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A Systematic Literature Review on the Impact of Robotics Extracurricular Activities in Improving Students' Creativity

Lis Astuti, Triyanto, Karsono

Universitas Sebelas Maret
lisastuti@student.uns.ac.id

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Abstract
Creativity is one of the qualities that pupils require in the 21st century. However, these skills have not yet developed to the desired level. This study was conducted to determine the impact and the challenges faced in implementing robotics in extracurricular learning activities. The method employed in this study was qualitative, including a comprehensive literature review. The study included 14 research publications. The publications were sourced from ERIC Journal, PubMed, Google Scholar, and Science Direct. The study looked at research publications published between 2019 and 2024 that had a comprehensive framework, was open access, and utilized English and Indonesian. The findings of this study demonstrated that robotics extracurricular activities can help kids develop their creative talents while also improving the cognitive domain in the form of learning outcomes, psychomotor in the form of problem-solving, and good conduct. This is demonstrated by kids' capacity to generate ideas and create work in robotics activities. The hurdles in adopting robotics extracurricular activities include a lack of infrastructure facilities to fulfill hardware and software requirements, as well as teachers who are highly competent in teaching robots that must be addressed. This study may have consequences for increasing pupils' creative thinking. These findings highlight the need for teacher training and infrastructural changes to fully realize the promise of robotics activities in developing creativity. More study is needed to look at the development of learning models that are connected with robotics learning and how they influence other 21st-century skills.
Keywords: Extracurricular, Creativity, Robotics, Systematic Literature Review

Abstrak
Kreativitas merupakan salah satu keterampilan yang diperlukan oleh peserta didik di abad 21. Namun, keterampilan tersebut belum sesuai yang diharapkan. Penelitian ini dilakukan bertujuan untuk mengetahui dampak ekstrakurikuler robotik dalam mengembangkan kreativitas peserta didik dan tantangan yang dihadapi dalam implementasi ekstrakurikuler robotik. Metode yang digunakan dalam penelitian ini adalah kualitatif dengan pendekatan *systematic literature review*. Jumlah artikel penelitian yang diteliti berjumlah 14 artikel. Artikel tersebut diperoleh dari ERIC Journal, PubMed, google scholar dan science direct. Kriteria artikel yang diteliti daam penelitian ini adalah tipe *reseacrh article* yang diterbitkan pada tahun 2019-2024, memiliki struktur yang lengkap, *open acces* dan menggunakan bahasa Inggris dan Indonesia. Hasil penelitian ini mengungkapkan bahwa kegiatan ekstrakurikuler robotik dapat mengembangkan keterampilan kreatif peserta didik baik sekaligus peningkatan pada domain kognitif berupa hasil belajar, psikomotorik berupa problem-solving, dan perilaku yang baik. Hal tersebut terlihat pada kemampuan peserta didik yang mampu mengembangkan gagasan dan ide dalam menciptakan karya dalam aktivitas robotik. Tantangan yang dihadapi dalam mengimplementasikan ekstrakurikuler robotik adalah kurangnya fasilitas infrastruktur untuk memenuhi perangkat keras dan lunak serta guru yang memiliki kompetensi tinggi dalam mengajarkan robotik. Selain itu, metode pembelajaran yang masih kurang dalam mengintegrasikan pengetahuan dengan perangkat lunak robotik menjadi tantangan yang harus dicarikan solusinya. Penelitian ini dapat memiliki implikasi untuk meningkatkan pemikiran kreatif siswa. Temuan ini menunjukkan perlunya pelatihan guru dan peningkatan infrastruktur untuk memaksimalkan potensi kegiatan robotika dalam menumbuhkan kreativitas. Penelitian lebih lanjut diperlukan untuk meneliti pengembangan model pembelajaran yang terintegrasi dengan pembelajaran robotika dalam memengaruhi keterampilan abad ke-21 lainnya.
Kata kunci: *Ekstrakurikuler, Kreativitas, Robotik, Systematic Literature Review*

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INTRODUCTION

Creativity is one of the qualities that pupils must have in the twenty-first century (Dilekçi & Karatay, 2023; Eguchi, 2016). Creativity is required since it has the potential to affect future workplace success (Li, 2022). Creativity has a crucial part in character formation, promoting self-confidence, and helping youngsters be more resilient in the face of adversity (Burhamzah et al., 2023). Creativity enables pupils to perceive problems from multiple angles and devise novel solutions to the challenges they confront(Mantau & Talango, 2023).

However, the skill sets of Indonesian students are not as predicted and remain inadequate (Ferdiani & Pranyata, 2022). According to the Martin Prosperity Institute's 2015 Global Creativity Index, Indonesia placed 115th out of 139 nations. According to this research, Indonesia is one of the world's least creative countries (Pratiwi et al., 2024). In addition, the results of the 2022 Programme for International Student Assessment (PISA) study showed that Indonesia was ranked 68 out of 81 countries with a mathematics score of 379, a reading of 371, and science 398 (OECD, 2023). The PISA results show a relationship between creative thinking because the questions used in PISA are contextual questions that require argumentation, reasoning, and creativity to solve them. Other research indicates primary school children's creative thinking remains poor (Afiani & Putra, 2017; Dorisno et al., 2023). Previous research also revealed that the lowest indicator of creative thinking for students to master was fluency (Alfitriyani et al., 2021). It demonstrates children's limited capacity to give ideas that are useful to problem-solving. Students who lack creative thinking have difficulties handling questions. Their replies are neither methodical, well-structured, or comprehensive (Yayuk et al., 2020).

Implementing extracurricular robotics can help kids overcome their lack of imagination (Fitriani et al., 2023). Robotics activities, both extracurricular and other, can give expertise in the IT industry, requiring students to be creative and imaginative to keep up with worldwide trends (Miselina & Muhid, 2020). Extracurricular robotics activities help pupils improve their creative capabilities (Putri et al., 2020).

In Indonesia, robotic learning is incorporated in extracurricular activities at the junior and senior high school levels, but not in intracurricular instruction (Febriani et al., 2022; Putri et al., 2020). Furthermore, the implementation of robotic learning is suboptimal since it has not been integrated into the national curriculum, resulting in learning aids that are developed separately and no national criteria for learning results (Akidah, 2020). Robotics education, if implemented, will significantly improve problem-solving abilities, as well as communication and technological skills following the 21st century (Yang et al., 2023). As a result, it is quite intriguing to investigate the role of robotic extracurricular activities in increasing student creativity. The primary school curriculum does not include robotic learning in intracurricular activities. Only a few schools provide robotic learning as an extracurricular activity in elementary school.

The invention of educational robotic ecosystems in Indonesia and overseas varies. Robotic learning is better developed elsewhere, such as in one of the southern European countries (Angeli & Valanides, 2020). The study found that robotic learning can help youngsters aged 5 to 6 years acquire computational thinking skills. The findings indicate that children at this young age may overcome the difficulty of learning tasks by breaking them down into several simpler subtasks via robotic learning. Second, research into robotic-based steam learning in Spain (Jurado et al., 2020). The study's findings revealed that using robotic-based STEAM learning improved students' abilities, with smarter students performing better in collaboration, communication, and creativity, while students with lower grades performed better in behavior and creativity. Third, studies were undertaken in Australian primary schools on the integration of robotic learning into the classroom (Chalmers, 2018). The study found that learning

activities with robotic kits helped instructors gain confidence and competence in introducing conceptual thinking, practices, and computational views to pupils.

However, this study differs from past investigations. This study will look at the influence and challenges of extracurricular robotics activities on kids' creativity. Furthermore, this study employs a comprehensive literature review to cover all aspects of the topic. Furthermore, this study's theme, robots and creativity, is relevant to the twenty-first century. The 21st-century capabilities in this study area help to improve creativity by developing and instilling engineering skills, scientific interests, and computer proficiency in students' robotic activities (Nemiro et al., 2017).

This research is important to be conducted to determine the impact and challenges of extracurricular robotic activities in improving student creativity. Robotic learning can improve scientific investigation, teamwork, social skills, technical skills, and soft skills/social aspects (Kandlhofer & Steinbauer, 2016). Robotics training can also boost pupils' inventiveness (Miselina & Muhid, 2020). The purpose of this study is to determine the effects and obstacles of extracurricular robotic activities in enhancing student creativity.

METHOD

This study employed the Systematic Literature Review (SLR) research approach. This SLR study will identify, assess, and explain the effects and limitations of robotic extracurricular activities in enhancing student creativity. This SLR followed the Preferred Reporting Items for Systematic Reviews (PRISMA) standards (Moher et al., 2009). The following is a picture of the process of the articles selected in this study in Figure 1.

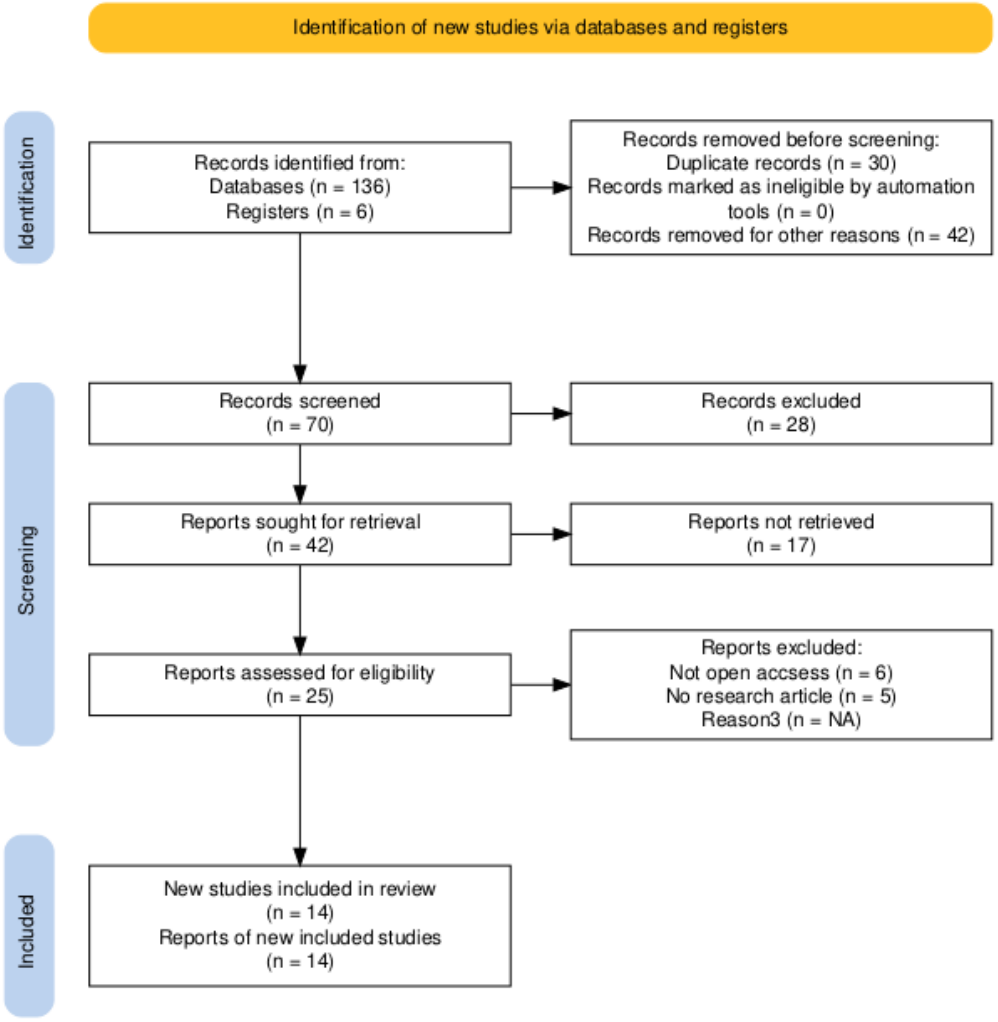

Figure 1. PRISMA Flowchart

The keywords used to find reviewed publications are "extracurricular robotics and creativity". The inclusion criteria for the publications analyzed in this study are available on ERIC Journal, PubMed, Google Scholar, and Science Direct, which are Scopus Q1-Q4. This study focused on research articles published between 2019 and 2024 that have a comprehensive framework, are open access, and are written in English and Indonesian. Furthermore, the selected publications address extracurricular robotic learning activities and demonstrate the outcomes of student innovation. The exclusion criteria in this study include that the paper should not have an incomplete structure, such as merely an abstract. Furthermore, the study's findings do not present empirical research findings and cannot be downloaded (not open access).

The article selection procedure was done in two steps. First, papers were reviewed based on their title and abstract to determine their relevance to the inclusion and exclusion criteria. Second, the articles that passed the initial screening were reviewed in their entirety to establish eligibility. The two researchers selected articles separately, and disagreements were resolved through conversations until a consensus was established. Data retrieved from each paper included the following: author, year of publication, research aims, research methodology, sample characteristics, robotic learning implementation, student creativity findings, and challenges and hurdles to adopting extracurricular robotic learning. The retrieved data was then narratively synthesized to address the study questions. Each article's findings were categorized by

theme and examined descriptively using the research questions that had been established. The analysis of this research utilized thematic analysis. Thematic analysis is a versatile tool for detecting and comprehending patterns of meaning in qualitative data that may be used in a wide range of theoretical and scientific settings (Clarke & Braun, 2017).

Based on the article selection findings, 14 research papers were identified as related to the specified study topic of the influence of extracurricular robotic learning on improving student creativity. There were three Indonesian articles (Faridawati et al., 2020; Fitriani et al., 2023; Munirah et al., 2023). The research methodologies employed in the publications analyzed in this study were quantitative approach (50%), and qualitative (50%).

RESULT AND DISCUSSION

According to the findings of the review, the following article data was obtained in Table 1:

Table 1. List of Reviewed Articles

ID	Authors, Years	Title	Country	Type of Research
1.	(Norris et al., 2023)	Fostering collaboration and creative thinking through extra-curricular challenges with primary and secondary students	Australia	Quantitative
2.	(Chen et al., 2020)	Teaching and learning with children: Impact of reciprocal peer learning with a social robot on children's learning and emotive engagement	USA	Quantitative
3.	(Ou et al., 2023)	Investigation and analysis of the current situation of programming education in primary and secondary schools	China	Quantitative
4.	(Sun et al., 2024)	Comparative experiment of the effects of unplugged and plugged-in programming on computational thinking in primary school students: A perspective of multiple influential factors	China	Quantitative
5.	(Malinverni et al., 2021)	Educational Robotics as a boundary object: Towards a research agenda	Spain	Qualitative
6.	(Sen et al., 2021)	Computational thinking skills of gifted and talented students in integrated STEM activities based on the engineering design process: The case of robotics and 3D robot modeling	Turkey	Qualitative
7.	(Kucuk & Sisman, 2020)	Students' attitudes towards robotics and STEM: Differences based on gender and robotics experience	Turkey	Quantitative
8.	(Cheng, 2019)	Exploring factors influencing the acceptance of visual programming environment among boys and girls in primary schools	Hongkong	Quantitative

9.	(Munirah et al., 2023)	Mengenalkan Edukasi Robot untuk Mengembangkan Kreativitas dan Imajinasi	Indonesia	Qualitative
10.	(Faridawati et al., 2020)	Pembelajaran Robotik Untuk Mempersiapkan Generasi Muda Menghadapi Revolusi Industri 4.0 Dan Society 5.0	Indonesia	Qualitative
11.	(Fitriani et al., 2023)	Manajemen Ekstrakurikuler Robotik dalam Mengembangkan Kreativitas Siswa di Era Social Society 5.0	Indonesia	Qualitative
12.	(Fakaruddin et al., 2024)	Creative thinking patterns in primary school students' hands-on science activities involving robotic as learning tools	Malaysia	Qualitative
13.	(Yıldız et al., 2020)	Determination of Situations of Extra-curricular Practices Carried About Robotics, Coding and Electronics	Turkey	Qualitative
14.	(Leroy & Romero, 2022)	Creative intention and persistence in educational robotic	France	Quantitative

The Impact of Robotics Extracurricular Activities in Increasing Creativity

According to the findings of the article review, extracurricular robotic learning, particularly coding, contributes to improving creativity, analytical thinking, and problem-solving (Yıldız et al., 2020). Activities in robotics education, such as construction and programming, will help pupils develop their creative thinking skills (Fakaruddin et al., 2024). These robotic exercises, beginning with idea stimulation and progressing to concept generation or development, will enhance creative thinking habits. Robotic learning also has an impact on students' creative intentions and behavior so that they can solve problems faster (Leroy & Romero, 2022).

Robotics learning also assists students in obtaining integrated material from the subjects of science, technology, engineering, and mathematics (STEM), which will play an important role in changing learning methods in schools and improving one of the 21st-century competencies, namely creativity (Faridawati et al., 2020). Robotic learning in extracurricular activities involves not only learning the content but also practicing robot media directly. In addition to boosting figurative and verbal creative thinking, programming in robot learning will improve problem-solving skills or flexibility in attempting several methods to a problem, as well as originality in developing novel or brilliant thoughts about a certain circumstance or topic (Cheng, 2019). Robotic learning for students may develop children's imaginations, enhance their abilities and creativity, and build a love of learning since it can be a fun game material or object to assemble the robot (Munirah et al., 2023).

Robotics extracurricular programs are one of the significant extracurricular activities to promote kids' inventiveness in embracing the age of society. 5.0 (Fitriani et al., 2023). This is because the period of civilization 5.0, with its quickly increasing technology, is supposed to benefit humans. The characteristics of this age place humans at the heart of innovation or human-centered. Extracurricular activities can help to stimulate curiosity, fine motor abilities, problem-solving, patience, and teamwork. Kucuk & Sisman (2020) Furthermore, robotic learning activities promote creative thinking, decision-making, problem-solving, communication, skills, computational thinking, and cooperation. Computational thinking resulting from robotic learning also promotes creative thinking by encouraging the creation of interactive

personal tales, games, animations, and goods using technological software (Sen et al., 2021). Other studies have indicated that initiatives that combine robots with other types of social, cultural, and creative motivation provide fresh views and allow for diverse approaches to its usage in educational activities (Malinverni et al., 2021). Programming in robotics learning focuses on enhancing students' overall talents, creative capacity, and process growth (Ou et al., 2023). Norris et al. (2023) It was also found that robots can facilitate individual expression in constructive contexts.

Overall, extracurricular robotics learning helps children improve their cognitive, emotional/ affective, and psychomotor skills. Affectively, robotics can promote attitudes and behaviors such as apologizing for mistakes, asking for assistance, and demonstrating interest and optimism in learning (Chen et al., 2020). The affective domain comes from interactions with instructors and peers who support learners' cognitive and emotional requirements while they play and learn robotics. In the cognitive domain, incorporating robotic learning with STEM will increase cognitive learning results (Pambayun & Shofiyah, 2023). Furthermore, robotic learning in extracurricular activities also has an impact on students' psychomotor skills (Fitriani et al., 2023). This is because the robotic system that can express verbal and nonverbal behavior was developed to play games with children and also to make learners have continued interest during the playing activity with it (Kim et al., 2022).

The findings of this study are consistent with prior literature review research, which demonstrated that robots have a good role in educational learning, as their actions can foster creative thinking and increase problem-solving abilities (Karim et al., 2016). Robotics allows students to engage in spatial programming by creating invented and sequential programs that mediate relationships among the environment, robots, and humans in responsive and creative ways, showing the innovative potential for advancing activities featuring computational thinking (Amri et al., 2022). Previous studies have shown that robotics, such as Lego, and programming activities may help children improve their creative thinking, teamwork, problem-solving skills, language abilities, and reasoning (Lathifah et al., 2019).

The findings of this study on the impact of robotic learning on creative thinking are consistent with constructivist learning theory, which states that knowledge is created by discoveries built from reality through the process of assimilation and accommodation to solve problems, with the teacher acting as a facilitator (Herviani et al., 2024). This is because when robotic learning happens, it results in a product that is created using a project-based learning paradigm. Furthermore, past research has shown that PjBL stresses the development of creativity and problem-solving abilities, encouraging students to think outside the box and devise new solutions to the projects they work on (Dalimunthe, 2024). So, the outcomes of this investigation are consistent with the constructivist learning theory.

Challenges of Robotics Extracurricular Activities in Increasing Creativity

Challenges in extracurricular robotics activities include using innovative educational methodologies to create robotic activities that will pique the attention of more kids (Malinverni et al., 2021). Furthermore, the issue in robotics education is helping small teams build abilities that necessitate the presence of skilled STEM professors (Norris et al., 2023). Then, Norris et al (2023) It was also shown that robotic activities must be built on problem-centered learning, inquiry-based learning, design-based learning, and cooperative learning cooperation. As a result, all aspects of the school must develop extracurricular activities that can address these difficulties.

Another challenge in implementing robotic extracurricular activities to boost students' creativity is how to foster a sense of friendship and social relationships, which have many potential benefits through social learning mechanisms and the psychology of social engagement. These benefits include not only skill learning and emotional

engagement but also broader developmental outcomes (Chen et al., 2020). This is because robotic learning is done in groups, thus the activities must be adaptable to foster more fascinating, appealing, and joyful reciprocity among students. Previous studies have also found that difficulties in integrating robotic learning or programming, particularly in poor countries, include a lack of attention from schools, an insufficient number of trained teachers, and pupils who fail to fulfill competency requirements (Ou et al., 2023).

Understanding programming languages and discovering computer program solutions can be a challenge when adopting robotic learning (Cheng, 2019). Students have difficulty understanding the programming language. Previous research has also found that problems related to the use of robotics in education include the expensive expense of delivering robots to students, maintaining and modifying robots, and the requirement for suitable school facilities and infrastructure to support robotics teaching. Another issue is a lack of teaching techniques that span the entire spectrum of knowledge in soft robotics since most current approaches focus on robots with fixed morphology and rigid structures (Fitria, 2024). Furthermore, there are obstacles to incorporating robots into extracurricular programs, such as the necessity for teacher training and the possibility of cultural norms and web-mediated education regulations/policies impeding virtual learning. Another issue is that not all families can afford to send their children to extracurricular robotics activities because of income and family economic status (Merino-Armero et al., 2023).

Based on the results of the study above, the impact of robotic extracurricular activities is that they can improve students' creative abilities. In addition to being creative, these activities can also develop analytical and problem-solving skills. Challenges in implementing robotic learning include the lack of infrastructure facilities to meet hardware and software requirements and teachers who have high competence in teaching robotics. In addition, learning methods that are still lacking in integrating knowledge with robotic software are challenges that must be solved. Further research needs to examine the development of learning models that are integrated with robotic learning in influencing other 21st-century skills.

CONCLUSION

Based on the findings of the research and discussions, it is possible to infer that extracurricular robotics activities can help kids develop creative skills in the cognitive, psychomotor, and emotional domains. This is demonstrated by kids' capacity to generate ideas and create work in robotics activities. Robotic exercises encourage students to focus on the ethical, social, and cultural consequences of creating technology. The problems of introducing extracurricular robotics include a lack of infrastructure resources to fulfill hardware and software requirements, as well as teachers who are highly competent in robotics instruction. Furthermore, there are still gaps in learning approaches for integrating knowledge with robot software, which must be addressed. These findings suggest the need for teacher training and infrastructure improvements to maximize the potential of robotics activities in fostering creativity. The findings of this study can help to advance technology while also improving students' creative abilities. Further research is needed to examine the development of learning models that are integrated with robotics learning in influencing other 21st-century skills.

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