navigate the challenges and opportunities of the twenty-first century, playful robotics emerges as a powerful tool for

Revista ARACÊ
ISSN: 2358-2472

empowering the next generation of creative thinkers and problem solvers. The future of education is undoubtedly fun, interactive, and profoundly transformative.

Revista ARACÊ
ISSN: 2358-2472

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