

PAPER

The Impact of Robotic Technology in Vocational Education towards the Development of Industry 5.0: A Systematic Literature Review

Herlin Setyawan¹,
Sukardi¹(✉), Risfendra¹,
Doni Tri Putra Yanto¹,
Tee Tze Kiong²

¹Universitas Negeri Padang,
Padang, Indonesia

²Universiti Tun Hussein Onn
Malaysia, Johor, Malaysia

sukardiunp@ft.unp.ac.id

ABSTRACT

The wrong use of learning models in the robotics learning process can cause students to not understand how to build a robotic system step by step. Likewise, the use of irrelevant technology in the learning process can result in low graduate competence, as the competencies possessed are not in accordance with industry needs. So, this study aims to assess the impact and how robotic technology is applied in vocational education. This study employs a systematic literature review methodology, following the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines. The review includes articles published between 2018 and 2024, focusing on the use of robotic technology in vocational education. A total of 26 relevant research studies were selected for analysis. The results of this study show that universities, vocational high schools, and robotics training institutions use robotics technology. The types of robots used include mobile robots, ARM robots, humanoid robots, animal robots, training kits, and robotics system simulator applications. Learning models integrated with this technology include project-based learning (PjBL), the most widely used, problem-based learning (PBL), computer-based robotics, hands-on learning, CPLM, pair learning, and EL-CP. Robotic technology impacts almost all knowledge domains, including cognitive, psychomotor, and affective.

KEYWORDS

robotic technology, learning model, learning outcomes, vocational education, Industry 5.0

1 INTRODUCTION

Robotic technology is one of the fastest-growing fields of science today, both in industrial development 4.0 and 5.0. The development of Industry 4.0 emphasizes the efficiency of robotics in the production process, which is supported by the concept of artificial intelligence (AI) control systems. However, it differs from the development

Setyawan, H., Sukardi, Risfendra, Putra Yanto, D.T., Kiong, T.T. (2025). The Impact of Robotic Technology in Vocational Education towards the Development of Industry 5.0: A Systematic Literature Review. *International Journal of Online and Biomedical Engineering (iJOE)*, 21(6), pp. 36–55. <https://doi.org/10.3991/ijoe.v21i06.53681>

Article submitted 2024-12-11. Revision uploaded 2025-01-17. Final acceptance 2025-01-24.

© 2025 by the authors of this article. Published under CC-BY.

of Industry 5.0. This era will emphasize the development of robotic technology that collaborates with humans, which is currently known as collaborative robots (COBOTS). By applying robotic technology in the industry, we can increase creativity, welfare, and the quality of human life. Through this development, humans, as drivers, will continue developing the latest ideas and innovations to solve their problems. Thus, it will form a sustainable development between technology, economic growth, social protection, and community welfare [1], [2]. Thus, the development of robotics technology will also impact the development of skills humans must possess to compensate. If this is not fulfilled, there will be a gap between technological development and human skills. So, sustainable development will not be achieved because many workers will be laid off due to inappropriate skill requirements [3], [4].

To overcome the gap between robotic technology and industry needs, robotic technology is also used as a learning medium in vocational schools [5]. The aim is to develop the knowledge and skills students acquire to meet industry demands. As an institution that focuses on preparing a professional and competent workforce in their fields, vocational schools must equip students with skills relevant to current industry needs [6]. Previous research indicates that the use of robotic technology in the vocational school learning process can improve students' skills, thus matching the needs of the industry in the use of robotic technology [7], [8]. The application of robotic technology in vocational education is essential due to the complexity of the knowledge and skills required. This technology involves various aspects, from AI-based programming systems to electronic circuits and robotic mechanical systems, which must be understood by students [2], [9], [10].

However, implementing the current learning process in vocational education often causes serious problems. The problem that often occurs is the unsystematic learning process carried out by students because the learning model applied is not based on the characteristics of robotic learning. This will confuse students about the robotic learning carried out, thus significantly affecting student learning outcomes [11], [12]. The complexity of robotics learning is expected to ensure that the learning model used can explain step-by-step how to build a robotic system so that students understand better and can improve their competence. In addition, using learning technology that is irrelevant to robotics' learning objectives is also a big problem. Often, with the robotic technology used in the learning process, students can only program robots and not build robotic systems from the beginning to testing [5]–[7]. Students should understand the robotics system as a whole. With things like this, competency is not maximally achieved. In robotic systems, students should be able to master programming competencies, electronic circuits, electrical control circuits, and robotic mechanics using robotic technology; these competencies are not well achieved [9], [13]. As a result of this problem, vocational education graduates have skills that are less relevant to industry needs because, in the industry, it is expected that vocational students can understand robotic systems as a whole and can solve problems that occur in these systems [14].

Robotic learning requires the proper technological support and an effective learning model to provide hands-on experience to students. Robotic control system learning will be more optimal if integrated with project-based learning [15], [16]. This model trains students to design, build, and test robots directly in a solid team. Besides encouraging students to think critically and innovatively in solving problems, this model also hones collaboration skills, which are indispensable in facing

the Industry 5.0 era [17], [18]. A suitable learning model is essential to ensure students' skills are industry-ready. Besides project-based learning, integrating robotics learning with problem-based learning or work-based learning models can also create a practical, interactive, and applicable learning process for students [19], [20]. These three learning models have one common characteristic: student-centered learning. In this approach, students play an essential role in the learning process, while the teacher is a facilitator who supports and directs. This model allows students to be more active in exploring the needed knowledge and skills, thus improving their understanding in a more profound and relevant way.

Mastering the robotic control system is an urgent task that must be fulfilled by vocational education institutions, given the growing demands of the industry. Through an effective robotic learning process, vocational education can prepare students to become skilled workers ready to face an increasingly automated industrial world [20], [21]. This implementation will also reduce the gap between vocational education and industry needs so that vocational education graduates will be work-ready and globally competitive. The overall impact of robotic technology in vocational education has been done previously through a meta-analysis [22], [23]. However, this study only looks at the impact of quantitative assessment. It does not examine how the learning process is carried out, the technology used, and the results obtained in a study. Therefore, this study is proposed to examine this so that the process and results of robotics learning can be known well. So, the study aims to discover the robotics technology, learning model, and learning outcomes obtained by students in the robotics learning process. This literature and research can provide readers and stakeholders with a comprehensive overview of the novelty of this field [24], [25]. Ensuring the focus and direction of the research objectives of the study, there are four research questions raised in the study, namely as follows:

- RQ1. What institutions use robotic technology as learning media in the learning process?
- RQ2. What robotic technologies are used by vocational education institutions to carry out the robotics learning process?
- RQ3. What are my learning models integrated with robotic technology in the learning process at vocational education?
- RQ4. What are the student learning outcomes in vocational education using robotic technology in the learning process?

This study is also based on previous research, which still has limitations in examining the application of robotic technology in vocational education. Darmawansah [23] revealed that STEM-based robotic learning can affect students' computational thinking (CT), creativity, collaboration, and communication skills in physics, technology, engineering, mathematics, and interdisciplinary disciplines. This study was also conducted by Adnan [26], revealing that the impact of robotic technology in the learning process can significantly improve CT and adversarial thinking (AT) skills, which are needed by the younger generation to face industrial development 5.0. Cayetano-Jimenez [27], from his research, also emphasized that robotic technology is currently being used at the K-12 school level, and in second place is higher education. The research results still focus on the impact of robotic technology on student learning outcomes, and the disciplines revealed are still general, not focusing on the application in vocational education. The process of applying

robotic technology in order to improve student learning outcomes has not been studied explicitly.

Explicitly, research conducted by Ouyang and Xu [28] through a meta-analysis of the application of robotic technology in the learning process in elementary schools, junior high schools, high schools, and high schools has a significant impact on improving learning outcomes and student attitudes and not a significant enough impact on students' CT skills. Sukardi [22] conducted a meta-analysis research that was more focused on vocational education, which obtained overall results by applying robotic technology in the learning process in vocational schools, which will significantly improve student learning outcomes. Based on the systematic literature review and meta-analysis research conducted previously, it does not consider how the learning process is carried out, the types of learning outcomes achieved by students, and the robotic technology used in the learning process. These factors are needed to investigate robotic technology's research trends and objectives, whether it can form new knowledge, or encourage students' motivation and creativity to improve their learning outcomes [29]. Based on results from previous studies, comprehensive research is still needed to investigate robotic technology's role in vocational education. Whether it is an investigation related to the learning process, the robotic technology model used, or the learning outcomes obtained, the results of this study can provide valuable information for researchers, practitioners, and teaching staff in vocational education.

2 METHODOLOGY

The study was conducted to explore the learning process, robotic technology, and the impact of robotic technology on student learning outcomes in vocational education, so SLR research was conducted in this study. SLR is carried out using the principles of preferred reporting items for systematic reviews and meta-analyses (PRISMA) [30]. The PRISMA method's principle of searching for articles uses three search steps: identification, screening, and including [31], [32]. Searching for articles using the PRISMA method has the advantage of filtering articles that are very strict because, in this method, the inclusion and exclusion criteria for articles used in SLR will be applied. In addition, through this method, the flow of article searches used in research is clearly described [33], [34].

2.1 Data collection

The article search strategy in this study is through two central databases, namely the Scopus database and the Wiley Online Library database, where articles published and indexed by Scopus through the Wiley Online Library publisher have gone through a rigorous selection and improvement process so that the quality of the article will also be guaranteed. The articles to be selected are those that discuss robotic technology in vocational education from various countries. In the article search process, three main keywords used in the Scopus database are the impact on learning, robotic technology, and the context of education. So that more specifically, the keywords used for the Scopus database search are as follows: ("impact" OR "influence" OR "increase knowledge" OR "improve skills" OR "improve learning outcomes") AND ("robotic technology" OR "robot education" OR

“robotic learning”) AND (“on education” OR “on teaching” OR “school” OR “on student skills” OR “on student knowledge”). Likewise, searching articles in the Wiley database also uses the exact keywords. Articles that will be selected are articles published from 2018 to 2024, and article searches are carried out from February 2024 to August 2024.

2.2 Inclusion and exclusion criteria

For the search for articles used in this SLR research to focus more on discussion, inclusion, and exclusion criteria were applied to all articles searched. Determining the inclusion criteria selects articles that can be used in this study, while the exclusion criteria reject articles that cannot be included [35]. Thus, it can be interpreted that all articles included in the inclusion criteria will be included as material in this SLR study. The inclusion and exclusion criteria set in this article are shown in Table 1. These inclusion criteria are set to tighten the selection process of articles used in research so that the articles obtained are genuinely eligible and of good quality. Thus, the articles that will be obtained will examine the impact of robotic technology on the learning process in vocational education.

Table 1. Inclusion and exclusion criteria for article selection

Inclusion Criteria	Exclusion Criteria
Articles that examine robotic technology in vocational education	Articles that do not examine robotic technology in vocational education
Articles published in international journals or conferences	Articles not published in international journals or conferences
Scopus indexed articles	Articles that are not scopus indexed
Articles published from 2018 to 2024	Unpublished articles from 2018 to 2024
Articles written in English	Articles written not in English
Using robotic technology in the learning process	Does not use robotic technology in the learning process
Contains the learning model used and the impact on students	Does not include the learning model used and the impact on students

2.3 Article selection procedure

The research procedure followed the PRISMA search method, which consists of three main steps: identification, screening, and inclusion. The first step involved searching for articles in Scopus and Wiley databases using the keywords mentioned in the data collection section. 140 were retrieved from the Scopus database, and 908 identifiable articles on the impact of robotic technology in vocational schools were retrieved from the Wiley database. This data resulted from an initial search and was not filtered using the inclusion criteria set. At this stage of identification, the same articles from the Scopus and Wiley databases were also filtered so that one of them had to be eliminated. This selection process uses the help of the Mendelay application so that it can speed up the process and manage the results well. At this stage, I also filtered articles that discuss industrial automation with

robotics in the learning process because these two topics often become one, or the discussion will also be separate. After this stage is completed, 308 articles are obtained, which will proceed to further selection stages by applying the inclusion criteria that have been set.

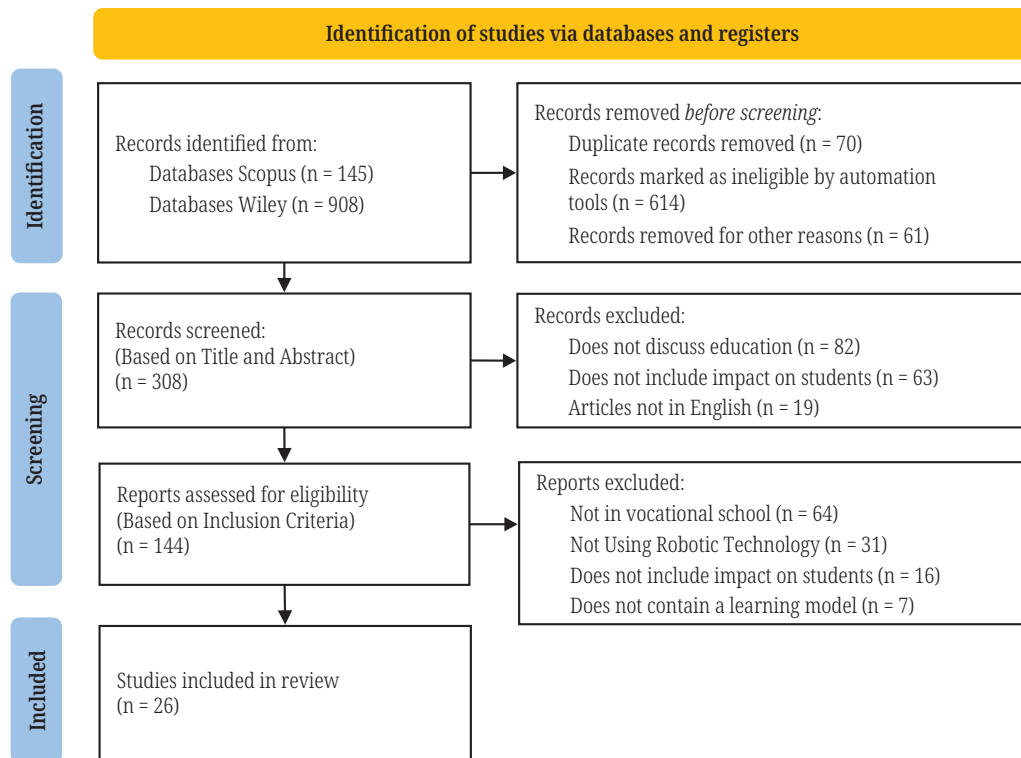


Fig. 1. PRISMA flowchart for searching research articles

The second stage in the PRISMA step is screening, divided into two activities: the first screening through the title and abstract and the second screening of articles by applying inclusion criteria and reading all parts of the article to ensure all the data needed is available. From the results of the screening based on the title and abstract, 82 articles did not examine the world of education, 63 did not examine the improvement or impact on students, and 19 were not in English. So, the articles obtained for in-depth analysis were 144 articles. Filtering the two articles by guiding the inclusion criteria set, 110 articles cannot be used as literature review material. Where 64 articles do not examine the world of vocational education, 31 do not use robotic technology in the learning process, 16 do not examine the impact on students, and seven do not contain learning models used in the learning process. Thus, from these results, 26 articles are declared relevant to the systematic literature research conducted. These 26 articles will be reviewed thoroughly to examine the impact and learning process of robotics learning in vocational schools. Systematically, the steps taken are shown in Figure 1.

3 RESULTS AND DISCUSSION

A total of 26 relevant articles in this study will be analyzed in depth to answer the research questions posed. Based on the data in the Table 2, it is known that

since 2018, research on the impact of robotic technology in vocational education has increased. In 2022, this research peaked, with eight scientific articles published. Research on the impact of robotic technology has been conducted in various parts of the world, especially in developed countries. Spain ranked first with six published articles, receiving 296 citations. Turkey ranked second with two articles cited 72 times, and Taiwan ranked third with two articles cited 16 times. Research conducted by p- is the most cited research by other researchers, with 134 citations. Researchers [36] are in second place with the number of citations 98 times cited by other researchers, and research conducted by [37] is in third place with the number of citations 92 times cited by other researchers.

Table 2. Data of articles performed systematic analysis literature review

Author	Year	Education Level	Country	Citation
Garduno-Aparicio et al., [36]	2018	VC	Mexico	98
Calvo et al., [37]	2018	VC	Spain	92
Aris and Orcos, [38]	2019	VHS	Spain	134
Huda et al., [39]	2019	VC	Indonesia	2
Wang et al., [40]	2020	VC	United States	4
Jormanainen and Tukiainen, [41]	2020	VHS	Finland	15
Zhong and Li, [42]	2020	VHS	China	59
Ibrahim et al., [13]	2020	VC	Malaysia	8
Morell et al., [15]	2021	VC	Spain	22
Çınar and Tüzün, [43]	2021	VHS	Turkey	25
Chookaew et al., [7]	2021	RTI	Thailand	5
Yilmaz Ince and Koc, [10]	2021	RTI	Turkey	47
Lee and Yi, [44]	2021	VC	South Korea	8
Hsieh et al., [45]	2022	VC	Taiwan	12
Bertacchini et al., [46]	2022	VC	Italy	19
Valls Pou et al., [47]	2022	VHS	Spain	42
Hussain et al., [17]	2022	VC	Australia	7
Hsu and Tsai, [48]	2022	VC	Taiwan	4
Boya-Lara et al., [49]	2022	VC	Panama	30
Souza et al., [21]	2022	VHS	Brazil	9
Veber et al., [50]	2022	VHS	Slovenia	11
Praveena et al., [9]	2023	VC	India	3
Pellas and Tzafilkou, [51]	2023	VC	Greece	9
Suarez et al., [52]	2023	VC	Spain	4
Díaz-Lauzurica and Moreno-Salinas, [53]	2023	VHS	Spain	2
Zhang, Chen et al., [54]	2024	VHS	China	9

Notes: VHS: vocational high school, VC: vocational college, RTI: robotics training institute.

Research in this field also experienced a rapid increase from 2018 to 2024; starting in 2020, there were published studies. In 2021, there was also an increase with five published studies, and the peak was in 2022 when eight studies were carried out, which have also been published in Scopus-indexed international journals. The findings also highlight that most developed and developing countries have researched the impact of robotic technology when integrated into vocational education. This finding reveals that researchers are increasingly interested in discovering the impact of robotic technology in vocational education every year. This finding also shows the importance of integrating robotic technology in vocational education to produce competent and globally competitive graduates.

3.1 RQ1. What institutions use robotic technology as learning media in the learning process?

The results of the analysis show three types of institutions that use robotic technology as a learning medium: universities, vocational high schools, and robotics training institutions. The percentage of each institution is shown in Figure 2. From the figure, it can be seen that the use of robotic technology is most prevalent in universities, with a percentage of 57.69%, followed by vocational high schools at 34.62%. Interestingly, robotics training institutions are also starting to play a role with a percentage of 7.69%, where training is provided by industry practitioners directly to students in schools both at the college level and vocational high schools. This data shows that today, educational institutions equip students with robotic technology skills, and industry practitioners are directly involved [7], [10]. This proves the alignment of curriculum between vocational education and the industrial world to produce graduates who are competent in robotics systems.

Robotic technology is now being applied as a learning medium in various departments. At the university level, robotic technology is used in electrical engineering, electronics engineering, and industrial electronics engineering, where students focus on building robotic systems, both in terms of electronic circuits and programming, so that robots can function as intended [13], [37], [46], [48]. In addition, the automation engineering, mechatronics engineering, and robotics engineering majors' study robotic technology in more depth. In these majors, students are equipped with knowledge of robot motion system design (mechanical), electronic circuit design, and robotic programming [15], [36], [44], [50]. The application of this technology has also been incorporated into the informatics engineering major, which focuses on the development of effective and reliable robotic programming. Robotic programming based on AI is widely developed in this department, allowing robots to make decisions independently. [9], [43], [52], [53]. The Mechanical Engineering Department has also utilized this technology, focusing on applying robotic technology in industry as done by [17], [51], where robotic technology is taught to students to perform welding processes. Research by [40], [49] shows that in learning robotics in this department, students are equipped with knowledge about the application of robotic systems to perform turning processes.

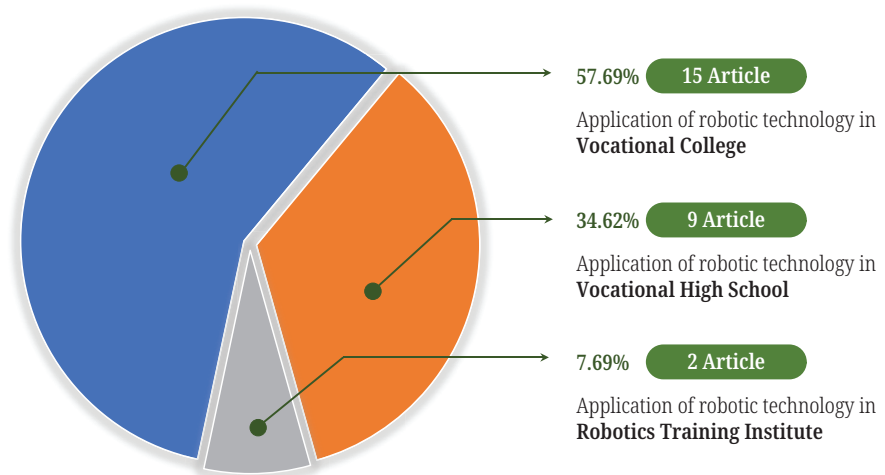


Fig. 2. Use of robotics technology in various educational institutions

The application of robotic technology is also carried out at the vocational high school level in the Mechatronics Engineering and Industrial Automation Engineering majors. At the vocational high school level, students are equipped with knowledge about the application of robotic components and how to apply robotic technology to run processes in industry. However, in high school, students are not yet equipped with the skills to analyze and design robotic systems but instead focus on using these technologies in industry [5], [41]. In addition to official educational institutions, industry practitioners provide robotic technology training for students through training programs. The training program provided by the industry focuses more on strengthening practical skills in robotic technology for industrial needs [7], [10]. These results show that the skills to master robotic technology are needed today to overcome production problems in the industry.

3.2 RQ2. What robotic technologies are used by vocational education institutions to carry out the robotics learning process?

Overall, six types of robotic learning media are used: mobile robotics, ARM robots, humanoid robots, animal robots, robotic training kits, and robotic software simulations, as shown in Figure 3. With 11 studies, mobile robotics technology ranked first as the most widely used by vocational education institutions. Mobile robotics focuses on developing robots that can move around using wheels as propulsion, either automatically or manually, and are controlled by students. Based on these 11 studies, mobile robotics is divided into three categories based on its operating system. First, mobile robots are controlled using joysticks or student smartphones [13], [38], [51]. Second, mobile robotics work with line guidance, where the robot moves following a predefined path [9], [48]. Third, robots with more complex systems, which already use the concept of AI, allow the robot to move by mapping the room in which it operates [5], [42], [44], [52].

The ARM robot, a mechanical arm designed for specific tasks, is among the most widely used types of robots in vocational education, with six studies highlighting its application. These robots are utilized in simulations to transport goods and in mechanical engineering classes to teach welding tasks [15], [37]. In mechatronics and automation engineering departments, ARM robots are integrated into automation

systems for assembly processes in manufacturing, demonstrating their versatility in industrial applications [7], [32], [40], [46]. Humanoid robots, featured in three studies, are designed to resemble humans, enabling students to create robots capable of movement and human interaction. These complex robots, studied primarily at the university level, involve advanced mechanical, motion, and embedded control system designs, often incorporating AI [45], [46], [54]. Lastly, animal robots, used to simulate animal movements, include four-legged robots resembling dogs and six-legged robots resembling spiders, which are employed for tasks such as transporting goods, further showcasing the diverse applications of robotic technology in education [41], [49].

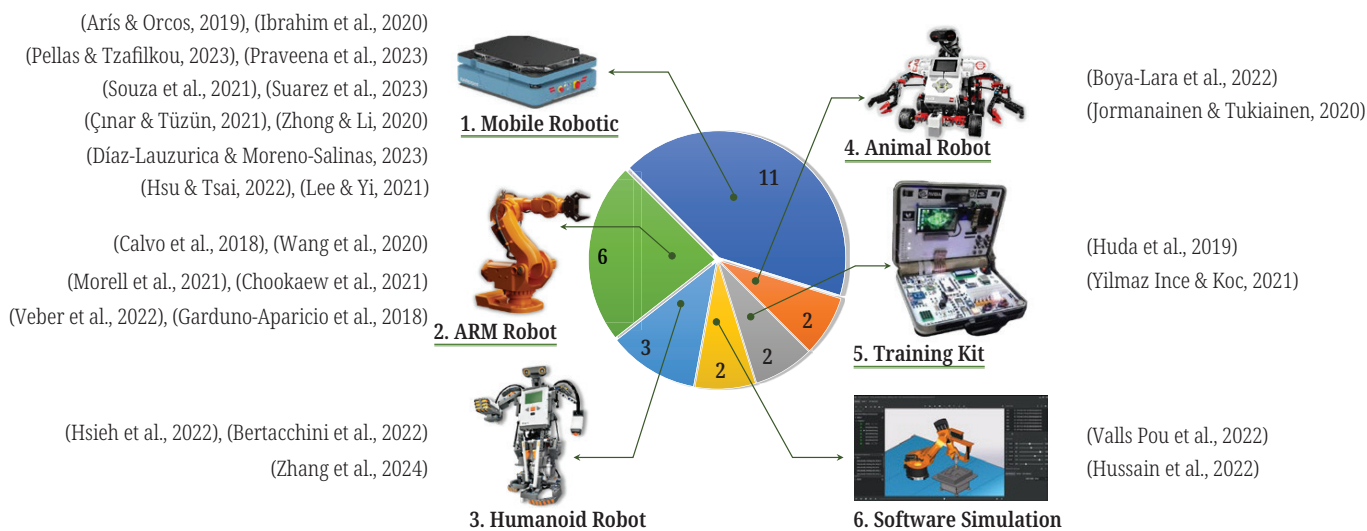


Fig. 3. Robotic technology used in the learning process in vocational education

In addition to robots designed in certain forms, robotic learning media are used only as simulation training kits, as shown in Figure 3. In the training kit, all robotic components are provided so that students can simulate and program robot parts using this technology, such as the use of sensors, microcontrollers, and actuators (DC motors, servo motors) to move a robot [10], [39]. Finally, with the rapid advancement of information technology, there are now applications that can be used to simulate robot movements, both mobile robots and ARM robots. By using the simulation application, students can practice robotic programming, and the results are simulated through the application directly according to the instructed working principle. Using this simulation application, students can learn robotic signs using physical robots so that the application can be a tool in the robotics learning process [45], [47].

3.3 RQ3. What are my learning models integrated with robotic technology in the learning process at vocational education?

Based on the results obtained, eight types of learning models have been developed and used in the learning process that integrates with robotic technology, as shown in Table 3. The project-based learning (PjBL) model is the most widely used learning method, and 17 studies use this method. Through the PjBL model, students will be directly involved in working on a robotic project that students do. Thus, students

will get direct experience designing and building a robotic system through this learning. Through direct teamwork, this learning will significantly improve students' problem-solving, communication, and collaboration skills. In addition, this learning process will also increase students' responsibility for the work they do to be adequately completed [10], [17], [36].

Table 3. Learning models integrated with robotic technology

Learning Model	NS	%	Researcher
Project-based learning	17	65.38	[9], [10], [13], [15], [17], [36]–[38], [40], [41], [44]–[49], [51]
Problem-based learning	3	11.54	[7], [39], [43]
Computer-based robotics	1	3.85	[21]
Hands-on learning	1	3.85	[52]
Cyber-physical learning model	1	3.85	[50]
Pair learning	1	3.85	[42]
Design thinking	1	3.85	[53]
Embodied learning-based computer programming	1	3.85	[54]

Note: NS: number of studies.

Second, a problem-based learning (PBL) model was carried out three times in the research and integrated into the robotics learning process. This learning model emphasizes problem-solving in a very complex robotic system. This learning process can improve students' analytical skills and help them solve problems when using robotic technology in the learning process [55]. In addition, several learning models have been developed by researchers to improve the success of robotics learning, as done by [5], who developed the computer-based robotics learning model. This learning model will train students to understand the basic concepts of robotics and CT skills of robotics programming that are needed today. Through this learning model, the educator is a facilitator who determines the learning content and guides students to complete the robotic tasks. This learning model is developed from the disconnection learning model, where this learning model is suitable for understanding robotics concepts but not for training students' practical skills.

Research conducted by [52] developed a robotics learning model called hands-on learning. This model emphasizes direct student involvement in the learning process through robotic practicum. In this model, students design, assemble, and program robots directly through practicum in the laboratory. In addition, [50] developed a robotics learning model known as the cyber-physical learning model (CPLM), which integrates virtual reality (VR) technology in the learning process. Through VR, students are trained to use robots in simulations directly connected to real robots. This model suggests ten steps of robotics learning, namely: VR motivational video presentation, provision of theoretical materials, simulation and demonstration, independent simulation exercises, evaluation of simulation exercise results, demonstration in the physical environment, training with VR, evaluation of tasks in VR environment, physical tasks, and overall evaluation. This model has been proven to be effective in the robotics learning process.

Project-base learning	6 Learning Syntax Essential Question → Designing Project Plan → Create a Schedule Project → Monitor Student and Project Progress → Assessing → Evaluating
Problem-base learning	5 Learning Syntax Student orientation to the problem → Organizing Students to Learn → Individual and group research guide → Develop and present the work → Analyzing and Evaluating
Computer-based robotics	2 Learning Syntax Presentation of learning materials (theory) → Conduct an experiment (practicum)
Hands-on learning	5 Learning Syntax Tutorial Introduction → Project Implementation → Direct Experience → Active Participation → Increased Complexity
Cyber-physical learning	10 Learning Syntax Motivation with Virtual Reality → Pre-test and Lecture → Problem Simulation → Simulation Training → Simulation Task Evaluation → Physical Learning → Cyber Virtual Reality Training → Evaluation of Procedural Knowledge → Physical Tasks → Post-test
Pair learning	7 Learning Syntax Introduction and Preparation → Pair Formation → Pair Learning Guide → Role Rotation → Learning Project → Evaluation and Feedback → Reflection and Discussion
Design thinking	5 Learning Syntax Empathy → Interpretation/Definition → Ideation → Experimentation → Evolution
Embodied Learning-Based Computer Programming	4 Learning Syntax Introduction → Knowledge and Skill Learning → Group Work → Presentation and Evaluation

Fig. 4. Learning model in robotics learning

A robotics learning model was also developed by [42] through applying the pair learning model, where students work in teams of two. This model significantly improves robotic systems’ teamwork, communication, and problem-solving skills. In addition, [53] developed the design thinking model, which consists of five steps: empathy, interpretation or definition, ideation, experimentation, and evolution. This model effectively develops creativity and increases student motivation in robotics learning. Recent research by [54] developed the embodied learning-based computer programming (EL-CP) model, which consists of four stages: introduction, knowledge and skills learning, group work, and presentation and evaluation. This approach creates active interaction between students and the learning environment. The results showed that the EL-CP model effectively improved students’ robotics learning achievement.

3.4 RQ4. What are the student learning outcomes in vocational education using robotic technology in the learning process?

Based on the results obtained, it is clear that robotic technology’s impact has spread to all three knowledge domains, namely the cognitive, psychomotor, and affective domains, as shown in Table 4. Table 4 shows that research in the cognitive domain is most widely carried out by researchers, especially in CT skills, problem-solving, and academic knowledge. In the field of CT skills, most researchers conducted 11 times. These results show that equipping students with logical and structured thinking patterns in the robotics learning process is essential. This skill is very influential in helping students solve problems found in robotic systems [41].

Second, problem-solving skills are also the main focus of researchers in the cognitive domain, with seven studies examining this skill. This skill is needed in the robotics control system, where learning is theoretical, and one must be able to apply this knowledge to solve problems in the robotics control system.

Table 4. The impact of robotic technology on student learning outcomes

SK	Knowledge and Skills	NS	%	Researcher
Cognitive	Computational thinking	11	42.31	[5], [10], [40], [41], [43], [45]–[49], [51]
	Problem-solving	7	26.92	[9], [13], [38], [42], [43], [50], [52]
	Academic knowledge	7	26.92	[17], [36], [37], [44], [49], [53], [54]
	Collaboration	3	11.54	[9], [15], [38]
	Creativity	2	7.69	[38], [48]
	Communication	1	3.85	[9]
Psychomotor	Robotics technical skills	1	3.85	[7]
Affective	Motivation	8	30.77	[15], [38], [39], [41], [50], [52]–[54]
	Interest	7	26.92	[36]–[39], [41], [50], [52]

Note: SK: scope of knowledge, NS: number of studies.

In addition, the knowledge area of robotic control systems has also been highlighted by research, with evidence of seven studies that have examined this. This shows that students need knowledge to solve problems in the robotics system. Without solid knowledge, this cannot be done well. In the cognitive domain, the aspects of communication, and creativity are still less highlighted by researchers. Until now, there have been only three studies that discuss the communicative aspect, two studies that discuss the creativity aspect, and one study that discusses communication. Collaboration and communication are indispensable in an industrial work environment with a teamwork system. Likewise, students need creativity to develop new ideas to innovate and solve problems in the robotic system [56].

The affective domain, highlighted in the research, encompasses two key aspects: motivation and interest. Eight studies have examined motivation, emphasizing the importance of creating innovative learning processes to make robotics education more engaging for students. Similarly, seven studies on interest demonstrate that incorporating innovative robotic technologies can significantly enhance student engagement. Both motivation and interest are critical in shaping student learning outcomes, as higher levels of these factors correlate with better academic performance [57]. Despite its importance, the psychomotor domain, efficient skills in robotic control systems, remains underexplored, with only one study delving deeply into this area [7]. Practical skills are vital for students entering the robotics workforce, necessitating further research to ensure students grasp theoretical concepts and acquire hands-on capabilities. Additionally, aspects such as communication, creativity, and collaboration, essential for teamwork-driven industrial environments, warrant more focused investigation. Future research should address these gaps to better prepare students for the demands of an increasingly complex industrial landscape.

4 DISCUSSION

The first finding in this study found that the application of robotic technology in the learning process is mainly carried out in vocational school colleges with a percentage of 57.69%, second in vocational high schools with 34.62%, and third in training institutions with 7.69%. This result is not without good reason; mastery of the robotics control system requires complex and in-depth knowledge and skills because the robotics control system involves various disciplines that must be mastered by students, such as programming systems, electronic circuits, control circuits, and mechanical robot movement systems [58]. Thus, in the curriculum at the university level, students are required to develop practical competencies, innovation, and the development of the latest technology through research [59], [60]. At the same time, in the vocational high school level curriculum, students are equipped with practical skills applicable to specific jobs according to industry needs, such as using robots in industry for production systems. However, to face the development of Industry 5.0, vocational high schools need to integrate robotic technology into the learning process. However, at this level, students can only use robots according to industrial needs [61], [62].

Various types of robotic technologies, such as mobile robots, ARM robots, humanoid robots, robotic training kits, and control system simulation applications, have been implemented [13], [38], [45]. Mobile robotic technology and ARM robots (robot manipulators) are the most widely used by vocational schools. The results obtained are also based on many uses in industry, such as the application of mobile robotic systems in the form of automatic guided vehicle (AGV) robots, which are very widely used by industry today for product distribution systems [63], [64]. In addition, the utilization of manipulator robots in industry today is no joke; almost all production systems in the industry use robots as production machines. Applications such as welding, turning, combining components, moving goods, and packing goods to paint cars in the automotive industry [65], [66]. Thus, by applying robotic technology in the learning process in vocational education, students can learn technology relevant to industrial needs—the competencies they acquire become very suitable with the current industrial progress.

In addition to using good technology, applying the right learning model will also affect the learning process in vocational schools. As the results obtained, eight learning models have been used and developed to carry out the robotics learning process. Where the most widely used models are PjBL and PBL, in all models, three similarities must exist in robotics learning: first, at the beginning of learning, students must be equipped with robotic science (theory) to deliver student understanding [41], [48]. In the second stage, students are asked to design a robotic control system according to their function (design) [15], [48], students make robots according to the design they have made (experimentation) [46], [47]. Thus, in the robotic learning process, students must be able to play an active role in the learning process (student-centered learning). Educators are only facilitators who direct the robotic work done by students [15], [53]. Involving students directly in the learning process will make them better understand the robotic system they are working on so that it can improve the competencies they will get [53], [54].

The suitable application of robotic technology and learning models in the robotics learning process will have a significant impact on student learning outcomes in terms of cognitive, psychomotor, and affective [9], [15], [46]. The research results show nine robotics robots have optics latencies, most of which are CT skills, problem-solving, and problem-solving knowledge. Vocational students need CT skills because

this ability trains students to solve problems logically and systematically with five primary elements: abstraction, generalization, algorithm, modularity, and decomposition [43], [51]. The good CT skills possessed by students will also improve vocational students' problem-solving skills. Students need these complex problems in robotic systems. Students must be able to analyze and fix problems in the system [47]. In addition, using robotic technology can also improve students' practical skills, creativity, collaboration, interest, and motivation in learning, where all skills are needed to overcome the challenges of industrial development 5.0 [9], [41], [48].

5 CONCLUSION

Based on the results of the study, it is known that three types of vocational education institutions use robotic technology in the learning process: vocational colleges, vocational high schools, and robotics training institutions from industry. The institutions that use this technology the most are vocational colleges, with 15 studies examined at this level, reaching a percentage of 57.69%. The robotic technologies used by these educational institutions consist of six types: mobile robots, ARM robots, humanoid robots, animal robots, training kits, and robotics simulation applications. The most frequently used technology is mobile robots, with 11 studies examining it. In its application, robotic technology is integrated with seven learning models: PjBL, PBL, computer-based robotics, hands-on learning, the cyber-physical learning model (CPLM), pair learning, and design thinking EL-CP. The most widely used learning model and considered most effective by researchers is PjBL, with 17 studies supporting it. The impact of robotic technology is also significant, spanning students' cognitive, psychomotor and affective domains. The most frequent research focuses on students' CT and problem-solving skills, as through these skills, students indirectly also exercise their critical thinking, communication, and collaboration skills in solving problems related to robotic systems.

Based on the results obtained, the implication is that it is important to integrate robotic technology in the learning process in vocational education because it significantly impacts the development of student skills and knowledge relevant to the needs of Industry 5.0. Vocational education institutions are also strongly encouraged to integrate robotic technology in the curriculum, such as robot manipulators (ARM) and mobile robotics, which can train problem-solving, collaboration, and critical thinking skills. In the learning process, students must be given hands-on experience in designing and operating robotic systems through experiential learning methods such as PjBL or PBL to produce work-ready graduates to produce work-ready graduates with robotic competencies the industry needs.

The results obtained in this systematic literature review are limited to assessing the impact and how robotic technology is applied in vocational education. Therefore, this study did not study the impact on other educational institutions, such as elementary schools, junior high schools, and senior high schools. Thus, future research can use this study as a reference to conduct further research to determine the impact and process of implementing robotic technology in various educational institutions.

6 ACKNOWLEDGMENTS

This study is supported by the Directorate General of Higher Education of the Ministry of Education and Culture of the Republic of Indonesia with contract

number 090/E5/PG.02.00/PM.BARU/2024. This study is part of the Register Towards Doctoral Education for Excellent Scholars (PMDSU) student research. All authors have approved this research included in this paper.

7 REFERENCES

- [1] M. Shahbakhsh, G. R. Emad, and S. Cahoon, "Industrial revolutions and transition of the maritime industry: The case of Seafarer's role in autonomous shipping," *Asian J. Shipp. Logist.*, vol. 38, no. 1, pp. 10–18, 2022. <https://doi.org/10.1016/j.ajsl.2021.11.004>
- [2] M. Poláková, J. H. Suleimanová, P. Madzík, L. Copuš, I. Molnárová, and J. Polednová, "Soft skills and their importance in the labour market under the conditions of Industry 5.0," *Heliyon*, vol. 9, no. 8, p. e18670, 2023. <https://doi.org/10.1016/j.heliyon.2023.e18670>
- [3] A. Knap-Stefaniuk, "The skills members of multicultural teams need to succeed in Industry 5.0 – the opinion of managers from Portugal, France, and Greece," *Procedia Comput. Sci.*, vol. 225, pp. 1478–1485, 2023. <https://doi.org/10.1016/j.procs.2023.10.136>
- [4] H. Zulnaidi, N. Mafarja, S. S. A. Rahim, and U. K. M. Salleh, "Ethical mediation: The influence of mathematics teachers cooperation on readiness for the industrial revolution era in Indonesia and Malaysia," *Acta Psychol.*, vol. 243, p. 104151, 2024. <https://doi.org/10.1016/j.actpsy.2024.104151>
- [5] I. M. L. Souza, W. L. Andrade, and L. M. R. Sampa, "Educational robotics applications for the development of computational thinking in a Brazilian technical and vocational high school," *Informatics in Educ.*, vol. 21, no. 1, pp. 147–177, 2021. <https://doi.org/10.15388/infedu.2022.06>
- [6] L. Dai and P. S. Martins, "Does vocational education pay off in China? Evidence from city-level education supply shocks," *Economic Modelling*, vol. 140, p. 106863, 2024. <https://doi.org/10.1016/j.econmod.2024.106863>
- [7] S. Chookaew, S. Howimanporn, S. Hutamarn, and T. Thongkerd, "Perceptions of vocational education and training teachers with regard to an industrial robot training," *TEMJ.*, vol. 10, no. 3, pp. 1149–1154, 2021. <https://doi.org/10.18421/TEM103-19>
- [8] C.-J. Liang, V. R. Kamat, and C. C. Menassa, "Teaching robots to perform quasi-repetitive construction tasks through human demonstration," *Autom. Constr.*, vol. 120, p. 103370, 2020. <https://doi.org/10.1016/j.autcon.2020.103370>
- [9] K. S. Praveena, Mahadevaswamy, B. S. Gowda, K. Bhargavi, and C. M. Patil, "An effective Build Your Own Robot (BYOR) skill development course for first year engineering students to promote interdisciplinary learning environment," *J. Eng. Educ. Transform.*, vol. 36, no. S2, pp. 207–213, 2023. <https://doi.org/10.16920/jeet/2023/v36is2/23029>
- [10] E. Yilmaz Ince and M. Koc, "The consequences of robotics programming education on computational thinking skills: An intervention of the Young Engineer's Workshop (YEW)," *Comput. Appl. Eng. Educ.*, vol. 29, no. 1, pp. 191–208, 2021. <https://doi.org/10.1002/cae.22321>
- [11] I. A. Yuldashevna and K. Khurana, "The impediments to the process of implementing robotics in the school education system in Uzbekistan," *Sage Open*, vol. 14, no. 2, pp. 1–14, 2024. <https://doi.org/10.1177/21582440241254595>
- [12] M. Andrée, P. Anderhag, S. Björnhammer, and N. Salomonsson, "Aesthetic experience in technology education – the role of aesthetics for learning in lower secondary school robotic programming," *Front. Educ.*, vol. 9, pp. 1–12, 2024. <https://doi.org/10.3389/educ.2024.1291070>
- [13] M. F. Ibrahim *et al.*, "Strengthening programming skills among engineering students through experiential learning based robotics project," *Int. J. Eval. Res. Educ.*, vol. 9, no. 4, pp. 939–949, 2020. <https://doi.org/10.11591/ijere.v9i4.20653>

- [14] W. Y. Lu and S. C. Fan, "Developing a weather prediction project-based machine learning course in facilitating AI learning among high school students," *Comput. Educ. Artif. Intell.*, vol. 5, p. 100154, 2023. <https://doi.org/10.1016/j.caeai.2023.100154>
- [15] V. Morell et al., "Project-based learning in robotics subject of a master's degree," *Int. Symp. Proj. Approaches Eng. Educ.*, vol. 11, pp. 176–183, 2021.
- [16] Y. Zadok, "Project-based learning in robotics meets junior high school," *J. Eng. Des. Technol.*, vol. 18, no. 5, pp. 941–958, 2019. <https://doi.org/10.1108/JEDT-01-2019-0023>
- [17] S. Hussain, P. K. Jamwal, and M. T. Munir, "Computer-aided teaching using simmechanics and matlab for project-based learning in a robotics course," *Int. J. Soc. Robot.*, vol. 14, no. 1, pp. 85–94, 2022. <https://doi.org/10.1007/s12369-021-00769-7>
- [18] S. Bitetti, E. Danahy, and J. Swenson, "Examination of student self-assessed learning in a project-based freshman robotics course," in *2018 IEEE Frontiers in Education Conference (FIE)*, 2018, pp. 1–6. <https://doi.org/10.1109/FIE.2018.8659344>
- [19] J. Avis, "Work-based learning: Expansive learning, désœuvrement, social justice and VET," *Power Educ.*, vol. 17, no. 1, pp. 113–124, 2024. <https://doi.org/10.1177/17577438241239826>
- [20] Ferdiansyah, H. Maksum, F. Rizal, and R. H. Ulya, "Problem-based blended learning models in vocational education: A developmental research," *Int. J. Inf. Educ. Technol. (IJJET)*, vol. 13, no. 12, pp. 1968–1976, 2023. <https://doi.org/10.18178/ijiet.2023.13.12.2011>
- [21] L. Dai and P. S. Martins, "Does vocational education pay off in China? Evidence from city-level education supply shocks," *Econ. Model.*, vol. 140, no. 1, p. 106863, 2024. <https://doi.org/10.1016/j.econmod.2024.106863>
- [22] L. Dai and P. S. Martins, "Does vocational education pay off in China? Evidence from city-level education supply shocks," *Econ. Model.*, vol. 140, no. 4, p. 106863, 2024. <https://doi.org/10.1016/j.econmod.2024.106863>
- [23] D. Darmawansah, G. J. Hwang, M. R. A. Chen, and J. C. Liang, "Trends and research foci of robotics-based STEM education: A systematic review from diverse angles based on the technology-based learning model," *Int. J. STEM Educ.*, vol. 10, no. 1, 2023. <https://doi.org/10.1186/s40594-023-00400-3>
- [24] M. Shurovi, M. F. Yahaya, H. Hajimia, and M. K. Hasan, "Five decades of achievement motivation research in ELT: A systematic literature review," *Malaysian J. Learn. Instr.*, vol. 21, no. 1, pp. 285–318, 2024. <https://doi.org/10.32890/mjli2024.21.1.10>
- [25] N. F. Alias and R. Abdul Razak, "Exploring the pedagogical aspects of microlearning in educational settings: A systematic literature review," *Malaysian J. Learn. Instr.*, vol. 20, no. 2, pp. 267–294, 2023. <https://doi.org/10.32890/mjli2023.20.2.3>
- [26] N. Adnan, S. N. H. S. Abdullah, R. J. Raja Yusof, N. F. A. Zainal, F. Qamar, and E. Yadegaridehkordi, "A systematic literature review in robotics experiential learning with computational and adversarial thinking," *IEEE Access*, vol. 11, pp. 44806–44827, 2023. <https://doi.org/10.1109/ACCESS.2023.3249761>
- [27] I. U. Cayetano-Jimenez, E. A. Martinez-Rios, R. Bustamante-Bello, R. A. Ramirez-Mendoza, and M. S. Ramirez-Montoya, "Experimenting with soft robotics in education: A systematic literature review from 2006 to 2022," *IEEE Trans. Learn. Technol.*, vol. 17, pp. 1261–1278, 2024. <https://doi.org/10.1109/TLT.2024.3372894>
- [28] F. Ouyang and W. Xu, "The effects of educational robotics in STEM education: A multi-level meta-analysis," *Int. J. STEM Educ.*, vol. 11, no. 1, p. 7, 2024. <https://doi.org/10.1186/s40594-024-00469-4>
- [29] X. Zhang, F. Zhu, K. Wang, G. Cao, Y. Xue, and M. Liu, "Bring the intelligent tutoring robots to education: A systematic literature review," *IEEE Trans. Learn. Technol.*, pp. 1–21, 2024. <https://doi.org/10.1109/TLT.2024.3428366>
- [30] M. J. Page et al., "The PRISMA 2020 statement: An updated guideline for reporting systematic reviews," *BMJ*, vol. 372, p. n71, 2021. <https://doi.org/10.1136/bmj.n71>

- [31] T.-C. Truong and Q. B. Diep, "Technological spotlights of digital transformation in tertiary education," *IEEE Access*, vol. 11, pp. 40954–40966, 2023. <https://doi.org/10.1109/ACCESS.2023.3270340>
- [32] C. Boya-Lara, D. Diaz-Solano, and A. Fehrenbach, "Educational robotics to enhance knowledge and skills in higher education: A systematic review," in *2023 VI Congreso Internacional en Inteligencia Ambiental, Ingeniería de Software y Salud Electrónica y Móvil (AmITIC)*, 2023, pp. 1–6. <https://doi.org/10.1109/AmITIC60194.2023.10366359>
- [33] C. Chuang and N. Jamiat, "A systematic review on the effectiveness of children's interactive reading applications for promoting their emergent literacy in the multimedia context," *Contemp. Educ. Technol.*, vol. 15, no. 2, p. ep412, 2023. <https://doi.org/10.30935/cedtech/12941>
- [34] A. F. Mena-Guacas, J. A. U. Rodríguez, D. M. S. Trujillo, J. Gómez-Galán, and E. López-Meneses, "Collaborative learning and skill development for educational growth of artificial intelligence: A systematic review," *Contemp. Educ. Technol.*, vol. 15, no. 3, p. ep428, 2023. <https://doi.org/10.30935/cedtech/13123>
- [35] M. Håkansson Lindqvist, P. Mozelius, J. Jaldemark, and M. Cleveland Innes, "Higher education transformation towards lifelong learning in a digital era—a scoping literature review," *Int. J. Lifelong Educ.*, vol. 43, no. 1, pp. 24–38, 2024. <https://doi.org/10.1080/02601370.2023.2279047>
- [36] M. Garduno-Aparicio, J. Rodriguez-Resendiz, G. Macias-Bobadilla, and S. Thenozhi, "A multidisciplinary industrial robot approach for teaching mechatronics-related courses," *IEEE Trans. Educ.*, vol. 61, no. 1, pp. 55–62, 2018. <https://doi.org/10.1109/TE.2017.2741446>
- [37] I. Calvo, I. Cabanes, J. Quesada, and O. Barambones, "A multidisciplinary PBL approach for teaching industrial informatics and robotics in engineering," *IEEE Trans. Educ.*, vol. 61, no. 1, pp. 21–28, 2018. <https://doi.org/10.1109/TE.2017.2721907>
- [38] N. Arís and L. Orcos, "Educational robotics in the stage of secondary education: Empirical study on motivation and STEM skills," *Educ. Sci.*, vol. 9, no. 2, p. 73, 2019. <https://doi.org/10.3390/educsci9020073>
- [39] S. Huda, I. A. Buditjahjanto, and E. Yundra, "Robotic learning media development for D3 students of information management Unesa," in *Proceedings of the 1st Vocational Education International Conference (VEIC 2019)*, 2019, pp. 206–213. <https://doi.org/10.2991/assehr.k.191217.035>
- [40] W. Wang, C. Coutras, and M. Zhu, "Situated learning-based robotics education," in *2020 IEEE Frontiers in Education Conference (FIE)*, 2020, pp. 1–3. <https://doi.org/10.1109/FIE44824.2020.9274168>
- [41] I. Jormanainen and M. Tukiainen, "Attractive educational robotics motivates younger students to learn programming and computational thinking," in *Eighth International Conference on Technological Ecosystems for Enhancing Multiculturality*, New York, 2020, no. 7, pp. 54–60. <https://doi.org/10.1145/3434780.3436676>
- [42] B. Zhong and T. Li, "Can pair learning improve students' troubleshooting performance in robotics education?," *J. Educ. Comput. Res.*, vol. 58, no. 1, pp. 220–248, 2020. <https://doi.org/10.1177/0735633119829191>
- [43] M. Çınar and H. Tüzün, "Comparison of object-oriented and robot programming activities: The effects of programming modality on student achievement, abstraction, problem solving, and motivation," *J. Comput. Assist. Learn.*, vol. 37, no. 2, pp. 370–386, 2021. <https://doi.org/10.1111/jcal.12495>
- [44] H.-J. Lee and H. Yi, "Development of an onboard robotic platform for embedded programming education," *Sensors*, vol. 21, no. 11, p. 3916, 2021. <https://doi.org/10.3390/s21113916>

- [45] M.-C. Hsieh, H.-C. Pan, S.-W. Hsieh, M.-J. Hsu, and S.-W. Chou, "Teaching the concept of computational thinking: A STEM-based program with tangible robots on project-based learning courses," *Front. Psychol.*, vol. 12, pp. 1–7, 2022. <https://doi.org/10.3389/fpsyg.2021.828568>
- [46] F. Bertacchini, C. Scuro, P. Pantano, and E. Bilotta, "A project based learning approach for improving students' computational thinking skills," *Front. Robot. AI*, vol. 9, pp. 1–25, 2022. <https://doi.org/10.3389/frobt.2022.720448>
- [47] A. Valls Pou, X. Canaleta, and D. Fonseca, "Computational thinking and educational robotics integrated into project-based learning," *Sensors*, vol. 22, no. 10, p. 3746, 2022. <https://doi.org/10.3390/s22103746>
- [48] R. C. Hsu and T.-H. Tsai, "Assessing the impact of a project-based learning robotics course with integrating of STEM education using content analysis method," *Eur. J. STEM Educ.*, vol. 7, no. 1, p. 9, 2022. <https://doi.org/10.20897/ejsteme/12633>
- [49] C. Boya-Lara, D. Saavedra, A. Fehrenbach, and A. Marquez-Araque, "Development of a course based on BEAM robots to enhance STEM learning in electrical, electronic, and mechanical domains," *Int. J. Educ. Technol. High. Educ.*, vol. 19, no. 1, p. 7, 2022. <https://doi.org/10.1186/s41239-021-00311-9>
- [50] M. Veber, I. Pesek, and B. Aberšek, "Implementation of the modern immersive learning model CPLM," *Appl. Sci.*, vol. 12, no. 6, p. 3090, 2022. <https://doi.org/10.3390/app12063090>
- [51] N. Pellas and K. Tzafilkou, "The influence of absorption and need for cognition on students' learning outcomes in educational robot-supported projects," *Educ. Sci.*, vol. 13, no. 4, p. 379, 2023. <https://doi.org/10.3390/educsci13040379>
- [52] A. Suarez, D. García-Costa, J. Perez, E. López-Iñesta, F. Grimaldo, and J. Torres, "Hands-on learning: Assessing the impact of a mobile robot platform in engineering learning environments," *Sustainability*, vol. 15, no. 18, p. 13717, 2023. <https://doi.org/10.3390/su151813717>
- [53] B. Díaz-Lauzurica and D. Moreno-Salinas, "Applying design thinking to enhance programming education in vocational and compulsory secondary schools," *Appl. Sci.*, vol. 13, no. 23, p. 12792, 2023. <https://doi.org/10.3390/app132312792>
- [54] X. Zhang, Y. Chen, D. Li, L. Hu, G.-J. Hwang, and Y.-F. Tu, "Engaging young students in effective robotics education: An embodied learning-based computer programming approach," *J. Educ. Comput. Res.*, vol. 62, no. 2, pp. 532–558, 2024. <https://doi.org/10.1177/07356331231213548>
- [55] H.-E. Chueh and C.-Y. Kao, "Exploring the impact of integrating problem based learning and agile in the classroom on enhancing professional competence," *Heliyon*, vol. 10, no. 3, p. e24887, 2024. <https://doi.org/10.1016/j.heliyon.2024.e24887>
- [56] S. Rapti and T. Sapounidis, "Critical thinking, communication, collaboration, creativity in kindergarten with educational robotics: A scoping review (2012–2023)," *Comput. Educ.*, vol. 210, p. 104968, 2024. <https://doi.org/10.1016/j.compedu.2023.104968>
- [57] L. Berto, P. Costa, A. Simões, R. Gudwin, and E. Colombini, "A motivational-based learning model for mobile robots," *Cogn. Syst. Res.*, vol. 88, p. 101278, 2024. <https://doi.org/10.1016/j.cogsys.2024.101278>
- [58] I. Arocena, A. Huegun-Burgos, and I. Rekalde-Rodriguez, "Robotics and education: A systematic review," *TEM J.*, vol. 11, no. 1, pp. 379–387, 2022. <https://doi.org/10.18421/TEM111-48>
- [59] M. Shibata, K. Demura, S. Hirai, and A. Matsumoto, "Comparative study of robotics curricula," *IEEE Trans. Educ.*, vol. 64, no. 3, pp. 283–291, 2021. <https://doi.org/10.1109/TE.2020.3041667>
- [60] S. P. Phokoye *et al.*, "Exploring the adoption of robotics in teaching and learning in higher education institutions," *Informatics*, vol. 11, no. 4, p. 91, 2024. <https://doi.org/10.3390/informatics11040091>

- [61] T. Zhu, Z. Ji, K. R. Cao, and Q. D. Ling, "Integrated design and exploration of curriculum system of engineering technology related majors for connection between secondary and higher vocational education," in *2021 2nd International Conference on Education, Knowledge and Information Management (ICEKIM)*, 2021, pp. 116–119. <https://doi.org/10.1109/ICEKIM52309.2021.00034>
- [62] Suharno, N. A. Pambudi, and B. Harjanto, "Vocational education in Indonesia: History, development, opportunities, and challenges," *Child. Youth Serv. Rev.*, vol. 115, p. 105092, 2020. <https://doi.org/10.1016/j.chilyouth.2020.105092>
- [63] J. E. Sierra-Garcia and M. Santos, "Federated discrete reinforcement learning for automatic guided vehicle control," *Futur. Gener. Comput. Syst.*, vol. 150, pp. 78–89, 2024. <https://doi.org/10.1016/j.future.2023.08.021>
- [64] J. C. Tejada, A. Toro-Ossaba, S. Muñoz Montoya, and S. Rúa, "A Systems engineering approach for the design of an omnidirectional Autonomous Guided Vehicle (AGV) testing prototype," *J. Robot.*, vol. 2022, pp. 1–13, 2022. <https://doi.org/10.1155/2022/7712312>
- [65] R. Ward and B. Sencer, "Accurate TCP position and orientation trajectory generation in 6DOF robotic manipulators and CNC machine tools using FIR filtering and haversine synchronisation," *Procedia CIRP*, vol. 120, pp. 27–32, 2023. <https://doi.org/10.1016/j.procir.2023.08.006>
- [66] A. Al Ali, J. F. Shi, and Z. H. Zhu, "Path planning of 6-DOF free-floating space robotic manipulators using reinforcement learning," *Acta Astronaut.*, vol. 224, pp. 367–378, 2024. <https://doi.org/10.1016/j.actaastro.2024.08.015>

8 AUTHORS

Herlin Setyawan is a doctoral student of Technology and Vocational Education, Graduate School, Universitas Negeri Padang. His research focuses on technology and vocational education, in the field of educational technology, artificial intelligence in learning, robotics in learning, industrial automation, development of STEM Learning, 4C, Computational Thinking students (E-mail: herlinsetyawan@student.unp.ac.id).

Sukardi is a Lecturer at the Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang. He research interests include Electrical Engineering Vocational Education and Training (TVET) (E-mail: sukardiunp@ft.unp.ac.id).

Risfendra is a Lecturer at the Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang. He is currently teaching and will conduct research in the field of industrial control systems, robotics, artificial intelligence, and educational technology in vocational education (E-mail: risfendra@ft.unp.ac.id).

Doni Tri Putra Yanto is a Lecturer and researcher at the Faculty of Engineering, Universitas Negeri Padang. His research extensively covers areas such as Electrical Engineering Education, Technology Vocational Education and Training (TVET), Technology-Enhanced Learning (TEL), Remote Learning, Blended Learning, and Learning Models in TVET (E-mail: donitriputra@ft.unp.ac.id).

Tee Tze Kiong is a Lecturer at the Faculty of Technical and Vocational Education, Universiti Tun Hussein Onn Malaysia (UTHM), Batu Pahat, Johor. His specializations lies in the areas of modular approach in teaching and learning, high order thinking skills, buzan mind mapping, and inventive problem-solving skills (E-mail: tktee@uthm.edu.my).