Technology Self-efficacy in Robotic-based Integrated STEM Learning: A Systematic Review

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ABSTRACT

This article explores Technology Self-Efficacy in integrated STEM learning using Robotics. Robotics allows students to engage directly with technology, providing a real platform for understanding complex STEM principles. One key element of this approach is the integration of robotics technology into STEM teaching. Students not only learn the technical aspects of robotics but also develop problem solving, critical thinking, and collaboration skills, all important skills. With the formulated research question, How is educational robotics received in STEM Learning and How does STEM Learning affect Technology Self-efficacy, students can apply their knowledge and skills in the real world through the use of technology in STEM education through robotics-based projects and Project Based Learning methodology, which can increase their self-efficacy with technology. Robotics is a powerful tool for strengthening STEM skills in students. When students engage in robotics-based projects, they not only understand how robots work, but also learn to solve complex problems, collaborate with peers, and develop critical thinking. In this process, they naturally increase their confidence in using technology. This approach not only prepares them for an increasingly automated world of work but also helps them become more confident individuals in facing future technological challenges. By using robotics as a learning tool, teachers can enrich STEM teaching with engaging hands-on experiences and provide a solid foundation for their understanding of important STEM concepts.

Keywords: *Educational Robotics, Integrated STEM, Systematics Literature Review, Technology Self-efficacy*

1. INTRODUCTION

The STEM approach (Science, Technology, Engineering, and Mathematics) is the education that gives a chance to the student in their experience learning [1]. First, can increase in this task related with STEM, in STEM program activity is very important to increase skill to identify problem, critical thinking and student technical knowledge, that all influence directly technology self-efficacy in STEM [2]. STEM education is to play in integrated robotics and STEM knowledge in educational robotics, using educational robots as a teaching tool can allow students to learn the fundamentals of technology [3]. A teaching strategy called educational robotics involves students in engaging, visually appealing tasks that spark their curiosity [4], [5]. Students can apply their skills and information in real life when innovation is incorporated into STEM teaching, thereby increasing self-efficacy towards technology [6]. The need for STEM experts is growing as a result of the growing worldwide effect of technology, making STEM education essential in the twenty-first century [7].

This research from Chiang et al., (2022) shows that the use of LEGO online stem robots can increase students' self-efficacy in working on technology tasks. Self-efficacy in the STEM Learning related with computer literate increasing and do the task, show the positive relationship between self-efficacy and technology, technology self-efficacy is defined is individual ability, related with technology tools [8]. However, currently there are few literature studies that elaborate on attitudes towards technology use in STEM learning [9].

Educational robotics is seen as an inventive, progressive, and adaptable teaching and learning tool, while appealing to students of all ages, as a key component in STEM (Science, Technology, Engineering, and Mathematics) education, educational

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robotics utilizes a curriculum of robotics projects and activities to develop students' understanding and skills, educational robotics is considered an inventive, progressive, and adaptable teaching and learning tool that appeals to students of all ages by utilizing a curriculum of robotics projects and activities, educational robotics plays a key role in introducing and developing students' STEM understanding and skills [10], [11]. Educational Robotics also provides students with the opportunity to work collaboratively [12]. More and more, robotics adopted as scenario education [13]. Because using of robotics had STEM learning [14], also offer new idea in the STEM learning [15]. The benefits of robotics among others are increase skill in problem solving, creativity and student self-efficacy [16]. Throw activity and STEM project, student can increase his competence and awareness self, that positive effect in their awareness, learning based project in STEM, as using robotics in the class, increase student ability in problem solving, in the finally can increase their awareness [17].

Students can apply their skills and information in real life when innovation is incorporated into STEM teaching, thereby increasing self-efficacy towards technology [6]. With stimulate the student critical thinking and create technical problem efficiently, educational robotics help them in to solve the complicated problem [18]. Educational robotics is not just about introducing technology to students, but also about increasing their self-efficacy in various aspects of learning from deeper understanding to practical, analytical, applied and collaborative skills [19]. One of way to apply educational robotics is using Project-Based Learning method, where Project-Based Learning in educational robotics learning give student experience directly in programming, robotics, and student control technique which participate in Project-Based Learning in a way show enhancement work habits and communication skill [20]. Therefore, when learn to handle new technology as like robot which use in teaching STEM concept has important consider self-efficacy with designing student participation [21]. In the next section, literature strategy explained. The findings and discussion which is taken from literature study stated in the third section. In the last, this article has been conclusion.

2. METHOD

This research explores knowledge accumulated from the literature pertinent to journal articles indexed by Scopus and the Web of Science database. The publication years were set between 2019 and 2023 to ensure the most recent literature was included.

The search conducted the indexing databases are meant to construct the answer upon two research questions: (1) How educational robotics adopted in STEM Learning; (2) How STEM Learning influence Technology Self-efficacy. In order to scope down the search, three keywords "Technology Self-efficacy", "Educational Robotics", and "STEM Learning" were run through the search engine. Which based on study taken, using robotics in STEM learning possible the student understand technology, which contribution on improvement self-efficacy of technology [22].

The distribution of indexing databases, the associated papers, and their corresponding publication year are presented in Figure 1.

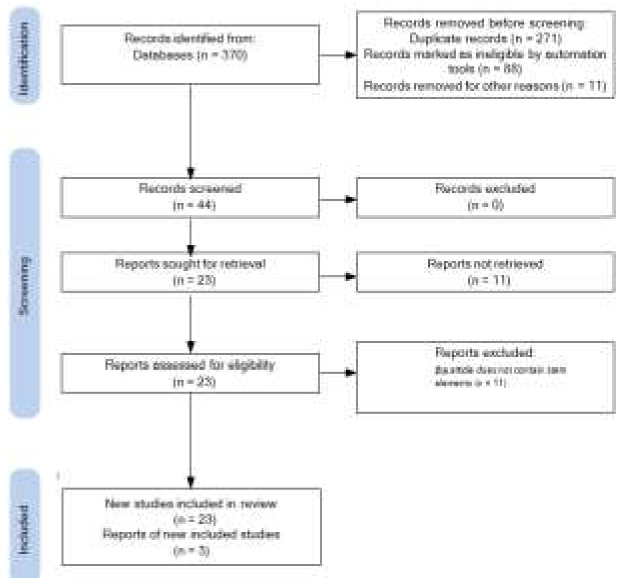

Figure 1 Prisma Diagram

"The Systematic Literature Review" advocated by Okoli & Schabram, (2012) were adopted. The review in depth was administered over 23 articles included in the review. The findings of each articles were teased out before synthesized to generate themes.

Further exploration of the research question, are presented in the matrix of concepts in Table 1. To discover out how Educational Robotics is embraced in STEM learning that's coordinates with technology self-efficacy, an analysis was carried out using VOS viewer. In Figure 2, research on the relationship between robotics in project-based learning strategies and confidence in technology in STEM learning is still limited. This suggests that there is a need for further research in this area to strengthen understanding of how the use of robotics in STEM learning can influence students' confidence in technology. By strengthening these findings, more effective and targeted learning strategies can be developed to improve students' STEM skills and their confidence in dealing with technology..

The information used is taken from valid and reliable databases, especially Scopus, with the keywords used to write this article.

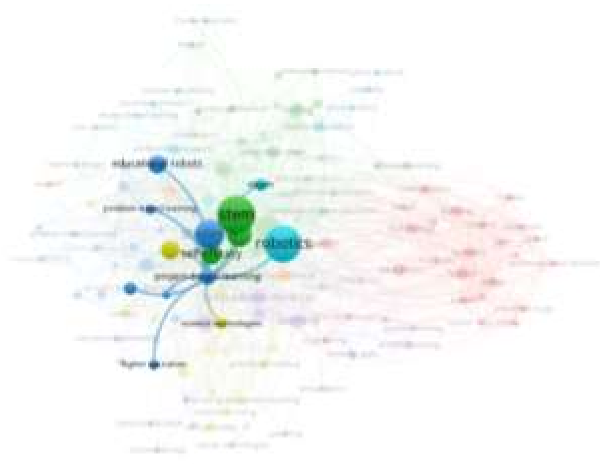

Figure 2 VOS Viewer Analysis

3. RESULT AND DISCUSSION

We discovered that the three themes mentioned above have an impact on students development when robots is used in STEM education. The discussion will include an overview of the theme's findings.

3.1 Integrating Robotics into STEM Educational

Educational robotics adopted in STEM Learning through the integration of robotics activities and projects into the curriculum [10]. Because of what happened at learning, the use of robotics in the class can help student learn technology [24]. Educational robotics in STEM learning improves students' teamwork skills, computational thinking, and self-efficacy, teachers have observed that students benefit from educational robotics by developing problem-solving skills, creativity, and self-confidence [2].

This integration of technology into the curriculum can be achieved by using platforms such as robotic devices and educational software that can support the teaching of robotics in education [25]. One of the robot tools that can be used in learning is Lego Mindstorms [26], [27]. Educational robotics provides students with a unique opportunity to confront and solve complex problems, encouraging them to think critically and develop effective problem solving strategies [28]. In this context, robots become a very useful tool to engage students in analytical and creative thinking, educational robotics provides more than just an introduction to technology to students this is a vehicle that encourages students to think critically, collaborate and innovate in solving complex problems, thus, educational robotics not only produces a greater understanding of technology, but also shapes students into independent, creative thinkers and ready to face the challenges of this digital era [18]. The robotics team curriculum structure was considered a great success, highlighting the importance of incorporating multicultural aspects in STEM education [29].

Thus, a robotics team curriculum structure that takes into account multicultural aspects makes a significant contribution in supporting inclusive STEM education and has an impact on all students [29]. Based on these results, it can be concluded that the integration of robotics into STEM education has a significant influence on student development. Robotics as a teaching and learning tool has been proven to provide various benefits that impact student progress in various aspects. Overall, the integration of robotics into STEM education not only provides technical benefits and skills, but also has an impact on student development in the aspects of problem solving, communication, creativity, and self-efficacy.

3.2 Robotics is used in STEM Education using the Project-Based Learning Method

The use of educational robotics is adopted in STEM Learning through Robotics Project Based Learning which integrates four STEM disciplines (Science, Technology, Engineering, Mathematics), Lego Mindstorms Education and compatible software are proposed as robotics tools in this framework, as they are easy to use and suitable for students from elementary to high school levels [27]. According to koray & uzuncelebi, (2023), we conclude that Lego-based educational applications have a more positive impact on the development of reflective thinking skills. Project Based Learning programs in educational robotics provide students with hands-on experience in programming, robotics, and control engineering. Students who participate in Project Based Learning programs often demonstrate better collaboration and communication skills, as well as an increased ability to explain ideas and meet deadlines [20]. Project-based learning in STEM fields, including the use of educational robotics, can improve students' problem-solving competencies [17]. By using Lego Mindstorms Education and a Project Based Learning approach to educational robotics, students not only gain knowledge about technology, but also develop important skills such as teamwork, communication, problem solving and the ability to express ideas clearly. Research by koray & uzuncelebi, (2023), shows that Lego-based educational applications have a strong impact in improving students' reflective thinking skills. The Project Based Learning approach to learning robotics provides students with in-depth practical experience in programming and control engineering, which in turn improves communication skills, collaboration, and problem-solving skills. The results of research by Coufal, (2022) show that project-based learning in the STEM field, especially with the use of educational robotics, can improve students' problem-solving competencies. Thus, the use of educational robotics and a Project Based Learning approach with tools such as Lego Mindstorms Education provides a strong foundation for students to develop important skills in STEM. By combining project based learning, this approach provides sustainable benefits for student development.

3.3 STEM Education Robotics builds Technology Self-efficacy

Robotics learning, part of STEM education, has been proven to increase students' self-efficacy in various dimensions such as understanding, practice, analysis, application, and collaboration, robotics learning provides hands-on learning experiences, allowing students to understand technology and relevant knowledge, which can contribute to improving self-efficacy towards technology [22]. In STEM learning, students are often faced with real problems that require technological solutions that they create, these projects provide a platform for students to apply their technical knowledge in relevant and significant contexts [31]. This experience gives them a strong sense of accomplishment, which directly increases their confidence in their ability to use technology their critical, analytical, and creative thinking skills are shaped by the problem solving process they face in these projects, which ultimately improves their ability to use technology their self-efficacy in a technological environment, thus, students build a strong foundation for their technological skills through real-world experience in completing relevant projects, while building their confidence to tackle complex challenges in an ever evolving technological world [32].

By engaging in STEM activities and projects, students can develop a sense of competence and mastery, which can have a positive impact on their self-efficacy beliefs STEM education encourages a growth mindset, where students believe that their abilities can be developed through effort and practice, which leads to increased self-efficacy in STEM fields [2]. The practical nature of STEM learning, such as engaging students in programming educational robots, provides significant opportunities for students to experience success and build confidence in their abilities [33]. When students successfully design a program that makes the robot move according to their instructions, they have a positive experience that immediately strengthens their self-confidence this process is not only about achieving concrete results, but also about seeing the real impact of the effort and thought they invest in learning [17].

Through robot programming, students directly see how the decisions and steps they take affect the robot's performance [34]. In doing so, they learn to identify errors, find solutions, and achieve desired goals, which directly strengthens their problem solving skills and creativity the success they experience in operating the robot also creates a positive cycle where they become increasingly enthusiastic to continue trying new and challenging things this contributes to increasing student self-efficacy, which is an individual's belief in their ability to face technological tasks and challenges, thus, the practical nature of STEM learning such as educational robot programming not only results in a deeper understanding of technological concepts, but also helps students build strong confidence in their technological abilities [17].

Technology integration also opens the door to collaboration and project-based learning, students can work over time to complete challenging projects, this process allows them to broaden their understanding of how technology operates in real contexts, while strengthening the ability to work collaboratively in teams, technology integration in STEM education is not just about introducing students to new tools and technologies, but also providing real-world experiences in applying knowledge and skills. They, in this way, students' self-efficacy in using technology is continuously strengthened, creating a strong foundation for their success with technology [6].

Table 1. Matrix

References	Method	Findings	RQ	Synthesize
Katbeh, T., Cieslinski, G. B., & Bazzi, H. (2023). Promoting STEM Education through the Preparation of Multicultural National Robotics Teams in Qatar (Evaluation). *ASEE Annual Conference and Exposition, Conference Proceedings.*		The curriculum structure of the robotics teams was deemed a great success, highlighting the importance of combining the multicultural aspect in STEM education .	1	The curriculum structure of the robotics teams was deemed a great success, highlighting the importance of combining the multicultural aspect in STEM education .

References	Method	Findings	RQ	Synthesize
Hussin, H., Jiea, P. Y., Rosly, R. N. R., & Omar, S. R. (2019). Integrated 21st century science, technology, engineering, mathematics (STEM) education through robotics project-based learning. *Humanities and Social Sciences Reviews*, 7(2), 204–211. https://doi.org/10.18510/hssr.2019.7222		Educational robotics is adopted in STEM learning through Robotics Project-based Learning, which integrates the four STEM disciplines (Science, Technology, Engineering, and Mathematics) LEGO(r) Mindstorms Education and its compatible software are proposed as the robotics tools in the framework, as they are user-friendly and suitable for students from primary schools to high school levels . Engineering design is highlighted as an approach for delivering STEM education and integrating STEM content, providing an ideal entry point to include engineering practices into existing secondary curriculum.	1	Robotics is used in STEM education using the Project Based Learning method
Chiang, F. K., Zhang, Y., Zhu, D., Shang, X., & Jiang, Z. (2022). The Influence of Online STEM Education Camps on Students' Self-Efficacy, Computational Thinking, and Task Value. Journal of Science Education and Technology, 31(4), 461–472. https://doi.org/10.1007/s10956-022-09967-y	Quantitative	The integration of robotics and STEM knowledge in online camps has been found to improve students' self-efficacy in technology-related tasks.	2	Integrating robotics into STEM education increases students' technology-related self-efficacy

4. CONCLUSION

STEM (Science, Technology, Engineering, and Mathematics) education provides students with valuable opportunities for hands-on learning. One of the main goals of STEM education is to increase students' self-confidence and belief in their abilities to successfully complete STEM-related tasks. Integrating robotic technology into STEM education has become an integral part of this methodology. Through robotics-based projects and project-based learning methods, students can use technology as part of their STEM education to apply their knowledge and skills in real-world situations, thereby increasing their self-efficacy with technology.

Involving robotics-based learning allows students to participate directly in a fun and problem-oriented learning process. This not only provides valuable experience, but also encourages the development of problem-solving, critical thinking and team collaboration skills. Developing, programming, and operating robots gives students the satisfaction of overcoming real-world technical challenges.

Therefore, the use of robotic technology in STEM learning not only helps in understanding technological concepts but also in developing positive attitudes towards technology. Through direct involvement in robotics projects, students learn to be innovative, creative, and confident in the face of rapidly developing technology. This increases the partner's self-efficacy in learning technology. This is an important skill when facing an increasingly connected and rapidly changing world.

Robotics in STEM education is not just a teaching tool, but also a tool for educating a generation that is ready to face technological challenges. This not only teaches students how to use technology, but also empowers them to become leaders who can understand, adapt, and develop the technology that will shape our future.

AUTHORS' CONTRIBUTIONS

Syahrul Bagas Himawan made the conceptual design. Also wrote the research method, result and discussion, and conclusion. Cucuk Wawan Budiyanto wrote the abstract and introduction. Also refined the manuscript draft. Aris Budianto wrote the introduction. Also refined the manuscript draft.

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