Journal of Applied Intelligent Systems & Information Sciences
Vol. 3, Issue 2, pp. 56-64, December 2022.
Available at: www.journal.research.fanapsoft.com
DOI: https://doi.org/10.22034/JAISIS.2022.374466.1056

A Review of Robotics Applications in the Education Industry

Majid Abedinzadeh Shahri[1,*], Rasool Taban[2]

[1] *School of Electrical and Computer Engineering, University of Tehran, Tehran, Iran,*
[2] *Center for Computational and Stochastic Mathematics, University of Lisbon, Lisbon, Portugal.*

Abstract

Robots are now becoming a part of our daily lives however, one of the main targets of social robots is the educational environment. Hence, the market for educational robots has grown, and accordingly, there has been a steady increase in the number of studies investigating educational robotics. Therefore, to have a deep understanding of the potential of robots in the education industry and analyze the current situation in this field, this work presents a review of the literature in the field of educational robotics. The primary purpose of this work is to identify the challenges in this context. To achieve this purpose, we found 37 relevant articles written in English and published between 2010 and 2019. After analyzing the selected articles, the main issues found in the literature are presented. Our main objective is to find the main key points related to developing educational robots. The results from our review provide guidelines and might be beneficial for robotic researchers and educators in educational institutes to support future research and development of educational robotics.

Keywords: Educational Robotics, Educational Robots, Developing Educational Robots

1. Introduction

In recent years, interest in robotics has increased, and thereby robots are incorporated into our society. Accordingly, several robotics societies indicated that the market of personal robots (including entertainment and educational robots) is growing over recent years. In 2008, the number of service robots outnumbered the number of industrial robots (Mubin et al., 2013). In other words, these robots are beginning to be integrated into our homes and school.

The previous works considered Seymour Papert's (Solomon & Papert, 1976) work (introducing LOGO as a programming language) as the root of Educational Robotics. He found that robotics learning is more effective when learners can discover and experience different concepts for themselves. Thereafter, LEGO Group, which worked on educational toys, and MIT Media Lab collaborated to develop an educational robotics kit called MINDSTORMS. Today, MINDSTORMS kits are very popular in the educational robotics context. Because of growing this industry, other companies (such as Aldebaran) in the world focused on this industry. These efforts have shaped the field of Educational Robotics.

The main theories behind Education are Constructivism (Bruner, 1997) and Constructionism (Wooster, 1982). Constructionism states that learned knowledge is shaped by what the learners know and experience. The other one states that learning occurs when a student engages in the construction of physical artifacts. The difference between these approaches is that while constructivism primarily refers to the mental processes of learners,

* *Corresponding Author, Email:* m.abedinzadeh@ut.ac.ir

Received: 27 November, 2022; Accepted: 17 December, 2022; Published Online: 28 December, 2022

constructionism mainly indicates physical processes (e.g., constructing a physical model, generating a mathematical equation, etc.). The work of Papert (Solomon & Papert, 1976) (introducing the programming language LOGO) has been grounded under the theory of Constructionism. Thereafter, most education robotics related to technical topics are defined as Constructionism.

Educational robotics is defined differently in the literature. The traditional one involves developing technical knowledge by constructing and programming the robot. However, several studies considered educational robotics as a tool to be used to teach non-technical modules (such as mathematics (Karim, Lemaignan, & Mondada 2015), physics (Karim, Lemaignan, & Mondada 2015), language (Van den Berghe et al., 2019), music (Han, Kim, D. H., & Kim, J. W., 2009), and cognitive development (Taheri et al., 2015). Nevertheless, to cover most aspects of education, (Angel-Fernandez & Vincze, 2018) tried to define Educational Robotics as "a field of study that aims to improve the learning experience of people through the creation, implementation, improvement (and validation) of pedagogical activities, tools (e.g., guidelines and templates), and technologies, where robots play an active role and pedagogical methods inform each decision".

The work done so far indicate robotics is not widely used in education (Alimisis, Frangou & Papanikolaou, 2009). On the other hand, the advantages of robotics are more than found until now and should be studied more. A question raised here is how we can better develop robots for educational purposes. To answer this question, a literature review was conducted in this work. This work, by analyzing the literature, highlights the main issues of robotics which should be considered in the development of educational robots.

The rest of the paper is structured as follows; Section 2 states the research methodology used for the literature review. Then, after analyzing the articles, in Section 3, we present the main issues found in the selected papers. The paper ends with discussions and conclusions in Section 4 and Section 5, respectively.

2. Research Methodology

The methodology used in this work for the literature review includes three steps: search, selection, and analysis. Accordingly, the searches were restricted to articles written in English and published between 2010 and 2019. The articles were searched in the Google Scholar database. Also, the search strings used were: {"application" or "applied" or "apply" or "implementation" or "applying"} and {"teaching" or "teach" or "education" or "educational"} and {"robotic" or "robotics" or "robot" or "robots"}.

After searching the database, we found 70 articles. However, according to the title and abstract of the articles and the purpose of this work, some of them were excluded from the analysis. The 37 selected articles were read to find the main issues in educational robotics (Afari & Khine, 2017; Alemi, Meghdari & Ghazisaedy, 2014; Alimisis, 2012; Atmatzidou & Demetriadis, 2014; Atmatzidou & Demetriadis, 2016; Bers, Seddighin & Sullivan, 2013; Bers et al., 2014; Castledine & Chalmers, 2011; Camilleri, 2017; Chalmers, 2018; Chaudhary et al., 2016; Chin, Hong & Chen, 2014; Damaševicius et al., 2017; Danahy et al., 2014; Elkin, Sullivan, & Bers, 2014; Fernández-Llamas et al., 2018; Karahoca, D., Karahoca, A. & Uzunboylub, 2011; Karim, Lemaignan, & Mondada 2015; Kennedy, Baxter & Belpaeme, 2015; Karaman et al., 2017; Kopcha et al., 2017; Lemaignan et al., 2016; Leonard et al., 2016; López-Rodríguez & Cuesta, 2016; McLurkin et al., 2013; Meghdari et al., 2013; Menegatti & Moro, 2010; Ntemngwa & Oliver, 2018; Ospennikova, Ershov & Iljin, 2015; Saerbeck et al., 2010; Scaradozzi et al., 2015; Taheri et al., 2015; Van den Berghe et al., 2019; Vega & Cañas 2018; Vogt et al., 2019; Witherspoon et al., 2017; Özgür et al., 2017). The other details of the research methodology are illustrated in Fig. 1.

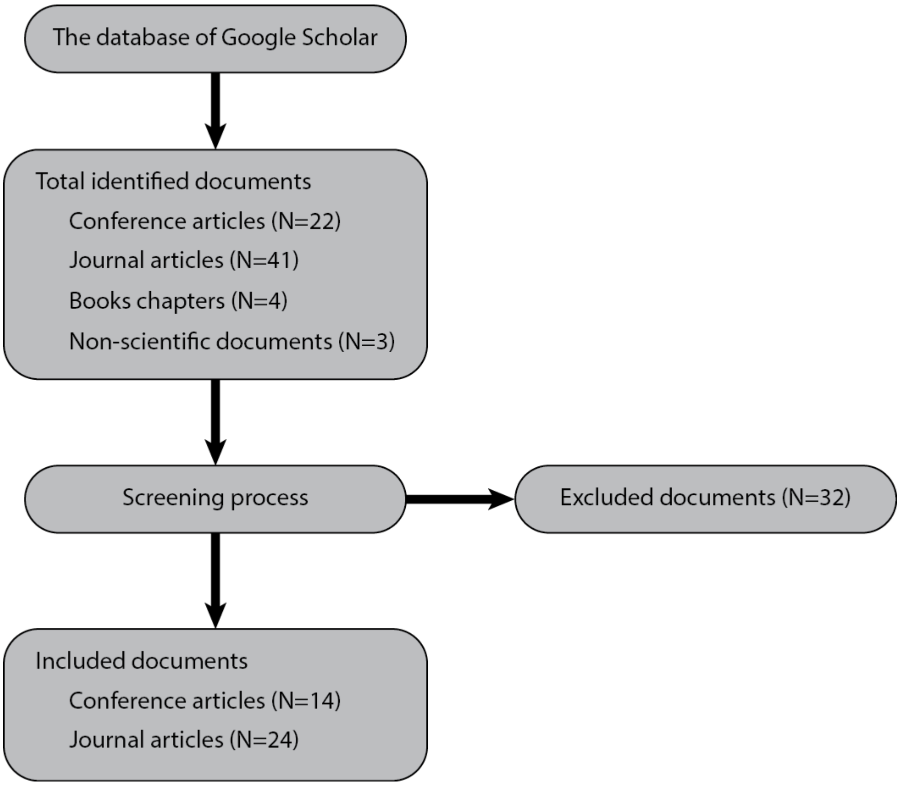

Fig. 1: The flowchart of the research steps

3. Research Results

In this section, the main issues found in the selected papers are presented:

Teaching methodologies found in the context:

- Discovery learning: In this approach, the teacher does not give direct answers to students, but s/he guides them toward their answers. In the cases where teachers did not know the guideline points, this approach is helpless. Usually, this approach takes more time than normal in the context of the curriculum.
- Collaborative learning: Collaboration is defined as actors sharing the same goal i.e., task realization. This approach could be organized in combination with any other approaches used in education if students are allowed to communicate with together.
- Problem-solving: Usually, when a student program a robot, the robot on the first try did not do what was expected. This process includes problem-solving (called debugging). However, students may be frustrated when dealing with problems related to a lack of knowledge about the programming environment of robots.
- Project-based learning: The main feature of this method is that each project is assigned to each group of projects. Accordingly, groups with better communication had more ideas and results. In other words, teamwork is important in the context of project-based learning.
- Competition-based learning: One of the main learning methods is competition-based learning. In this approach, competition motivates more participants to learn more about robots. Accordingly, knowledge and skills obtained through this method are memorized and understood better than through fact-based learning (Papert, 1993). However, this approach may result in disappointment if learners do not succeed as expected.

Also, from another point of view, the preferred scenarios for learning can be grouped into three categories: 1- individual learning, 2- group learning, and 3- learning in the classroom.

3.1. *Topics (subjects) taught in the context*

Most of the applications of robotic technology in education focused only on technical and digital skills that are closely related to the Robotics field (such as programming, construction, or mechatronics). It was found that this topic can improve computational thinking skills. This includes several fundamental skills that are important for everyone's analytical ability. These aspects are an abstraction (i.e., the process of creating something simple from a complicated concept), generalization (i.e., the process of transferring a solution to a wide variety of problems), algorithm (i.e., the ability to plan step-by-step instructions for performing a task), modularity (i.e., ability to develop processes that can be used in different problems), and decomposition (i.e., breaking down problems into smaller parts that have simple solutions). However, a few works show that educational robotics can be used in physics and mathematics (including Newton's Laws of Motion, distance, angles, kinematics, ratios, and geospatial concepts). Nevertheless, a lot of studies addressed STEM (Science, Technology, Engineering, and Mathematics) topics for using robotics in education. Indeed, this category covers both technical and non-technical issues. Language learning is another non-technical topic that was the focus of some of the reviewed papers. Also, a work used robots in education to treat Autism. Teaching handwriting is another field that a previous work focused on. Table. 1 presents this categorization in more detail.

Table. 1: The articles found on different educational topics

Education topic	Number of articles
Technical and digital skills	13
Math & Physics	3
STEM	10
Language learning	5
Handwriting	1
Autism treatment	1
Other*	4

3.2. *Types of robots in education*

For teaching robotics-related skills, a few of the works tried to provide mechatronics materials for students to teach them how to design and implement their robots. Also, some of the works used programmable mobile robots for this purpose. For teaching STEM skills, most of the works used robotics kits (such as Lego Mindstorms and Bioloid Robotics). Furthermore, for teaching non-programming-related curricula, usually instructors preferred to use social robots (such as NAO and Pepper robots).

As shown in Fig. 2, we categorized the materials used in the reviewed works into four groups: 1- construction of individual robots (including 2 papers), 2- programmable mobile robots (including 6 papers), 3- robotics kits (including 18 papers), and 4- social robots (including 10 papers).

3.3. *Robots' roles in education*

Robots in education can be used in three different roles: teaching assistant, tutor, and independent teacher.

In the first one (teaching assistant), the robot is used as a tool in the learning process and includes three scenarios: 1- "learning object" as a tool to teach robotics-related topics (e.g., using Lego Mindstorms to learn programming skills), 2- "learning tool" as a tool to teach other subjects (e.g., using robotics kits to teach math & science), and 3- "remote learning": as a robot to telepresence the teacher or student (e.g., using Baxter robot for remote teaching). Studies claimed that among instructors this role has the most preference.

In the second role, robots help teachers to teach different topics (e.g., using social robots for language learning).

Also, the robots in the third role are used independently as intelligent robots to teach learners. The studies indicate that using robots in this role has less preference in education.

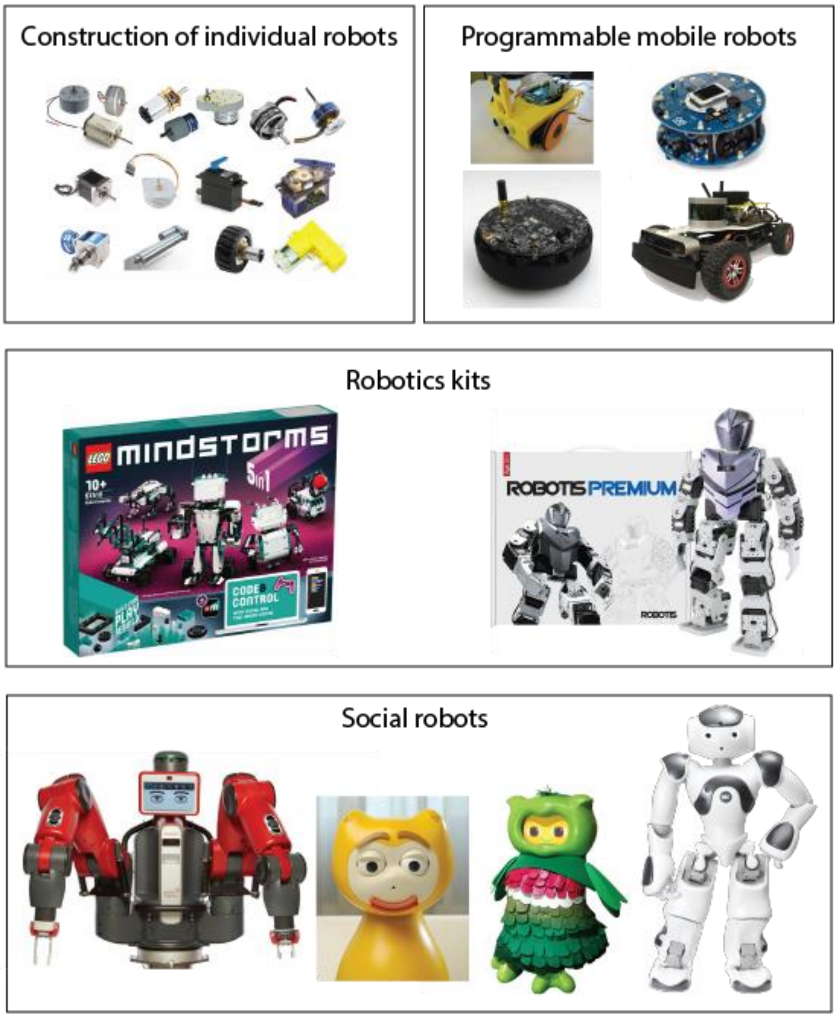

Fig. 2: The types of robotic tools used in the reviewed articles

4. DISCUSSIONS

Teaching includes inherently social interactions between educators and learners. To improve education, different technologies such as computers, tablets, and smartphones offer a wide array of possibilities (especially interactivity). Although for educational purposes using software for simulating robots' behavior is cheaper than using physical devices, robots have at least two advantages over software-based technologies. The first one is that the other technologies provide virtual agents while a robot has a physical body and exists in the real world, rather than being only virtually present via a screen. This feature provides the same physical reality to the user. Moreover, according to Constructionism theory, visualization uses fewer senses than real physical objects. Hence, hardware and the embodiment of robots have a significant role in education. The second advantage is that robots (due to their appearance which is often humanoid or in the shape of an animal) provide a more natural interaction medium than the other forms. Furthermore, robots can be used as typical teachers, peers, or friends. Moreover, robotics can provide this opportunity for students to apply their innovative solutions to real-world problems.

Nevertheless, to take advantage of both strategies for educational purposes, one can combine the virtual with the physical world. To achieve this goal, we suggest using Augmented Reality technology (as a software tool) to integrate the real-world environment with virtual objects. Accordingly, one can use virtual robotics devices on physical surfaces. This approach can reduce the cost of materials used in educational robotics.

In this study, we categorized educational robotic products into four groups: 1- construction of individual robots, 2- programmable mobile robots, 3- robotics kits, and 4- social robots. Note that from the first category to the fourth one, the required technical knowledge of the users is reduced. Also, this study showed that Robotics kits and social robots (in comparison with the construction of robots and programmable mobile robots) are preferred in education. To discuss this, we should consider the required technical knowledge as a distinguishing criterion. Indeed, because the construction of individual robots needs more technical knowledge, students, and teachers with low technical knowledge encounter more problems in practice. Moreover, the materials used for the construction of robots usually have a bad User Experience (UX). On the other hand, robotics kits and social robots usually have good UX and users with low technical knowledge can use these educational tools. Hence, simplicity in use and having good UX are two major features that could be considered in robots' development for educational purposes.

Moreover, the results indicated that robotics kits are most preferred in the education industry. Comparing robotics kits with social robots may help us find out why robotics kits are most attractive. From the morphological point of view, social robots have static morphology while the robotics kits provide variable morphology. The variable morphology gives the users this opportunity to plan and build different robots with a variety of functions. Also, in terms of transparency, the social robots are made and programmed in advance (named as "black box"). However, construction and programming are demanding for students. On the other hand, the robotics kits are more transparent (in comparison with the ready-made products) to illustrate the technical view of robots (named as "white box") and these tools achieve this opportunity for users to build and program their desired robot. Hence, it is better to have modular robots with diverse and white box functions for the education industry.

However, some young people may not be interested in traditional approaches to robotics. Nevertheless, robots can provide this possibility for teachers to integrate educational content in a fun and playful way. For example, a teacher can design a story and character for robots (for example, creating a mechanical puppet show). Also, connecting robotics with other disciplines and areas of interest, such as music and art can motivate students in education (Rusk et al., 2008). In general, we suggest integrating Story, Artistic Design, Character, and Technology to develop attractive robotics devices for education.

Nevertheless, the embodiment of robots has a critical effect on making them attractive. Indeed, proper embodiment design is another way to make robots more meaningful for children. For example, to attract young students the robot must have an animated body. However, the culture of the users should be considered in its design.

It should be emphasized here that using robotic devices for educational purposes has its disadvantages. Especially, when robots are used as an independent teacher. Perhaps, the main concerns raised for such cases are the privacy of the users, the inability to detect deceptions, and the loss of human (teacher) contact.

In the literature, reliable evidence confirming the effectiveness of educational robots remains limited. Accordingly, without validation of the direct impact of robotics on students' learning, robotic activities in the education industry might be just a fashion. Hence, educational robotics needs a systematic evaluation and reliable experiments to verify its benefits. It should be considered a major problem for researchers in this field.

(Alimisis, 2012) found that the focus on educational robotics should be shifted from hardware to methodology. Indeed, the main fundamental issue in educational robotics is not the robot itself; rather, it is the curriculum of education and the learning environment. Robots are just another tool for this purpose, and it is the curriculum that will determine the learning result and the alignment of technology with the sound theories of learning. Accordingly, teachers need to be properly trained, and the selection of the technology should be appropriate.

5. CONCLUSIONS

Today, educational robotics in comparison with traditional education approaches have the potential to be considered effective tools to develop cognitive and social skills (such as decision-making, communication, team working, and problem-solving skills). Thus, in this work, we present a review of the literature in the field of educational robotics. The main purpose of this work is to identify the challenges in this context. To achieve this purpose, we found 70 articles written in English and published between 2010 and 2019. After targeting 37 articles, by analyzing them (especially, focusing to find the main key points related to developing robotics devices for the education industry), the main issues found in the literature were presented. The results of our review provide guidelines and might be beneficial for educators, researchers, and administration in educational institutes to support future research and development of educational robotics.

REFERENCES

Afari, E., & Khine, M. S. (2017). Robotics as an educational tool: Impact of lego Mindstorms. *International Journal of Information and Education Technology*, 7(6), 437-442.

Alemi, M., Meghdari, A., & Ghazisaedy, M. (2014). Employing humanoid robots for teaching the English language in Iranian junior high schools. *International Journal of Humanoid Robotics*, 11(03), 1450022.

Alimisis, D., Frangou, S., & Papanikolaou, K. (2009). A constructivist methodology for teacher training in educational robotics: The TERECoP course in Greece through trainees' eyes. *In 2009 ninth IEEE international conference on advanced learning technologies* (pp. 24-28). IEEE.

Alimisis, D. (2012). Robotics in education & education in robotics: Shifting focus from technology to pedagogy. *In Proceedings of the 3rd International Conference on Robotics in Education* (pp. 7-14). Prague, Czech Republic: Charles University in Prague.

Angel-Fernandez, J. M., & Vincze, M. (2018). Towards a definition of educational robotics. *In Austrian Robotics Workshop 2018* (Vol. 37).

Atmatzidou, S., & Demetriadis, S. (2014). How to support students' computational thinking skills in educational robotics activities. *In Proceedings of 4th International Workshop Teaching Robotics, Teaching with Robotics & 5th International Conference Robotics in Education* (Vol. 18, pp. 43-50).

Atmatzidou, S., & Demetriadis, S. (2016). Advancing students' computational thinking skills through educational robotics: A study on age and gender relevant differences. *Robotics and Autonomous Systems*, 75, 661-670.

Bers, M., Seddighin, S., & Sullivan, A. (2013). Ready for robotics: Bringing together the T and E of STEM in early childhood teacher education. *Journal of Technology and Teacher Education*, 21(3), 355-377.

Bers, M. U., Flannery, L., Kazakoff, E. R., & Sullivan, A. (2014). Computational thinking and tinkering: Exploration of an early childhood robotics curriculum. *Computers & Education*, 72, 145-157.

Bruner, J. (1997). Celebrating divergence: Piaget and Vygotsky. *Human development*, 40(2), 63-73.

Camilleri, P. (2017). Minding the gap. Proposing a teacher learning-training framework for the integration of robotics in primary schools. *Informatics in Education-An International Journal*, 16(2), 165-179.

Castledine, A. R., & Chalmers, C. (2011). LEGO Robotics: An authentic problem-solving tool? *Design and Technology Education: An International Journal*, 16(3).

Chalmers, C. (2018). Robotics and computational thinking in primary school. *International Journal of Child-Computer Interaction*, 17, 93-100.

Chaudhary, V., Agrawal, V., Sureka, P., & Sureka, A. (2016). An experience report on teaching programming and computational thinking to elementary-level children using lego robotics education kit. *In 2016 IEEE Eighth International Conference on Technology for Education (T4E)* (pp. 38-41). IEEE.

Chin, K. Y., Hong, Z. W., & Chen, Y. L. (2014). Impact of using an educational robot-based learning system on students' motivation in elementary education. *IEEE Transactions on learning technologies*, 7(4), 333-345.

Damaševicius, R., Narbutaite, L., Plauska, I., & Blažauskas, T. (2017). Advances in the use of educational robots in project-based teaching. *TEM journal*, 6(2), 342.

Danahy, E., Wang, E., Brockman, J., Carberry, A., Shapiro, B., & Rogers, C. B. (2014). Lego-based robotics in higher education: 15 years of student creativity. *International Journal of Advanced Robotic Systems*, 11(2), 27.

Elkin, M., Sullivan, A., & Bers, M. U. (2014). Implementing a robotics curriculum in an early childhood Montessori classroom. *Journal of Information Technology Education. Innovations in Practice*, 13, 153.

Fernández-Llamas, C., Conde, M. A., Rodríguez-Lera, F. J., Rodríguez-Sedano, F. J., & García, F. (2018). May I teach you? Students' behavior when lectured by robotic vs. human teachers. *Computers in Human Behavior*, 80, 460-469.

Han, J. H., Kim, D. H., & Kim, J. W. (2009). Physical learning activities with a teaching assistant robot in elementary school music class. *In 2009 Fifth International Joint Conference on INC, IMS and IDC* (pp. 1406-1410). IEEE.

Karaman, S., Anders, A., Boulet, M., Connor, J., Gregson, K., Guerra, W., ... & Vivilecchia, J. (2017). Project-based, collaborative, algorithmic robotics for high school students: Programming self-driving race cars at MIT. *In 2017 IEEE integrated STEM education conference (ISEC)* (pp. 195-203). IEEE.

Karahoca, D., Karahoca, A., & Uzunboylub, H. (2011). Robotics teaching in primary school education by project-based learning for supporting science and technology courses. *Procedia Computer Science*, 3, 1425-1431.

Karim, M. E., Lemaignan, S., & Mondada, F. (2015). A review: Can robots reshape K-12 STEM education? *In 2015 IEEE international workshop on Advanced robotics and its social impacts* (ARSO) (pp. 1-8). IEEE.

Kennedy, J., Baxter, P., & Belpaeme, T. (2015). Comparing robot embodiments in a guided discovery learning interaction with children. *International Journal of Social Robotics*, 7(2), 293-308.

Kim, C., Kim, D., Yuan, J., Hill, R. B., Doshi, P., & Thai, C. N. (2015). Robotics to promote elementary education pre-service teachers' STEM engagement, learning, and teaching. *Computers & Education*, 91, 14-31.

Kopcha, T. J., McGregor, J., Shin, S., Qian, Y., Choi, J., Hill, R., ... & Choi, I. (2017). Developing an integrative STEM curriculum for robotics education through educational design research. *Journal of Formative Design in Learning*, 1(1), 31-44.

Lemaignan, S., Jacq, A., Hood, D., Garcia, F., Paiva, A., & Dillenbourg, P. (2016). Learning by teaching a robot: The case of handwriting. *IEEE Robotics & Automation Magazine*, 23(2), 56-66.

Leonard, J., Buss, A., Gamboa, R., Mitchell, M., Fashola, O. S., Hubert, T., & Almughyirah, S. (2016). Using robotics and game design to enhance children's self-efficacy, STEM attitudes, and computational thinking skills. *Journal of Science Education and Technology*, 25(6), 860-876.

López-Rodríguez, F. M., & Cuesta, F. (2016). Andruino-a1: Low-cost educational mobile robot based on android and arduino. *Journal of Intelligent & Robotic Systems*, 81(1), 63-76.

Meghdari, A., Alemi, M., Ghazisaedy, M., Taheri, A. R., Karimian, A., & Zandvakili, M. (2013). Applying robots as teaching assistant in EFL classes at Iranian middle schools. *In Proceedings of the international conference on education and modern educational technologies (EMET-2013)*, Venice, Italy.

Menegatti, E., & Moro, M. (2010). Educational robotics from high school to the master of science. *In Workshop Proceedings of Intl. Conf. on Simulation, Modeling, and Programming for Autonomous Robots (SIMPAR 2010)* (pp. 639-648).

McLurkin, J., Lynch, A. J., Rixner, S., Barr, T. W., Chou, A., Foster, K., & Bilstein, S. (2013). A low-cost multi-robot system for research, teaching, and outreach. *In Distributed autonomous robotic systems* (pp. 597-609). Springer, Berlin, Heidelberg.

Mubin, O., Stevens, C. J., Shahid, S., Al Mahmud, A., & Dong, J. J. (2013). A review of the applicability of robots in education. *Journal of Technology in Education and Learning*, 1(209-0015), 13.

Ntemngwa, C., & Oliver, S. (2018). The implementation of integrated science technology, engineering, and mathematics (STEM) instruction using robotics in the middle school science classroom. *International Journal of Education in Mathematics, Science and Technology*, 6(1), 12-40.

Ospennikova, E., Ershov, M., & Iljin, I. (2015). Educational robotics as an innovative educational technology. *Procedia-Social and Behavioral Sciences*, 214, 18-26.

Papert, S. (1993). The children's machine: Rethinking school in the age of the computer. Basic Books, Inc.

Rusk, N., Resnick, M., Berg, R., & Pezalla-Granlund, M. (2008). New pathways into robotics: Strategies for broadening participation. *Journal of Science Education and Technology*, 17(1), 59-69.

Saerbeck, M., Schut, T., Bartneck, C., & Janse, M. D. (2010). Expressive robots in education: varying the degree of social supportive behavior of a robotic tutor. *In Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 1613-1622).

Scaradozzi, D., Sorbi, L., Pedale, A., Valzano, M., & Vergine, C. (2015). Teaching robotics at the primary school: an innovative approach. *Procedia-Social and Behavioral Sciences*, 174, 3838-3846.

Solomon, C. J., & Papert, S. (1976). A case study of a young child doing Turtle Graphics in LOGO. *In Proceedings of the June 7-10, 1976, national computer conference and exposition* (pp. 1049-1056).

Taheri, A. R., Alemi, M., Meghdari, A., Pouretemad, H. R., & Holderread, S. L. (2015). Clinical application of humanoid robots in playing imitation games for autistic children in Iran. *Procedia-Social and Behavioral Sciences*, 176, 898-906.

van den Berghe, R., Verhagen, J., Oudgenoeg-Paz, O., Van der Ven, S., & Leseman, P. (2019). Social robots for language learning: A review. *Review of Educational Research*, 89(2), 259-295.

Vega, J., & Cañas, J. M. (2018). PiBot: An open low-cost robotic platform with a camera for STEM education. *Electronics*, 7(12), 430.

Vogt, P., van den Berghe, R., de Haas, M., Hoffman, L., Kanero, J., Mamus, E., ... & Pandey, A. K. (2019). Second language tutoring using social robots: a large-scale study. *In 2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI)* (pp. 497-505). IEEE.

Witherspoon, E. B., Higashi, R. M., Schunn, C. D., Baehr, E. C., & Shoop, R. (2017). Developing computational thinking through a virtual robotics programming curriculum. *ACM Transactions on Computing Education (TOCE)*, 18(1), 1-20.

Wooster, J. S. (1982). Mindstorms: children, computers, and powerful ideas.

Özgür, A., Lemaignan, S., Johal, W., Beltran, M., Briod, M., Pereyre, L., ... & Dillenbourg, P. (2017). Cellulo: Versatile handheld robots for education. *In 2017 12th ACM/IEEE International Conference on Human-Robot Interaction (HRI)* (pp. 119-127). IEEE.