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The rise of educational robots: A review of classroom applications

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Abstract. As critical mechanics and artificial intelligence have improved at a fast pace, the application of robots has become a trending research domain. Robot has a golden opportunity to be a game-changer in the education domain. A large group of studies have noted that robots can offer a promising learning design in the classroom to help students boost their studying. This article analysed papers published in the science database between 2012 and 2022 relating to robot settings and tried to conduct a review on robots used in the classroom. The review focuses on features in these studies, including the age of participants, duration of the study, field of discipline, interaction method, and studying strategies, identifying roles of robots and evaluating the performance of students. This study also indicates shortages in robot deployment and provides several suggestions for future research.

Keywords: Robot, Education, Student, Interaction, Tutor.

1. Introduction

With the fast development of artificial intelligence (AI) and mechanics, including friendly material, sensor technologies, image recognition, and voice sampling, robots have been recognized as a potential tool for students learning when they can mimic and understand humans' emotions and behaviours. Some research argued that robots could become one of the standard tools, similar to the blackboard, projector, computer, etc., in the classroom [1].

Many practitioners and researchers have endorsed this innovative technology as game-changer for modern education [2-4]. A research agreed that students, with the assistance of robots, can develop their abilities, including solving problems, boosting effectiveness, and being more cooperative and creative [3]. Moreover, robots could be good teachers to help students learn languages and science [4-5], even the domain of STEAM (Science, Technology, Engineering, Art, Mechanics) [6-7].

In this article, we try to figure out how good robots would be capable of in a classroom by conducting three types of investigation relating to previous studies: 1) What were the interesting features in these studies? 2) What were the roles of robots in the classroom? 3) How do we evaluate the students' performance?

2. Related work

A research conducted a review of 10 studies on the robot in the classroom, analysing the effectiveness of interaction with students, where positive outcome in the field of STEM was identified [8-9].

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Moreover, a paper studied 22 experiments on robots deployed for children under 12, mostly in primary school, learned with LEGO robots. Besides, researchers noticed that the roles of robots could be peer, teacher or tool to help students [9-11].

Several papers have agreed that it is important to compile systematic reviews on specific research fields [12-14], which could be helpful to understanding and innovation.

This article analysed papers published in the science database and tried to conduct a review on robots used in the classroom. It is an extension of some previous research, intending for a further study relating to [13-14].

3. Methods

The review and analysis of this article followed the principles and guidelines of PRISMA proposed by [15] and referred to the studies of [16] and [17]. Data collection and analysis were involved later.

3.1. Data collection

In the review, we focused the keyword and abstract in Science Direct, Google Scholar and Web of Science, with a combination of the following lists: “artificial intelligence” (or “machine learning”, “personal tutor”, “automated tutor”, “intelligent system”, “teacher”) and “robot” and “education” (or “classroom”, “student”). The adoption of articles for this research is based on the recommendation of previous studies [16] and [17]. The publication quality was a major factor to be considered if a review study was expected to be reliable.

A total of 60 articles were initially selected for the study on education and robotics. Papers that were early public editions or correction notes were excluded, as were studies that did not involve practical application in real classrooms. Additionally, articles focused on adult subjects were eliminated, resulting in a final selection of 26 articles.

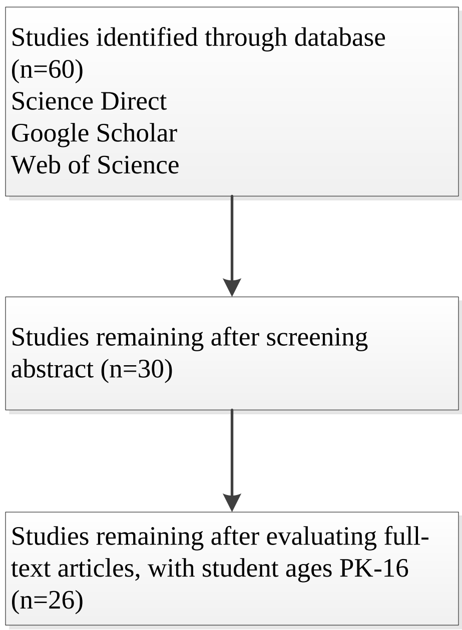

Figure 1. Articles selection.

3.2. Data analysis

For this article, it was expected to answer the following questions:

1) What were the features in these studies, including the age of participants, duration of the study, field of discipline, interaction method, and studying strategies?

2) What were the roles of robots in the classroom?

3) How do we evaluate the students' performance?

Figure 2 shows the answer to the age of participants. For the subjects, kindergartners (n=6, 23.08%), elementary school students (n=9, 34.62%), secondary school (n=2, 7.69%). In addition, nine articles involved mixed participants, consisting of children in kindergarten and elementary school, especially with ages from 5 to 7.

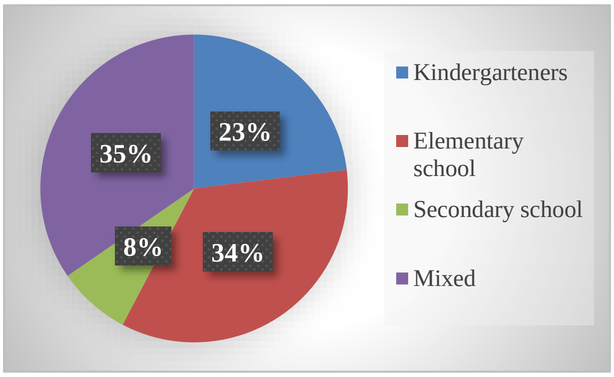

Figure 2. Age of participants.

Figure 3 shows the duration of the study. All papers explicitly informed the time for the experiment. 7.69% of studies finished only in one day, while a major proportion of 50% was conducted within 4 weeks. Only three experiments lasted more than one year, engaging students with age from 6 to 16 [18-20].

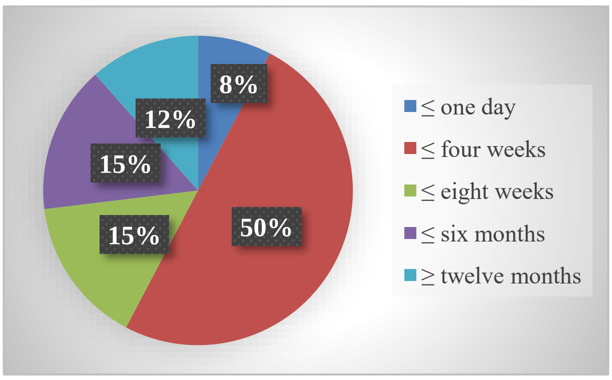

Figure 3. Duration of the study.

Figure 4 shows the field of discipline. In terms of the topic, Language (n=7, 26.92%) and Science (n=7, 26.92%) are the most frequently studied, followed by courses on storytelling (n=6, 23.08%). Most students who interacted with robots for language and science lessons were in elementary school [21-22], while the ones for storytelling were kindergarteners' students, and the engineering course was in secondary school [23-24].

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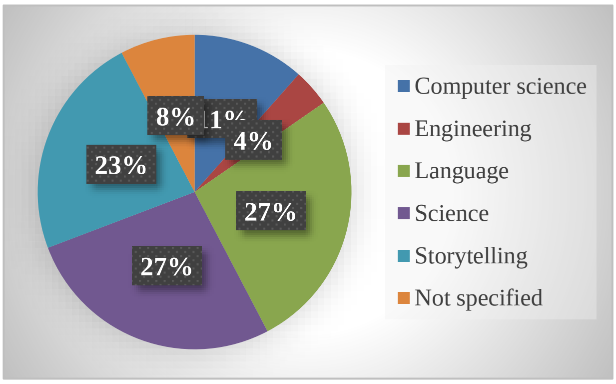

Figure 4. Field of discipline.

Figure 5 displays the robot interaction method. Physical robots (n=21, 80.77%) and mixed ones (n=3, 11.54%) are a developing trend in education. Nevertheless, the effect of digital tools cannot be ruled out, as they still offer robust software for simulation.

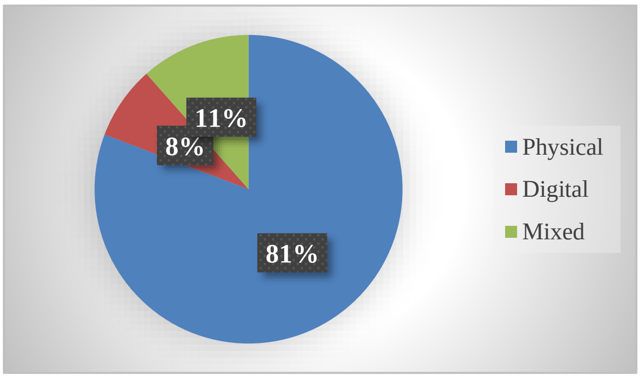

Figure 5. Robot interaction methods.

Figure 6 shows what strategies studies used. Game based (n=9, 34.62%), problem solving (n=6, 23.08%) and mixed strategies (n=5, 19.23%) were mostly employed. As many research subjects were children in kindergarten and elementary school, the major strategies were expected to be in the classroom. Notably, a research used a combination of collaborative related and game based methods to enhance students' interaction with robots [21].

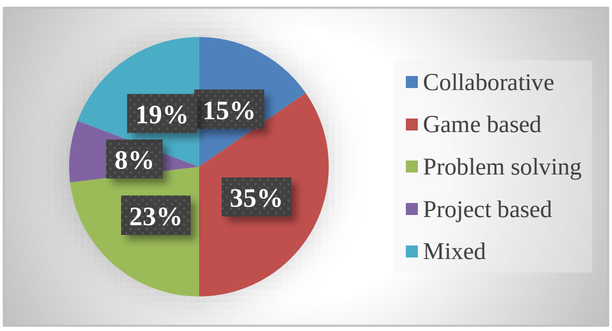

Figure 6. Studying strategies.

Figure 7 shows the distribution of roles of robot-student interaction. Robots were used in roles of tutee/peer (n=10, 38.46%) and tutor (n=10, 38.46%), where tutee related to play a role as a learner [23],

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and tutor as a teacher providing students guidance [25]. One study used the robot as a tool to boost young students' inquiry capability [26].

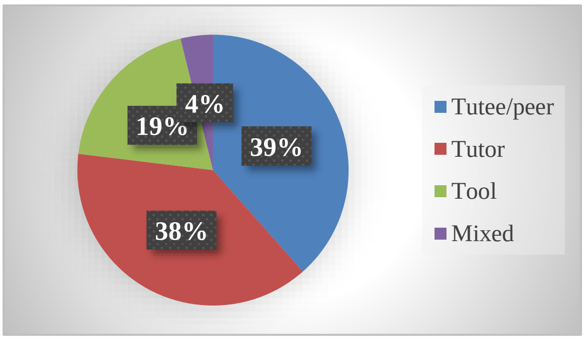

Figure 7. Roles of robot.

Figure 8 shows methods to assess students' performance. The top3 methods were Questionnaire (n=10, 28.57%), Exam (n=10, 28.57%) and Observation (n=7, 20%) [21, 23], while some researchers used interviews with students (n=6, 17.14%). Many researchers used mixed methods, including observation, interviews and tests to find out performances during interaction with robots.

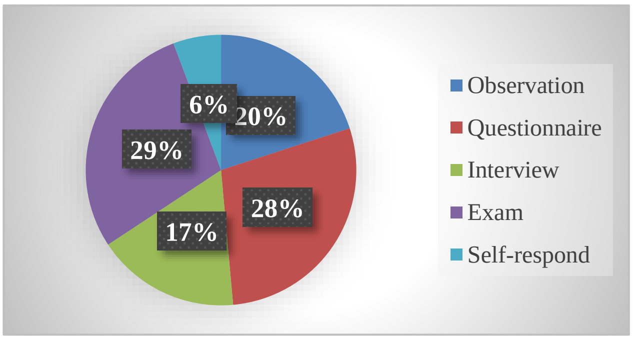

Figure 8. Assess methods.

4. Results

Most research focuses on students of K-12, including ones in kindergarten and elementary school. 15 of the 26 articles in our database involved elementary school kids. It would be partly due to a consensus that younger students could benefit from robots more effectively. Research presented that robots are a positive factor in enhancing learning performance under 12 [8].

Some researchers argued that young students involved with special needs could benefit from learning with robots. The interaction can boost the social skills, and attention engagement of students, even the ones who suffer from autism [19].

Many experiments only lasted less than 4 weeks (nearly 60%). However, it was noticed that learners received positive outcomes [27-28]. On the contrary, around 27% of researchers deployed robots in classrooms for a relatively long-term study lasting more than six months. Some researchers recommended that students need more time to build a robust relationship with robots for completing tasks. Considering the learners' decreasing interest in robots over time, it is essential to factor in the length of deployment to ensure reliable study outcomes [20].

Language, science and storytelling were the most investigated disciplines. The reason would be related to the research subjects in kindergarten and primary school (ages less than 10), where kids learned how nature worked, how to express appropriately what they were thinking or how to interact with others. Besides, more prominent students in programming, mathematics or engineering also used robots as tools for disciplines due to this topic being close to robotics [29-31]. Unfortunately, it could refer to robotic study and application still squeezing in a tiny region. Further studies in diverse regions were expected to deploy to confirm their benefits.

Since studies with multiple targets or focus, mixed methods were more frequently used than qualitative or quantitative methods [25].

Most studies used game-based strategies to draw attention from kids due to the subject age of studies. Meanwhile, problem-solving-related strategies have become a new trend considerably, as to improve students' interest and motivation in fulfilling missions [21, 32-33]. As for collaborative strategies, kids were expected to assess and offer recommendations for the work of their classmates, helped by robots compared to the ones by teachers. Kids could be capable of obtaining knowledge from different perspectives. Their comprehensive understanding could also be boosted during the learning.

Robots were set diverse roles in the classroom, such as teacher or teacher assistant, peer, and tool for guide. The most common roles played by robots were peer and teacher in the robot-involved classrooms, followed by instructional tools. Some studies mainly focused on mixed topics, including social engagement and instrument playing, for comparison [33]. However, no study can judge whether a robot can replace a human teacher. The research studied the performance of a robot compared to a human by deploying two learning groups [34]. However, the outcome only showed that in statistics, there was no guarantee that a robot was a superior storyteller compared to a human. The research noted that if students needed an expected outcome from assisted robots, it was crucial for human teachers to be familiar with deployed robots and have an appropriate schedule to work with them [35].

The learning effectiveness, affection and learning behaviour drew the attention of researchers the most. Relating to affection, studies on attitudes, opinions and perceptions top the rank. The result represented that learners' conceptual recognition, attitudes and skill enhancement intrigued researchers [16, 20, 36-38].

Studies were almost interested in physical instructions rather than digital ones between kids and robots. The physical interaction could be classified as a one-to-one mode [8, 20, 39] and a one-to-group mode [28, 32, 36-37].

Few studies explicitly analyzed the safety of robot, regarding theri physical or emotional impact on kids. The research indicated that teachers double-checked the schedule and made sure robot's operation be safe, before conducting the lessons [35]. The research introduced concerns from some teachers that robot was expected not to be broken by those notorious kids, while students were also offered guidance that "please do well with robots" and particularly "do not put your finger into the joints of robot" [40]. The research emphasized that not only the physical safety needed to be guaranteed, but also the privacy of students and teachers involved in experiments with robots [20].

Another topic rarely involved was ethics. Several studies explicitly noted that approval from schools in relation to ethics in research existed. Given teachers and students spent a lot of time supporting these studies, it would be considerably important to offer an ethical introduction to them. Furthermore, The research indicated a key issue: based on the fact that not all students had an opportunity to interact with a deployed robot in the classroom, even if the robot cost a huge expense, it was necessary to find a solution for realizing "equal access" [29].

Some studies showed concerns about robotic reliability. The research noted that two renowned brands of robots shared common technical problems during the research, such as failure in voice/image recognition, inability to move as required and unstable battery [35]. The research mentioned that sometimes, the robot was unable to connect to network, and delivered pronunciation problems [31].

5. Conclusions

The article assessed published research in the scientific database, analysing features, including the age of participants, duration of experiments, the field of discipline, robot interaction methods, studying strategies, roles of robots, and evaluation of students' performance. According to the outcomes, suggestions for this research are represented for future study.

1) The performance of students in the studies was mostly promising. However, we still need more long-term duration experiments, which would give us more robust outcomes with regard to critical thinking cultivation, problem-solving capability, creative skill and perceptions.

2) Before deploying a robot in the classroom, it should consider the role of a robot. When a robot is treated as a member of a group with students, teachers should compile an appropriate studying schedule to fulfil tasks. If the robot is regarded as a tutor, we should consider whether it can offer emotional support, similar to what a human teacher does, to students in class. More tests should be conducted to ensure which role played by robots would be better for kids' learning.

3) Age would be a very critical factor for robot-human interaction. We should also evaluate the performance of higher education students. It is expected to find out what the relationship involving age, the robot's role, assisted-topic and deploying strategy.

4) It is still early to judge if physical interaction is superior to a digital screen, even though many researchers are inclined to investigate the project on the former. We still need to engage more attempts in different environments.

5) Articles involved in this study are relatively small. A larger sample, including discipline domain, performance of students, and compassion for human teachers, shall be evaluated in future studies.

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