EXPLORING THE ASPECTS OF EDUCATIONAL ROBOTICS: A MINI SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Educational robotics is employed in both formal education and extracurricular activities to foster student interest, engagement, and academic performance across various subjects. The research on robot-based learning and its impact on academics has been continuously growing in recent years. Hence, this mini Systematic Literature Review (SLR) is aimed at reviewing previous studies on using robotics in education. Articles accessed from 2019-2023 across three databases, Scopus, Springer and ScienceDirect, to discover relevant papers and documents for highlighting were considered. This research implements the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) mode. The findings of the articles from the nations demonstrated that ASIA had carried out more research. The research method employed in educational robotics articles focused on survey questionnaires with the highest ratings of 40%. Most of the articles focused on primary education. The findings can guide future research that needs to be conducted concerning educational robotics among remedial students.

KEYWORDS

Educational Robotics, Educational Robots, Mini Systematic Literature Review

1. INTRODUCTION

The application of education has been greatly impacted recently by the development of technology. Technology in education is anticipated to enable students to participate in hands-on learning activities that will help them develop their social and cognitive abilities. According to Rosanda & Starcic [1], robotics education fosters a learning environment in which students may develop and discover answers to real-world issues due to the sensors as well as actuators. Furthermore, robotics education may be a tool for teachers and students to instruct learning more active and motivate students [2]. Additionally, robotics education is regarded as a means of developing the abilities required for success in the twenty-first century [3].

Therefore, a Systematic Literature Review (SLR) was performed by assessing research articles from five years before. Robotics have been utilized in classrooms worldwide to promote new teaching methodologies. There are virtual and non-virtual varieties of robotics. The Robomind program, which attempts to give coding education, is an example of a well-known virtual robot [4]. LEGO robotics is the most prominent non-virtual robotics used in educational activities. Several LEGO sets have been released for each generation. Since the introduction of LEGO MINDSTORMS in 1998, there have been three generations of MINDSTORMS products available in the market. The first generation, LEGO MINDSTORMS (RCX), was released in 1998, followed by LEGO MINDSTORMS (NXT) in 2006, and LEGO MINDSTORMS (EV3) in

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2013, targeted for adult and general users. Additionally, LEGO offers products like LEGO Duplo and LEGO WeDo designed specifically for young children. LEGO Duplo features vibrant colors and large, easy-to-handle building bricks, making it a fun way for children to learn through play as they construct buildings and explore their creativity. LEGO WeDo robot is a hands-on classroom kit of building bricks and electronics for young children. In addition, robotics is used in pedagogy in various subjects, although it is confined to psychology, art, and music [5].

In recent years, with the help of robotics, an inexorable change has occurred in education. Many researchers have conducted a wide range of studies and evaluations regarding educational robotics. Research has shown that educational robots may successfully communicate and increase student satisfaction and class involvement [6]. Michaelis & Mutlu [7] utilized educational robots as social companions to interact with youngsters as another example of ER's benefits. The robots boosted students' interest in learning while encouraging them to enhance their English proficiency [8].

In addition, robotic technology has gained popularity as a tool to help secondary and tertiary education. Using robots in teaching and learning at all levels, from secondary school to university, is a hot research area right now [9]. Furthermore, robotics is utilized in a wide range of disciplines outside advanced systems, including science and literature. In view of this, the robotic revolution has been sparked by the usage of robotics by non-engineers and non-technical specialists [10].

According to the review's findings, computational thinking may impact learning, robotics-based learning is useful, and computational thinking can be promoted during early childhood by employing robots. Therefore, this review paper aims to explore and review the relevant aspects of educational robotics.

i. What are the countries where the study was conducted and the year of robot-based learning research?
ii. What are the research methods used in the articles gathered?
iii. At which educational stage is the use of robot-based learning more commonly applied?

2. METHODOLOGY

PRISMA will govern the highlights of these systematic literature studies. PRISMA Model is a quality standard since its methods are highly detailed when dealing with large quantities of data [11]. Furthermore, PRISMA can assist researchers in producing a qualitative report via a particular process. The benefit of utilizing the systematic review method with PRISMA is that the articles are retrieved from a reliable, high-quality database. Additionally, it is acknowledged by all researchers and prevents the author from trifling and doubting whether they have written enough articles [12]. As per Moher et al. [13], PRISMA assists the author in tracing articles based on the study's objectives through four processes: identification, screening, eligibility, and inclusion. This strategy was adopted as it can aid in synthesizing relevant scholarly literature.

2.1. Identification

In a systematic review, identification is essentially the first step. The main goal of identification is to choose the appropriate search terms and construct the keyword list. In other words, the researcher simultaneously searches for all relevant keywords associated with the research topic in both databases. According to earlier research on systematic reviews, the keywords selected could be synonyms, related terms, professional judgements, or keywords from earlier literature.

Hence, this study utilized three (3) major online databases from the UPSI library resources: Scopus, Springer and ScienceDirect, to discover relevant papers and documents for highlighting. These databases are well-suited for this area of study. This is consistent with Gusenbauer & Haddaway's [14] recommendation, which confirms the ability of three sources to discover resources. According to Xiao and Watson [15], no database is accurate. Hence, they recommend using more than one database. The type of database utilized is not specified as long as a strict procedure is followed. As a result, it has the designation of systematic literature analysis [11].

Two sources act as supporting databases, and Google Scholar and Web of Science were chosen as the sources. This database is primarily required to obtain extra sources, such as journals that are not indexed and any articles that are missing from popular databases. According to Junoh et al. [17], a supporting database is required since there exist no perfect database. Moreover, the database's sensitivity to keywords utilized to discover relevant articles does not attain 100%.

Advanced search strategies, including boolean operators, phrase searching, field code functions, truncation, and merged wild cards in a search strategy, are used to support the keywords-based search process on major databases. The literature was searched with several keywords (Table 1). Additionally, manual search methods like handpicking and hand-searching are employed.

Specifically, Scopus, Springer and ScienceDirect indexed a total of 306 journals related to educational robotics. Meanwhile, other resources indexed 62 journals. Note that 368 articles were discovered as a result of the search using search engines.

Table 1. Keyword search.

Keyword search
(“Elementary Education” OR "Primary Education” OR “Elementary School” OR “Primary School”) AND (“Robot” OR “Educational Robotics” OR “Robotics”)

2.2. Screening

This study only considers journal papers published between 2019 and 2023. The aim is to obtain the latest information on robot-based learning concept integration towards students’ performance in mathematics in the education world. Here, only empirical data are presented in a few articles. Furthermore, this study’s literature must comprise solely of journal articles. In addition, the criteria applied to choose articles included only those involving open access. This is to make the process of downloading and collecting articles easier. The preliminary survey was based on the titles, abstracts, as well as articles' keywords. Not only that, but full text is also searched and reviewed for articles that satisfy the title and abstract requirements. Then, it is determined if the article will be included or excluded from the previous search. Note that Table 2 summarizes the exclusion and inclusion criteria.

Table 2. The exclusion and inclusion criteria.

Criteria	Inclusion	Exclusion
Year of publication	2019-2023	< 2019
Document Type	English	Conference proceeding, chapters in book, books, book series as well as journal (systematic review)
Language	English	book, conference proceeding Excluded English

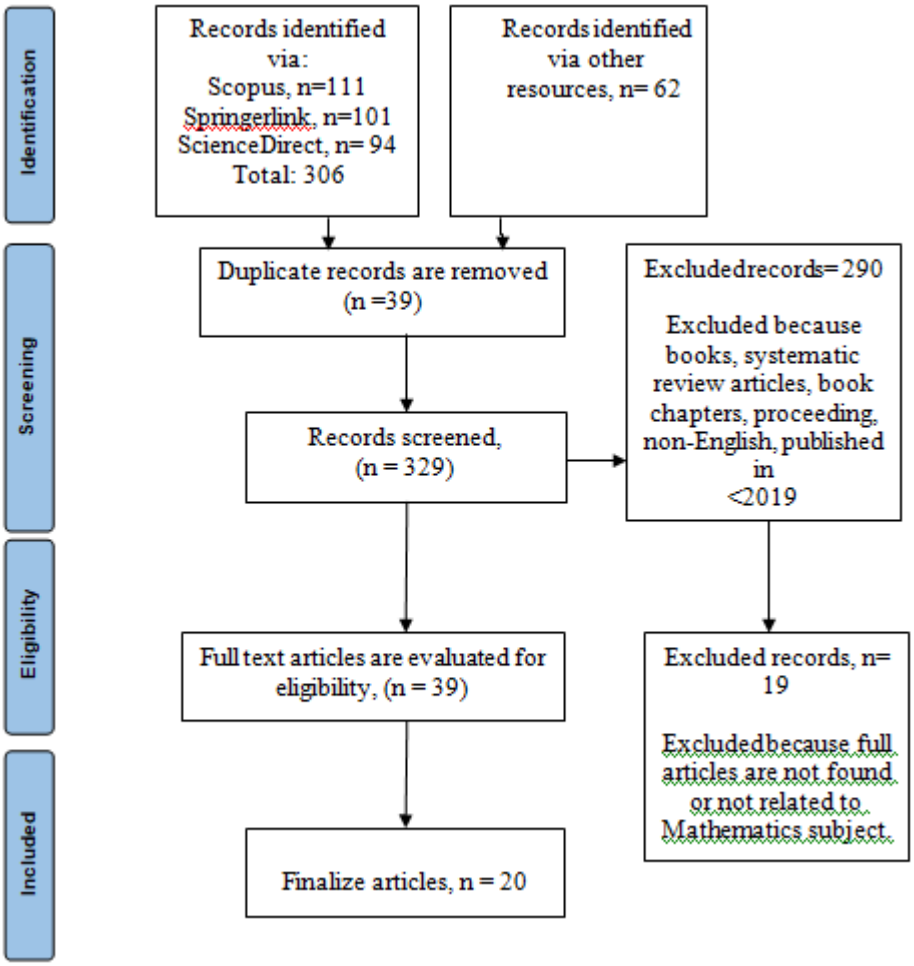

Figure 1. PRISMA flow chart (Adapted from [8])

2.3. Eligibility

The eligibility step comprises a human evaluation of articles to verify that only those that are qualified and meet the objectives are admitted for the subsequent phase. According to Kraus et al. [18], simply reading the abstract of an article can tell a researcher whether it can answer a specific research question. Thirty-nine articles were rescreened by reviewing the abstract, title, methodology, findings, as well as discussion study to ensure that they met the selection criteria and the goal of the study. Nineteen articles were rejected at this stage as they lacked a detailed description of the usage of robotics (eleven articles) and a clear discussion and presentation of the findings in the research findings section (eight articles).

2.4. Inclusion

After completing the eligibility phase, 20 articles were eligible for the procedure of reading the entire text utilizing the PRISMA method and analyzed to accomplish the SLR's purpose. Figure 1 displays the PRISMA flow chart in this study, which is adapted and modified from Moher et al. [13].

2.5. Quality Assessment and Data Extraction

In order to execute systematic analysis and provide a cohesive presentation to meet the review questions, the data extraction procedure attempted to precisely reflect the material presented in the article. Quality Assessment (QA) is as substantial as exclusion and inclusion criteria [14]. Table 3 provides the quality evaluation checklist, which is a modified version of the recommendations in [15]. It was not meant to argue on any of the research programs. The parameters for rating the chosen articles' quality related to the SLR quality evaluation standards are shown in Table 4 [16]. Note that Partially = 0.5 points, No = 0 points, and Yes = 1 points on the ratio scales. According to the following QA standards, each article was assessed:

Table 3. Quality assessment checklist.

Item	Answer
Was there a clear statement of the research's objective?	Yes/No/Partially
Was the study designed to achieve these objectives?	Yes/No/Partially
Was there a sufficient description of the context in which the research was carried out? For example, clearly stated the problems that lead to the research, descriptions of the research methodology used etc.	Yes/No/Partially
Was the data collection done very well?	Yes/No/Partially
Do the findings add to the literature?	Yes/No/Partially

The findings of each research's QA are shown in Table 4, which demonstrates that all 20 studies satisfied the criteria, establishing their acceptability and competency for further investigation.

Table 4. Quality assessment findings.

Study	Q1	Q2	Q3	Q4	Q5	Total	%
P1	1	1	0.5	1	1	4.5	90
P2	0.5	1	0.5	1	1	4	80
P3	1	1	1	0.5	1	4.5	90
P4	1	1	0.5	1	1	4.5	90
P5	1	0.5	1	1	0.5	4	80
P6	1	1	1	0.5	1	4.5	90
P7	1	0.5	1	1	1	4.5	90
P8	1	1	1	1	0.5	4.5	90
P10	1	1	1	1	1	5	100
P11	1	0.5	1	0.5	1	4	80
P12	1	0.5	1	0.5	1	4.5	90
P13	1	1	1	1	0.5	4.5	90
P14	1	0.5	0.5	1	1	4	80
P15	1	1	1	0.5	1	4.5	90
P16	0.5	1	1	1	1	4.5	90
P17	1	1	0.5	1	1	4.5	90
P18	1	1	1	0.5	0.5	4	80
P19	1	1	1	1	1	5	100
P20	1	1	1	1	0.5	4.5	90

2.6. Data Coding and Data Analysis

Given the thorough database search illustrated in Figure 1, 20 articles (Appendix) were evaluated by examining the abstracts. Subsequently, the full texts were assessed to determine the effectiveness of robot-based learning. The following research methodology reliability characteristics were categorized: (a) year of publication, (b) primary research area in educational robotics, (c) research methodology (interview, example, experiment, survey, etc.), (d) education level (for example, elementary school, high school, including higher education), (e) region, (f) as well as database (for example, ScienceDirect, Springer, Scopus, etc.).

3. RESULTS AND DISCUSSION

Finally, after four stages to establish which articles were reviewed, this mini systematic review examined 20 research publications on the usage of educational robotics in education published between 2019 and 2023. The publications were utilized to help researchers address three research questions.

RQ1: What are the countries where the study was conducted and the year of robot-based learning research?

3.1. Country Study

Table 5 presents the 20 countries where the research was carried out. According to the table, most studies were conducted on the Asian continent. Singapore, Taiwan, Spain, Chile and the United States with two studies, while the rest only possess one study.

Table 5. Countries of study.

Continent	Country	N	Articles
Asia	Israel	1	Zviel-Girshin et al. [22]
	Turkey	1	Üçgül & Altıok [23]
	Singapore	2	Chiazzese et al. [24]; Leoste & Heidmets [25]
	Malaysia	1	Kangungu [26]
	Taiwan	2	Al Hakim et al. [27]; Weng et al. [28]
	China	1	Xiaojing Shang et al. [29]
Europe	Portugal	1	Santos et al. [30]
	Greece	1	Chatzopoulos et al. [31]
	Spain	2	Amador-Terrón et al. [32]; Trigo et al. [33]
	Netherlands	1	Kert et al. [34]
	Poland	1	Smyrnova-Trybulska et al. [35]
South America	Chile	2	Castro et al. [36]; Seckel et al. [37]
North America	United States	2	Ching et al. [38]; Cruz [39]
	Canada	1	Lindsay et al. [40]
Oceania	Australia	1	Khaksar et al. [41]

3.2. Year of Studies

The frequency of the study during the past five years is analyzed and tabulated. Table 6 displays the number and percentage of articles published each year. According to the table, the year 2019 has the largest percentage, with seven articles and 35%. Articles from 2020 and 2022 had the same rate of 20.0%. Meanwhile, 2021 had the lowest percentage of 10%, which might be attributed to the Covid-19 pandemic.

Table 6. Frequencies of studies.

Years	Numbers of article	Percentage
2023	3	15.0%
2022	4	20.0%
2021	2	10.0%
2020	4	20.0%
2019	7	35.0%

RQ2: What are the research methods used in the articles gathered?

We may observe that roughly 40% of educational robotics focuses on collecting data through survey questionnaires. This result may be linked to the survey instrument's standing as the most popular method for a variety of technology acceptance evaluations as well as its usefulness as a model testing resource in educational robotics. Figure 2 illustrates the frequency of the assessed publications based on the research approaches used.

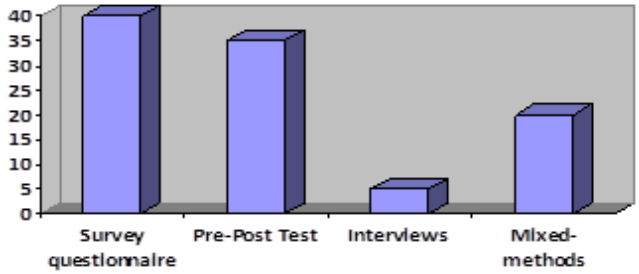

Figure 2. The research methods

RQ3: At which educational stage is the use of educational robots more commonly applied?

Several observations can be drawn from the data that has been presented. Figure 3 displays the findings on the educational stage, highlighted in the articles. Note that the majority of the studies centered on primary education (N = 7, pct. = 35%), followed by K-12 education (N = 6, pct. = 30%), higher education (N = 5, pct. = 25%) as well as secondary education (N = 2, pct. = 10%).

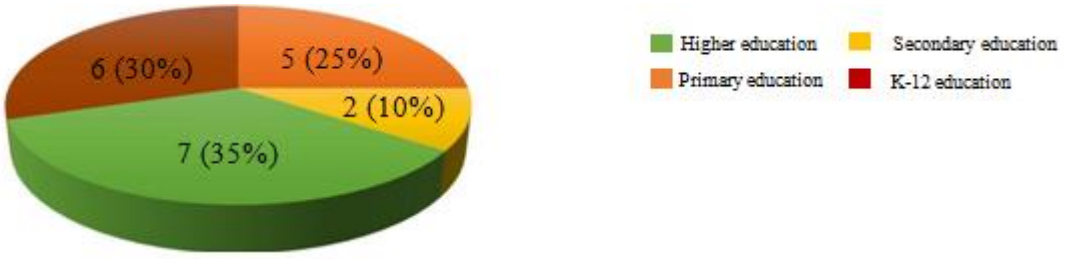

Figure 3. Educational stages

4. DISCUSSION

Educational robotics has emerged as a dynamic and innovative approach to enhance learning experiences for students across different educational levels. With real-time usage, it offers interactive and engaging opportunities that foster critical thinking, problem-solving, and creativity. The integration of robotics in classrooms has the potential to transform traditional teaching methods and empower students to actively participate in their own learning journey. For

example, Papadakis et al. [42] shed light on the importance of understanding teacher attitudes towards educational robotics, as they play a pivotal role in shaping its successful implementation in early childhood education. By exploring the profiles of pre-service and in-service early childhood teachers, the study provides valuable insights into how teachers perceive and embrace this technology in educational settings. Meanwhile, Anwar et al. [43] present a comprehensive systematic review of studies on educational robotics, showcasing its diverse applications and impact in pre-college education. By collating existing research, the paper highlights the effectiveness of robotics in fostering students' interest and proficiency in STEM fields, paving the way for more informed and evidence-based decisions in implementing educational robotics. Moreover, Khairy et al. [44] propose an innovative framework that combines educational robotics with artificial intelligence and context-awareness technology. This integration enables personalized and adaptive learning experiences, allowing students to interact with intelligent systems in real-time. The study introduces a novel approach to enhancing the effectiveness and applicability of educational robotics, further advancing the frontier of technology-enhanced education.

These studies demonstrate the potential and significance of educational robotics in real-time learning scenarios. They underscore the need for continued research, teacher support, and intelligent system integration to harness the full benefits of this transformative technology in education.

The area of educational robotics is expanding and has the potential to have a big influence on how science and technology are taught from kindergarten through higher education. Regarding the employment of robotic technology as a tool to assist creativity and other 21st-century learning abilities, Kangungu [26] examines the state of educational robotics at the moment and highlights new difficulties and trends. As novel educational robotics that provides engaging, hands-on activities in a captivating learning environment, educational robotics has come to be recognized [36].

In rural schools, companion robots may be used to encourage kids to pursue science and technology. A robot designed to provide actual or perceived companionship for people is called a companion robot. According to Broadbent et al. [45], the companion robots were well received by all the 207 students and 22 teachers from Brazil who participated in the 30-minute session. Most of the participants prefer to have robots in their schools. This study suggests that robots make students more interested in science. In addition, both teachers as well as students perceive the robot as a pet and beneficial for providing comfort.

Kangungu [26] expressed that the robot-based learning approach produced a more active classroom with students that were always looking forward to the lesson. The sample size of the respondent is 20. The implication of this study encouraged academic researchers to conduct more research on the benefits of the educational robotics approach as an alternative teaching and learning tool to enhance students’ understanding of learning programming.

Broadbent et al. [45] have found a positive outcome in the review on educational robotics. There is a positive sign that educational robotics may be an appropriate method to encourage students’ attitudes toward Science, Technology, Engineering, and Mathematics (STEM) learning. This method meets the needs of students, and this is due to the fact that each student has a different level and style of learning. This method can also allow students to be actively involved in the class. Understanding how to carry out teaching and learning processes will enable teachers to provide appropriate educational robotics assistance. It is also hoped that future research on this topic will be expanded in the education context. Other than that, the several research focusing on Malaysian educational robotics is limited. Therefore, this research may be employed in the

context of educational robotics in Malaysia, and the study's findings are anticipated to offer thorough knowledge.

5. CONTRIBUTION AND IMPLICATION OF THE RESEARCH

This mini SLR aims to contribute to knowledge and provide enlightenment through article analysis about the effectiveness of robot-based learning. Theoretically, the results suggested that research on robot-based learning is increasing. This indicates that there is still a need for more studies among remedial students in rural areas. According to the literature search, this study is relevant since few SLRs concentrate on remedial students in rural areas. Many studies on educational robotics exist, but not in rural schools among remedial students. As a result, this mini SLR can shed light on exploring educational robotics among remedial students. The information gained from multicounty studies is useful in this study and is predicted to generate ideas for analyzing the effectiveness of robot-based learning. The results presented that primary children made up the majority of the research on educational robotics analyzed, which is another potential for a future study to take remedial students from rural areas into account.

6. CONCLUSION

This study investigates the role of educational robotics in schools and develop appropriate criteria for incorporating robotics activities into the teaching and learning process. Here, the study's findings suggest that the usage of robotics in schools may enhance the learning environment. Other than that, teachers' perspectives on new technologies differ, both positively and adversely. As a result, teachers believe that they may utilize robotics learning if they already possess a fundamental understanding of robots. Robot-based learning is a good fit for robotics learning among the numerous learning methodologies. Nevertheless, the number of articles reviewed in this article is regarded as scarce. Further empirical research into linked issues is required.

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APPENDIX

Analysis of educational robotics research papers.

No	Ref	Country	Objective	Database	Method & sample	Sample
1	Santos et al. [30]	Portugal	Assess the implementation of the Festival de Robótica-AZORES miniBOT, a robotics festival for the youngsters	Scopus	Questionnaire 155	Primary education
2	Üçgül & Altıok [23]	Turkey	Examine the impacts of robotics summer camps with STEM activities on students' perceptions and attitudes toward STEM.	Springer	Pre-test post-test quasi-experimental 48	Secondary education
3	Shang et al. [29]	China	To examine the impacts of STEM camp programs on rural students' self-efficacy as well as computational thinking skills.	Scopus	Quantitative and qualitative pre-test post-test 153 students	K-12 education
4	Chatzopoulos et al. [31]	Greece	Develop an open, easy-to-use robotics platform for education applications centered on primary education and developing new modules.	Springer	Survey questionnaire 30	Primary education
5	Castro et al. [36]	Chile	ADetermine how efficient an educational robotics unit in a simulated environment is for enhancing primary school teachers' understanding of basic concepts in robotics while examining their didactic use when teaching mathematics	Scopus	Questionnaire 17 teachers	Primary education
6	Amador-	Spain	To analyze the opinion of	Scopus	Questionnaire	Higher

No	Ref	Country	Objective	Database	Method & sample	Sample
	Terrón et al. [32]		future Primary Education teachers on the use of robotics in mathematics		59 students	education
7	Seckel et al. [37]	Chile	Describing the understanding applied when teaching and learning mathematics using educational robots	Google Scholar	mixed methods using a descriptive design. 83 teachers	Higher education
8	Zviel-Girshin et al. [22]	Israel	Demonstrates findings concerning the addition of robotics education in kindergarten and elementary school as a tool for improving technological thinking, increasing confidence among children in utilizing technology, developing fundamental 21st-century skills and increasing self-confidence among children	Springer	Quantitative survey 197	K-12 education
9	Chiazzese et al. [24]	Singapore	To evaluate the effect of a robotics laboratory on the acquisition of computational thinking (CT)-related skills in primary school children.	ScienceDirect	Quasi-experimental post-test 32	K-12 education
10	Leoste & Heidmets [25]	Singapore	To explain how educational robots may be utilized as learning tools in mathematics lessons and the teachers' and students' attitudes towards educational robots.	Springer	Quantitative and qualitative 10 teachers and students	Primary education
11	Ching et al. [38]	USA	To investigate the impacts of a project-based STEM integrated robotics curriculum on elementary school students' attitudes toward STEM and perceived learning in an after-school setting.	Springer	Quantitative and qualitative 3 elementary school teachers and 18 students	K-12 education
12	Kangungu [26]	Malaysia	To weigh the efficiency of the robot-based learning approach by comparing it to the traditional teaching approach in learning programming	Science Direct	Quasi-experimental 20	Higher education
13	Smyrnova - Trybulska et al. [35]	Poland	To assess various aspects of utilizing robotics in education and examines the level of preparation and motivation of children and pupils	Scopus	Questionnaire 69	Primary education
14	Trigo et al. [33]	Spain and UK	To determine the main reasons for the low uptake of robots in SE, gained from an analysis of past studies using robots in the area and from interviewing SE teachers about the topic.	Springer	Interview 13 teachers	Primary education
15	Kert et al. [34]	Netherlands	To investigate the effect of educational robotics on	Science Direct	Pre-test post-test control	Primary education

No	Ref	Country	Objective	Database	Method & sample	Sample
			middle school students' development		group quasi-experimental design 78 students	
16	Al Hakim et al. [27]	Taiwan	To address the gap by creating an interactive situational learning environment with a robot as a companion to conduct and offer situational real-time evaluation as well as guidance during digitally situated learning tasks.	Science Direct	Quasi-experimental - a pre-and post-test - questionnaire 101 students	Higher education
17	Weng et al. [28]	Taiwan	To identify the development of CT in problem-solving skills (PSS) and programming learning attitude by integrating LEGO robotics kits in a project-based learning course.	ScienceDirect	pre-post-test 32 students	Higher education
18	Khaksar et al. [41]	Australia	To clarify the role of social robots in the education industry, specifically, within special developmental schools, as a part of an innovative technology portfolio	Springer	Qualitative 4 teachers 20 students	K-12 education
19	Lindsay [40]	Canada	To discover the quality, experience, and skills learned in a group-based robotics program for youth with disabilities	Scopus	Qualitative Survey 23	K-12 education
20	Cruz [39]	United State	Examined the effectiveness of robotics in promoting the critical thinking skills of middle school students in a public-school classroom setting	Scopus	Quasi-experimental pre-post-test 64 middle school students	Secondary education