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“Storytelling and educational robotics: A scoping review (2004–2024)”

Maria Palioura, Theodosios Sapounidis *

School of Philosophy and Education, Department of Education, Aristotle University of Thessaloniki (AUTH), 54124, Thessaloniki, Greece

A R T I C L E I N F O

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A B S T R A C T

Storytelling has been used for years in educational practice and Educational Robotics is a rapidly growing field worldwide. Accordingly, researchers have attempted to combine Storytelling and Robotics in education. However, no systematic record exists on this combination. Therefore, we conducted a scoping review of 82 papers out of 5272 articles published in 5 Databases in the last 20 years to map the conducted research so far. In detail: the educational levels and the school subjects in which storytelling and educational robotics are applied, the types of robots used, the duration, the sample size, participants' age and the skills that students may develop through this combination. Additionally, we analyzed, grouped, and presented the tools used for measuring the potential effects of storytelling and educational robotics. Finally, the students' role in the activities was sought. Based on our findings, most interventions mainly addressed preschool and primary school students, the robots used the most are humanoid, most interventions did not exceed 6 h, and the number of participants was less than 20 students. Besides, most interventions tried to develop students' skills (communication, creativity, collaboration) and attitudes (engagement, motivation, participation) with qualitative tools borrowed from other domains (e.g. psychology, healthcare). This scoping demonstrates a gap in the use of storytelling and educational robotics in secondary and university education and subjects like history, geography, etc. Finally, this combination seems to have the potential to enhance the educational process, but more research is needed to shed light on all the aspects of the combination.

1. Introduction

The multidimensional impact of technology on our everyday lives has led to its integration into the education field. As a new cultural asset in education, the integration of technology can contribute to a potentially holistic approach to knowledge acquisition. Among the goals of the modern school are the students' technological literacy and their familiarity with digital systems and techno-literacy, in a critical way, so that students can adapt to the modern globalized regime (Koutsogiannis, 2007). Storytelling (ST) has been used in the educational process throughout time, while Educational Robotics (ER) is a new and rapidly developing sector that also extends to education. In recent years there has been an attempt to combine the two fields in educational settings (see Table 1).

* Corresponding author.
E-mail addresses: mpalioura@edlit.auth.gr (M. Palioura), teo@edlit.auth.gr (T. Sapounidis).

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1.1. Storytelling

A concept that uses stories as a communication tool for valuing, sharing, and utilizing people's knowledge is called "Storytelling" (Scolari, 2009; Serrat, 2017). In the 21st century, ST is also known as Transmedia/Digital Storytelling since ST seeks to engage and interact with users across multiple channels, transforming into a holistic educational tool for developing creativity and providing an entertaining educational experience for students (Perry M.S., 2020). ST is a method that can enhance teaching and learning as well as improve the quality of it (Alismail, 2015). This could be achieved through various technological devices such as tablets, smartphones, and laptops. Regarding the benefits of ST, researchers claim that they are significant in promoting and improving students' oral and language skills, developing self-confidence, and enhancing their motivation (Arroba J.; Acosta H., 2021; Hava, 2019; Jessica C.; Yunus M., 2018; Sintonen S.; Kumpulainen K.; Vartiainen J., 2018). Related to ST's impact on students' language skills, according to Kouvara et al. (2019), ST could enhance them, reconstruct Language school subjects and sharpen students' critical thinking. Moreover, based on the findings of a systematic review by Nair and Yunus (2021a,b), ST has the potential to become a useful teaching tool to improve students' speech skills at various educational levels. Focusing particularly on English language learning research has shown that ST may promote students' language skills and enhance the learning process in terms of speed and efficiency (Mirza, 2020; Nair, V., & Yunus, 2021; Ya-Ting Carolyn Yang, Yi-Chien Chen, 2020). In addition to this, related to skills development and attitudes, ST might promote the development of 21st-century skills such as visual and techno-literacy, collaboration and improve students' engagement (Sagri et al., 2018).

1.1.1. Reviews on ST in education

ST in education has attracted researchers' attention who conducted reviews to explore the related field and provide a comprehensive and objective review of the available literature. Specifically, the systematic review by Wu and Chen (2020) examined 57 educational studies from 1993 to 2018, revealing a continued interest in the US and a growing adoption in Asian and European countries at all education levels, primary, secondary, and tertiary. According to them, ST is used independently or in combination with other pedagogical methods, particularly in humanities and social science contexts. Nair et al. (2021a,b) conducted a systematic review of 45 articles from Google Scholar and Eric from 2017 to 2021 and showed that ST may improve students' speaking skills from primary to tertiary education. Additionally, based on the systematic literature review conducted by Quah and Ng (2022) and included 91 studies from 2010 to 2020, 21st-century skills can be developed through the implementation of ST in subjects such as English, Science, and Social Sciences.

Moreover, Sarica (2023) presents a systematic review of the effect of ST on students' emotions during the educational process. The review examined 70 research articles through a mixed methodological approach, combining systematic mapping and systematic review. Results show that ST may contribute to the design of learning activities and be an effective learning tool for both students and teachers. Additionally, Sarica (2023) argued that ST might facilitate emotional exchange and empathy, enhance participants' engagement, and develop emotional competencies. Thus, students end up in self-reflection and self-awareness of emotions.

However, research reveals some limitations of ST because its effectiveness depends on several factors. More specifically, students might encounter problems in terms of coordination and understanding of the way to use ST in the educational process (Borges & Vivacqua, 2010). Still, students may find it hard to cooperate while utilizing ST in groups in learning activities. Based on Carminatti et al. (2005) group size may affect the results, as a large number of participants may show less effectiveness. Furthermore, there seems to be a lack of appropriate educational ST material at users' disposal. Moreover, the gear and time required for the creation of ST content may discourage educators from utilizing ST in educational settings (Har et al., 2019).

In conclusion, ST may be a traditional teaching method encompassing modern technology to enhance and expand the interaction with the educational subject and the teacher's collaboration with the students. However, the factors involved in the ST process should be considered each time to avoid failures that could potentially reduce its effectiveness.

1.2. Educational robotics

ER is intended to improve the students' learning experience through pedagogical activities in which robots play an active role (Zech & Piater, 2018). Common educational robots are low-cost programmable robots (e.g. Lego Mindstorms, Ozobot, Sphero) and Humanoid Robots (e.g. NAO, Pepper) (Gubenko et al., 2021; Kerimbayev et al., 2023; Malinverni et al., 2021; Mubin et al., 2013). Specifically, humanoid robots are designed to resemble the appearance and characteristics of a human, to perform tasks in a human-like manner, to interact with their environment and to interact with humans (Kajita et al., 2014). Research results show that

Table 1
Research results: number of papers per database (excluded/included articles).

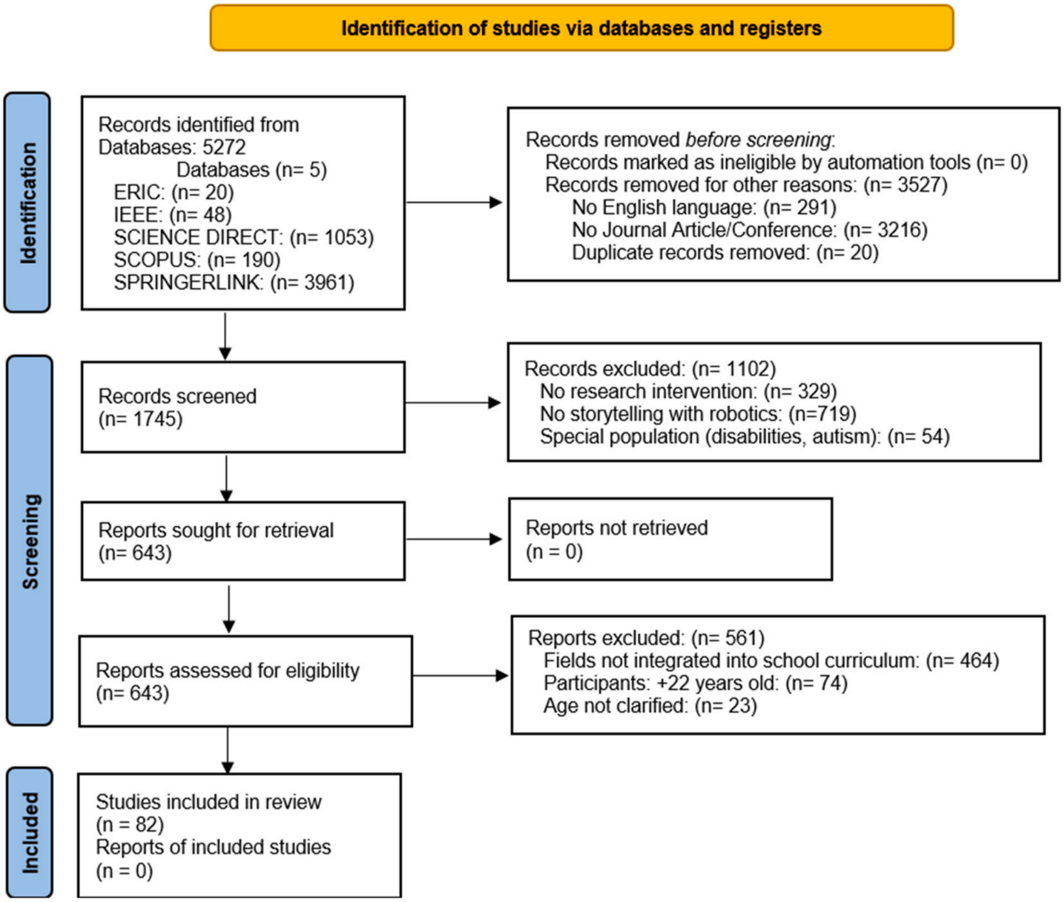
BASES	*ARTICLES APPEARED*	*EXCLUDED ARTICLES*	*INCLUDED ARTICLES*
ERIC	20	10	10
IEEE	48	34	14
SCIENCE DIRECT	1053	1037	16
SCOPUS	190	169	21
SPRINGERLINK	3940	3961	21
RESULTS	5272	5190	82

robots' social character might enhance learning, as they seem attractive to children because they can probably encourage imagination, innovation and creativity by stimulating all the senses (Belpaeme, Kennedy, Ramachandran, Scassellati, & Tanaka, 2018a; Chen, Nurkhamid, 2011; Sapounidis and Demetriadis, 2013). On the other hand, an educational programmable robot is usually a lower-cost robot and they are designed mainly to perform specific repeated operations (Istenes & Pásztor, 2007; Sapounidis et al., 2022a).

Based on existing literature, ER may be a flexible and interdisciplinary approach to teaching because it can be applied to various educational frameworks and fields (Anwar et al., 2019). It can be used in STEM (Science, Technology, Engineering and Mathematics) education, Language and Art, Special Education, Environmental Science and Health Education (Pei & Nie, 2018a; Tselegkaridis & Sapounidis, 2022). In particular, other researchers support that students could develop skills such as problem-solving, self-efficacy, collaboration, and computational thinking, which might be reinforced through hands-on and experiential learning activities through robots (Amo et al., 2021; Chu et al., 2022; Rapti & Sapounidis, 2024). Research on robot-assisted vocabulary learning and language production has also demonstrated positive results (Kanero et al., 2018). Overall, researchers deduce that educational robotics as a teaching tool has the potential to promote an integrated approach to technical and social topics, optimize the learning process, increase students' performance and engagement, and reduce stress (Ziouzios et al., 2021; Bers et al., 2019a,b; Sapounidis et al., 2015; Wang et al., 2023).

As for the humanoid robots' contribution to children's refinement of abilities, Peretti et al. (2023) argues that these can enhance various social interactions as long as the educational robotics activities are designed and implemented by experienced educators. Besides, the fact that humanoid robots resemble real people can facilitate children's interaction and successful communication between robots and participants (Di Dio et al., 2020; Manzi et al., 2020). In addition, humanoid robots may create learning activities featured by edutainment and help children collaborate effectively with them under appropriate conditions that respond to the needs of the audience (Crompton et al., 2018). Moreover, other researchers claim that humanoid robots might contribute to children's skills promotion like critical thinking, communication, creativity, engagement and their computational thinking capacities, in various educational settings from kindergarten to upper levels adapted to the characteristics and requirements of the specific educational level

Table 2
PRISMA flow diagram of data collection.



From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021; 372:n71. https://doi.org/10.1136/bmj.n71

(Keane et al., n.d.; Keane et al., 2019).

Related to special education, robotics' impact on teaching fundamental behaviors to children may be positive in terms of knowledge acquisition, language and social skills. Specifically, robotics' special traits such as simplicity and repetition of behaviors could facilitate the children's with ASD (Autism Spectrum Disorders) effective interactions and emotional behaviors (Costa et al., n.d.). Additionally, social robots can be utilized as tutors, and peer learners during learning activities and contribute to children's enhanced learning outcomes and socialization of children with autism and learning disabilities (Belpaeme et al., 2018b). Moreover, in terms of learning and intellectual disabilities (e.g. dyslexia, dysgraphia etc.), ER can enhance children's engagement and interpersonal relations (Suneesh and Ruiz Garate, 2022). Furthermore, Papakostas et al. (2021) claim that children with various impairments can improve their social abilities through their encounters with robotics. Yet, based on McColl et al. (2016), to gain the most of social robots' benefits, we should consider the robotics special traits (appearance, usability) and tailor them to the children's special needs.

1.3. Reviews on ER in education

In the field of ER, several reviews have been conducted at various educational levels. The research conducted by Anwar et al. (2019) presented a systematic literature review on educational robotics in secondary education and included 147 studies published from 2000 to 2018. Based on the findings, ER may be increasingly used in education to enhance the interest, engagement, and academic performance of students in secondary STEM courses.

In another systematic review conducted by Zhang et al. (2021), the impact of ER on computational thinking and STEM attitudes examined. Specifically, 17 surveys from kindergarten to 12th grade published from 2010 to 2019 were presented. The systematic review revealed that educational robots are likely to have negative effects because their effectiveness depends on factors such as the educational level, the school course, or the number of participants. According to the same paper, although there are studies that claim that ER could contribute to the development of students' communication, there are also studies that claim the opposite.

Additionally, a systematic review carried out by Bano et al. (2023) included 20 articles to evaluate the importance of educational robotics (ER) in STEM education from primary to high school students. Specifically, it explored the skills developed in young students through ER and investigated the impact of the intervention. Findings suggested that ER helped with understanding STEM concepts and contributed to acquiring scientific and technical skills. The articles highlighted ER as a tool that promoted understanding in mathematics, computer science, and programming and highlighted the positive effects of ER in STEM education.

Similarly in kindergarten, Rapti and Sapounidis (2024) conducted a scoping review including 59 articles published from 2012 to 2023. The article examined the potential positive impact of ER on kindergarteners' 4Cs (Critical Thinking, Communication, Collaboration, and Creativity). Findings revealed that critical thinking is the most frequently tested skill, creativity is the least explored, and cognitive skills are enhanced. Finally, the types of robots commonly used are BeeBot, Lego, and social humanoid robots.

Furthermore, Author et al. (2022a) conducted a systematic review and meta-analysis examining ER in primary education. The analysis involved 57 studies with 10.913 participants and revealed that most studies are not experimental and have limited duration, and more interventions in language classes are needed. Also, the meta-analysis showed that ER has a positive effect on students' knowledge acquisition and skill development.

However, educational robots are probably not effective in all circumstances, since their effectiveness probably depends on parameters such as different age groups and learning objectives (Pashevich, 2022). According to Pashevich (2022), the use of educational robots in the educational process probably has disadvantages in terms of their technical functionality which limits their interaction with students. Among the disadvantages of social robots' technical functionality are the limited communication skills in terms of unclear voice and the inability to answer verbal questions (Pashevich, 2022; Pei & Nie, 2018a,b). Additionally, the perception of the social robot as inhuman, and clumsy, with limited communication skills and impersonal behavior could evoke negative emotions and distract them. According to Reich-Stiebert and Eyssel (2015), an intervention was conducted regarding the introduction of robotics in different educational fields (e.g. STEM, arts, social sciences). The results of this intervention showed that older people were not willing to participate in an educational process with robots. Also, younger participants (around 25 years old) expressed that they felt embarrassed and uncomfortable being under the supervision of social robots. Regarding the use of programmable educational robots, it is argued that more time is needed to integrate them into lessons and to familiarize students with them which is an inhibiting factor for their use in teaching (Elgarf et al., 2021a,b).

In conclusion, ER is a recently emerging and rapidly growing field in which effectiveness, weaknesses and challenges have not been fully explored. Therefore, more research should be carried out on ER focusing on their possible combination with other tools or teaching practices and examining their effect with different parameter conditions.

1.4. Studies combining ST and ER in education

There are studies in the literature that focus on the combined use of ST and ER in education. Some interventions have been conducted in the context of drama activities. Specifically, an intervention conducted by Bravo, Hurtado, and González (2021a), involving 8 students aged 11–13 years old concluded that using ER in a storytelling and drama activity might provide students with a multi-sensory experience. The authors also concluded that students could become more active in the learning process, increase their attention and motivation, interact in a positive classroom environment, and increase student interest and participation in learning. Other interventions focus on combining ST and ER in STEM courses. Tengler and Sabitzer (2022) using Ozobots conducted an intervention involving 40 third-grade and fourth-grade students on the effect of storytelling and educational robotics on computational thinking. Authors reported that teachers expressed enthusiasm for Ozobots in combination with ST and students could enhance basic computer science problem-solving skills and comprehension.

ST and ER were also used in language teaching. Specifically, Caceffo et al. (2022) using mBots conducted an intervention with 26 preschool students (4–5 years old). The mBot was used to tell the story of Red Riding Hood. The results showed that the use of robots in storytelling may encourage cooperation and social interaction. In a similar study conducted by Chen Hsieh (2021), 59 students aged 5–7 years old participated in a storytelling intervention with robots in a collaborative word-learning activity. The results of the intervention showed that new vocabulary words can be introduced, and storytelling skills (e.g. the structure and coherence of the story) can be reinforced. In the same context, Liang and Hwang (2023) conducted an intervention with 2 groups of high school students consisting of 40 participants to learn English as a second foreign language. The findings indicated that the ST-robot could reduce students' hesitation in communicating, improve their ability to speak English, and develop narrative ability and narrative engagement. Also, they claim that students could be taught language through engaging stories during an enjoyable learning experience that combines ST and ER.

Based on the above, it is obvious that on the one hand, there is a limited number of systematic reviews and meta-analyses that focus on either ST or ER. Still, on the other hand, there is no systematic review and record of interventions that combine ER and ST. Consequently, a scoping review is designed to facilitate the mapping and better understanding of the ST and ER's impact on students.

1.5. Scope and aims of the current study

A scoping review is a type of literature review that aims to map existing literature on a particular topic, providing an overview of the available evidence by analyzing both quantitative and qualitative studies (Arksey & O'Malley, 2005) and to identify research gaps. Unlike systematic reviews, which focus on specific research questions and use a rigorous methodology to synthesize and analyze the available evidence, scoping reviews are more exploratory (Tricco et al., 2016). Several studies have explored the utilization of ST or ER in education. Yet, fewer have investigated the combination of ST and ER in learning activities. Even more, no systematic or scoping review has been designed to map the related research field. Thus, this current paper presents a scoping review to explore the field related to ST and ER combination in education by providing a deeper insight into special traits of the interventions conducted (educational level, participants' number, school subject, evaluation tools, type of robot, duration of interventions, skills, and attitudes).

2. Methodology

This research focuses on conducting a scoping review according to Peters et al. (2015a,b) guidance. It attempts to map the field of ST and ER combination in various educational settings and clarify the conditions of the implemented interventions. In detail, we aim to explore a. the educational levels at which ST and ER were utilized, b. the curriculum subjects at which ST and ER interventions were applied, c. the type of research, the number of participants and the duration of the ST and ER interventions, d. the type of robots used and evaluation tools, e. the skills that students are likely to develop by using ST and ER in the educational process. Hence, this current study could be used to guide future studies in this research area. To address the above, the research questions are structured as follows.

RQ.1. On which educational levels do ST and ER interventions mostly focus?

RQ.2. In which subjects of the school curriculum are ST and ER interventions commonly used?

RQ.3. What are the special traits of the implemented interventions regarding the type of research, the number of participants, and the duration?

RQ.4. What kind of evaluation tools and robots are used the most in ST and ER interventions?

RQ.5. Which skills and attitudes can ST and ER develop while being combined in the educational process?

RQ.6. What is the children's role in the storytelling interventions?

2.1. Search strategy

For the needs of the scoping review, a search for articles had to be carried out. The search focuses on the combination of ST and ER in education in pre-school to university students and the attitudes/skills that are likely to be developed. Five (5) digital libraries - databases were selected due to their credibility in the domains of education and technology to find relevant articles. The databases included ERIC (Electronic Registration Information Center), IEEE (Institute of Electrical and Electronics Engineers), ScienceDirect, Scopus and SpringerLink. In the next phase, the keywords "storytelling" and "robotics" were used and 5272 papers were initially extracted.

2.2. Study selection: inclusion and exclusion criteria

Articles were selected according to PCC (Population, Concept, Context) criteria proposed by Peters et al. (2015a,b) according to the JBI framework for scoping review (Aromataris & Riitano, 2014). Thus, our criteria should meet the PCC as follows:

Population: The articles include interventions with participants aged 4–22 years, covering educational levels from early education to university. There is no restriction on gender or previous experience with ER and ST. The ages of the participants in the interventions were distinguished according to their educational levels. More specifically, students aged 4–5 years old are classified in the early education category, students aged 6–12 years old are classified in the primary school category, students aged 13–18 years old are classified in the secondary education category, students aged 19–22 years old are classified in the university category.

Concept: The concept of interest in this current scoping review is the combination of ST and ER for students of all educational levels. All studies relevant to this concept, written in English, available in full text, and published in peer-reviewed journals or conferences from 2004 to May 31, 2024 are included.

Context: This scoping review aims to scope how the ST and ER combination is implemented in all educational levels to affect students' learning, skills, and attitudes. It considers all the research articles (quantitative and qualitative) examining the effectiveness of ST and ER in educational settings. Therefore, studies that focused on combining ST and ER out of the framework of the school curriculum were excluded.

In detail, a total of 5272 articles were found by the search from the 5 databases using the keywords "storytelling" and "robotics". Of these, 3527 articles were excluded for several reasons: 1. They were in a different language than English (291 articles), 2. The articles weren't published either in journals or in conference proceedings (e.g. editorials, position papers, book/book chapters) (3216 articles), 3. Articles that were duplicated in different bases (20 articles). For the remaining articles (N = 1745) we both examined the abstract and full content of the article. In this full-text screening stage, we narrowed our search, setting new exclusion criteria for the final articles selection: 1. They did not include an intervention (329 articles), 2. They did not combine storytelling and robotics (719 articles), 3. Articles that involved special populations (e.g. disabilities, autism, visual impairments) (54 articles), 4. The examined fields were out of the school curriculum (464 articles), 5. The age of the participants exceeded the university level (74 articles), 6. The participants' age was not clarified (23 articles). Finally, the remaining 82 articles were included in the review that examined the following parameters: the educational level of the participants, the curriculum subjects in which ST and ER are applied, the type of data analysis of the intervention, the type of research (quantitative/qualitative), the number of participants, the duration of the intervention, the assessment tools, the type of robot used and the skills students possibly developed with ST and ER.

3. Results

3.1. Educational levels

Based on this distinction, of the 82 articles, 18 articles concern early education, 33 articles concern primary education, 13 articles concern secondary education, 5 articles concern university students and 13 articles concern mixed ages. ER and ST's combination is a more widespread teaching practice in primary education than at other educational levels. Immediately afterward, more interventions were carried out in preschool than in secondary or academic education (See Fig. 1) (see Fig. 2).

3.2. Subjects of the school curriculum

A key research question of the scoping review is the curriculum courses in which ST and ER have been preferred as teaching approaches. The research data reveals 36 articles focusing on Language, 32 on STEM, 7 on free play (in the framework of preschool education), 4 in the framework of projects (focusing on nutrition, health, environmental education and design-creativity) and 1 on Arts. Finally, 2 articles focused on STEM and language together.

3.3. Type of research of implemented interventions

Regarding the research method the researchers chose for their interventions, both qualitative and quantitative data analysis was used. Research data show that 50% of the articles (41 articles) used qualitative and quantitative analysis together. The remaining 28% of articles (23 articles) used qualitative analysis and only 22% (18 articles) of articles used quantitative analysis (See Fig. 3).

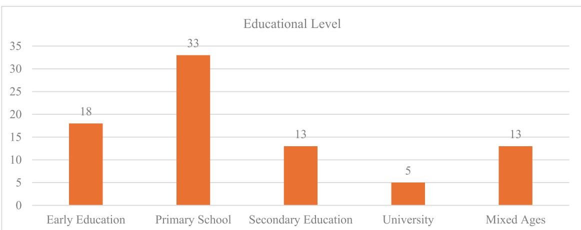


Fig. 1. Educational levels ST and ER focus on.

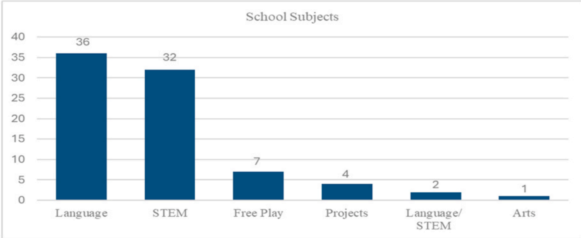


Fig. 2. Subjects of the school curriculum ST and ER used in.

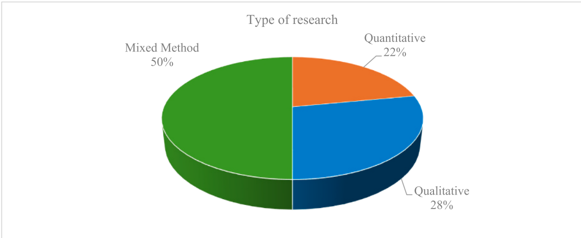


Fig. 3. Type of research of implemented interventions.

3.4. Number of participants in interventions

Related to the number of participants in the examined interventions, the data show that: a. 1–20 students were examined in 25 interventions, b. 21–40 took part in 17 interventions, c. 41–60 participants were investigated in 16 interventions, d. 61–80 participated in 4 interventions, e. 81-100 in 4 interventions, f. 101+ participants are found in 10 interventions. Finally, the number of participants is not mentioned in 6 of 82 interventions (See Fig. 4).

3.5. Duration of interventions

The duration of the interventions was divided into segments of 6 h. The results showed that some interventions lasted only a few minutes while others more than 24 h. In detail, 35 (43%) of the 82 interventions lasted 0–6 h, 9 (11%) interventions lasted 6–12 h, 7 (8%) interventions lasted 12–18 h, 3 (4%) interventions lasted 18–24 h, and 3 (4%) interventions lasted more than 24 h. In 25 (30%) of the 82 articles, the duration of the interventions is not recorded (See Fig. 5).

3.6. Type of educational robots used in interventions

Another parameter considered in the scoping review is the type of robots used in the interventions. The research confirms that the main categories of educational robots commonly used in educational interventions are low cost programmable and humanoid robots. Specifically, 34% (28 articles) utilize programmable robots, 44% (36 articles) of interventions utilize humanoid robots, and 22% (18 articles) of interventions do not mention the type of robots they use (See Fig. 6). In addition to this, researchers used various low-cost programmable robots such as Lego (5 articles), Ozobot (6 articles) and Mbot (2 articles) (See Fig. 7). Related to the humanoid robots used, Nao (15 articles), Pepper (4 articles) and Tega Robot (4 articles) were the most frequently selected (See Fig. 8).

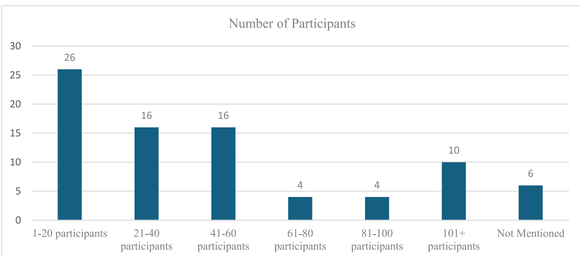


Fig. 4. Number of participants. Classification of participants in the interventions by 20 participants.

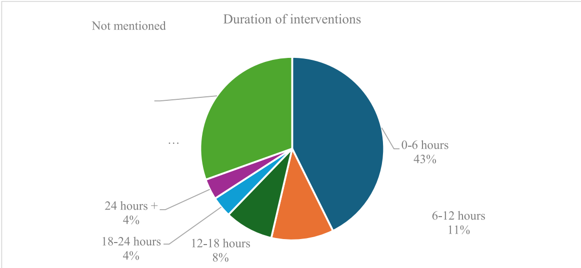


Fig. 5. Duration of interventions.

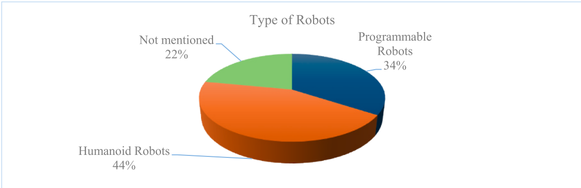


Fig. 6. Types of robots that used in interventions.

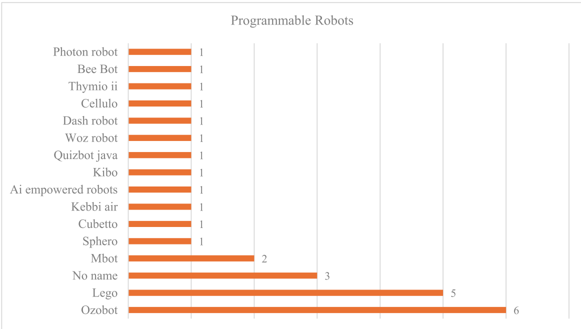


Fig. 7. Types of low-cost programmable robots that used in interventions.

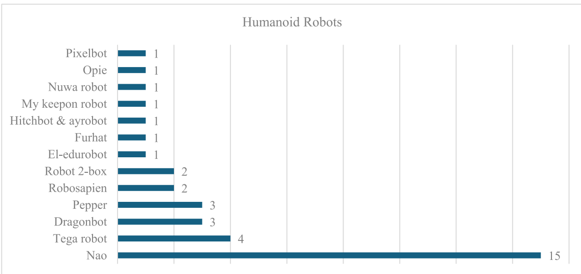


Fig. 8. Types of humanoid robots that used in interventions.

3.7. Students' skills and attitudes developed with ST and ER

Based on the findings, ST and ER used to enhance learning and engagement in 54% of the articles (44 papers). Furthermore, 17 % of the researchers utilized ST and ER to enhance collaboration and communication skills (14 papers). Additionally, 9% of them attempted to foster students' motivation in the educational process (7 papers). Moreover, 7% of researchers investigated the impact of ST and ER on students' participation (6 papers) and 2% of them on their creativity (2 papers) (See Fig. 9). Finally, 11 % of researchers used ST and ER to activate simultaneously several skills (collaboration/communication, creativity) and attitudes (engagement, participation) (9 papers).

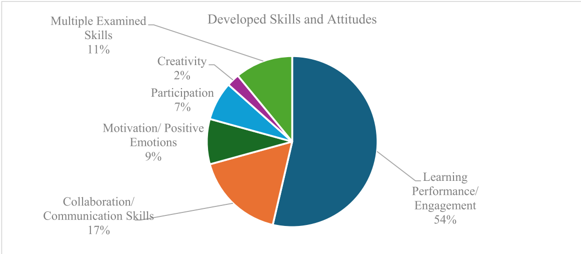


Fig. 9. Developed skills via ST and ER.

3.8. *Children's role during the ST and ER interventions*

Regarding the children's role in the ER activities combined with ST, we classified participants' role in three categories: 1. Active, 2. Passive 3. Not mentioned. Regarding the students who actively (category 1) participated in the intervention, it was found that: a. The students took on the role of programmer, so they programmed the robot to follow the planned routes, b. The students assumed the role of scriptwriter, so they created the plot of the narration, c. The debater, so students had a dialogue with robots, d. Students participated in the intervention with a double role, combining both programming and story creation. Additionally, in some interventions the students had a passive role (category 2), listening to a story from the robot without interacting with it nor participating in the creation of the story. Eventually, only one article does not mention the role of students (category 3) in the context of an intervention combining ST and ER (See Fig. 10).

In detail, most of the reviewed studies revealed that students were actively involved as programmers in the educational process that utilized the combination of ST and ER. Specifically, in some studies, students were assigned to actively contribute to the design of the robot regarding its digital appearance, characteristics, and how it should behave (e.g. (Maure & Bruno, 2023)). In addition to designing the robot, the children were tasked with guiding their robot through obstacles in order to understand the concepts of spatio-temporal skills (e.g. (Angel-Fernandez & Vincze, 2018a,b; Hu et al., 2022a,b, pp. 496–500; Matthews et al., 2022; Obaid et al., 2018; Pelizzari et al., 2023; Veltman, 2012)). Moreover, many of the students were introduced to programming, as they were asked to program the robots to perform the actions dictated by the narrator, and thus, they were introduced to various technological tools such as Classcraft, Scratch, and HTML5. The broaden results of these studies revealed that students were creative because they applied principles of computational thinking, developed solutions through programming, made design decisions, solved problems and worked together to achieve the goal (e.g. (Frank et al., n.d.; Baltazar Reyes et al., 2022; Bers et al., 2019a,b; Coxon et al., 2018a,b; Ottenbreit-Leftwich et al., 2021; Tengler et al., 2021a,b,c; Tzou et al., 2019; Yang et al., 2023)). Students also were engaged in hands-on activities, electromechanical integration, programming, 3D modeling, and robotic engineering (e.g. (Fowler et al., 2022; Shang et al., 2023)).

Furthermore, children were supported in creating stories (scriptwriter). Specifically, they were involved in story creation tasks, in which they established the structure, shaped the content, created the protagonists and story dialogue (e.g. (Kory-Westlund & Breazeal, 2019b; Rubegni et al., 2022)). Additionally, children participated in tasks such as defining the plot of the story and discussing the roles and emotions of the characters (e.g. (Fridin, 2014; Ligthart et al., 2020; Smyrnaiou et al., 2020)). Regarding the drama activities combining ER and ST, children were responsible for creating the story script and adapting the robotic actors to it (Bravo et al., 2021b).

As for the interventions in which children interacted with the robot as debater through dialogue and play, the participants took part in personalized conversations with the robots while answering questions arising about various topics (e.g. (Balzotti et al., 2023; Konijn & Hoorn, 2020; Tozadore et al., 2018)). Participants communicated verbally by asking questions, making comments and reacting to the robot's behavior in tasks of graded difficulty (e.g (Gambarato & Dabagian, 2016; Heath et al., 2017; Ihamäki & Heljakka, 2019; Ioannou et al., 2015; Keren et al., 2012; Kory-Westlund & Breazeal, 2019b)). In addition, children interacted actively with the robots in the activities both as tutors and peer learners. Specifically, they asked and answered questions during playful vocabulary activities (e.g. (Chen et al., 2020b)), recycling tasks (e.g. (Castellano et al., 2021)) and even human rights discussions (e.g. (Leoste et al., 2021)). In the context of second language learning, robot told a story, which the students had to repeat in order to practice the second language they were learning (e.g. (Lu et al., 2007)).

In some interventions, students were involved both as scriptwriters and programmers. Particularly, the students were tasked with shaping the robot, programming the movements and paths it would follow based on the story and the protagonists they created (e.g.

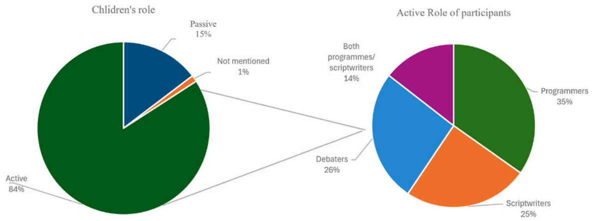


Fig. 10. Children's role during the intervention via ST and ER.

(Soleimani et al., 2019; Stork, 2020; Tengler et al., 2022; Tengler & Sabitzer, 2022; Chen Hsieh & Lee, 2023a)).

However, there were interventions in which the students did not play an active role as writers in creating the stories or programmers in programming the robot, nor did they participate as debaters in a dialogue with the robot. Particularly, students were passive listeners to the robot's narration. In these interventions, after listening to the robot narration, students evaluated the personality traits and narration style of the robots (e.g. (Shibasaki et al., 2020; Sung et al., 2013; Velentza et al., 2021a; Zinina et al., 2020)). Furthermore, in some cases children were asked to listen carefully to different stories narrated by the robot and then recall details (e.g. (Chang et al., 2023; Conti et al., 2020; Shen & Lin, 2018)). Moreover, while aiming to teach a second language (French), students were encouraged just to pay attention to the robot's gestures to learn specific vocabulary (e.g. (Alimardani et al., 2021)).

3.9. *Assessment tools used in the studied papers*

The tools were explored related to the domains in which they are commonly used. Hence, we categorized them into three groups: "Skill Tools", "Attitudes Tools", and "General Purpose Tools". Additionally, we examined their validity and we let them at researchers' disposal to choose effortlessly the most appropriate tool among several for their work (see Table 2).

1. The category "Skill Tools" includes all tools that researchers have used to investigate the skills that students are likely to develop through ST and ER. The skills that are commonly evaluated are cognitive skills, soft skills such as communication and collaboration, and Computational thinking. Regarding soft skills and positive behaviors, Bers et al. (2019a,b) designed the PTD tool (Positive Technology Development) which is a multidimensional framework including "the six Cs"-positive behaviors supported by technology—content creation, creativity, communication, collaboration, community building, and choices of conduct. This tool can also be used as a framework for the design and implementation of educational programs considering the learning environment, pedagogical practices, and cultural values. Regarding cognitive skills, CogAT7 (Cognitive Abilities Test Screening Form 7) is a tool developed by Warne (2015) for K-12 students assessing their reasoning attitudes. It is composed of 9 subtests and can provide scoring procedures, standard age scores, percentile ranks, stanines, and normal curve equivalents (Coxon et al., 2018b; Warne, 2015). Additionally, BCTt (Block Based Computational Thinking test) is a tool for young learners designed by Zapata-Caceres et al. (2020) that assesses Computational Thinking using items ordered with increasing difficulty. Furthermore, TACTOPI is a playful environment to promote Computational Thinking at children from 4 to 8 years old and created by Abreu et al. (2020). The impact of the TACTOPI system was measured with Reflective Thematic Analysis (RTA) which is based on coding the data to reveal patterns that influence the interpretive process (Table 3A).
2. Regarding "Attitudes' tools", these are instruments used to measure the potential effects of ST and ER on students' attitudes. In this category, some tools measure attitudes like engagement, participation, motivation and empathy. Particularly, PANAS-C (Positive and Negative Affect Scale for Children) developed by Laurent et al. (1999) is a 27-item measurement of positive and negative attitudes, such as being interested, excited, sad, and gloomy. This tool differentiates anxiety from children's depression (Hughes & Kendall, 2009; Laurent et al., 1999). In addition to this, the mYPAS tool designed by Kain et al. (1995) measures young children's anxiety. This is a tool composed of 21 specific behaviors indicating anxiety within 5 domains (use of adults, activity, emotional expressivity, state of arousal, vocalization). Furthermore, we detected Schema Questionnaire which is a 160-item questionnaire with a 5-point scale for each item. This is a tool developed by Schmidt et al. (1995) and is highly associated with physiological distress ranging from 0 to 4. This specific tool allows the identification of a variety of 16 primary EMSs (Early Maladaptive Schemas). Moreover, the Measuring Narrative Engagement tool created by Busselle and Bilandzic (2009) distinguishes the different aspects of engagement through a 12-item scale divided into 3-item subscales. This tool is based on a mental model approach to narrative processing. It encompasses 4 dimensions of narrative engagement: narrative understanding, emotional focus, emotional engagement, and narrative presence. Another tool, that focuses on measuring engagement is EEG-based engagement level designed by Coelli et al. (2015) examining the relationship between mental engagement and sustained attention. In the reviewed articles, we also found that Smileyometer which is a part of a fun toolkit developed by Read and MacFarlane (2006) and Zaman et al. (2020). Smileyometer is a tool supporting the idea of score engagement according to the face or smiley scales which is based on a 5-point Likert scale ranging from "awful" to "brilliant". Finally, Em Que-CA (Empathy Questionnaire for Children and Adolescents) tool created by Overgraauw et al. (2017) measures empathy using the scales of affective empathy, cognitive empathy, and intention to comfort. Specifically, it is a 14-item tool based on a 3-factor structure for children aged 10 and older (Table 3B).
3. Finally, in the "General Purpose tolls" there are tools for the analysis of facial expressions, text analysis, analysis of qualitative data and video. The "General Purpose Tools" group contains the following tools: The AFFDEX SDK is a software development kit

Table 3a
Tools per skill.

Skill Tools	Tool used	Domain	Validation
Creativity, Communication, Collaboration	PTD Tool (Positive Technology Development), (Strawhacker & Bers, 2018)	Language/STEM courses	–
Cognitive Abilities	Cogat7 (Cognitive Abilities Test Screening Form 7), (Coxon et al., 2018b; Warne, 2015)	Language/STEM courses	✓
Computational Thinking	Bbct (Block Based Computational Thinking Test), (Zapata-Caceres et al., 2020)	STEM	✓
	TACTOPI Instrument, (Abreu et al., 2020; Pires et al., 2023a,b)		–

Table 3b
Tools per attitude.

Attitudes Tools	Tool used	Domain	Validation
Anxiety	PANAS-C (Positive And Negative Affect Scale For Children), (Hughes & Kendall, 2009; Laurent et al., 1999)	Psychology	✓
	Mypas (Measurement Tool For Preoperative Anxiety In Young Children, The Yale Preoperative Anxiety Scale), (Kain et al., 1995)	Psychology	✓
Engagement	Measuring Narrative Engagement By Busselle And Bilandzic, (Busselle & Bilandzic, 2009)	Narration	✓
	Eeg-Based Engagement Level, (Coelli et al., 2015)	E-Learning	✓
	Smileyometer, (Read & MacFarlane, 2006; Zaman et al., 2013)	Language courses/ Coding	✓
Empathy	Em Que-CA (Empathy Questionnaire For Children And Adolescents), (Overgaauw et al., 2017)	Language courses	✓
Distress	Schema Questionnaire, (Schmidt et al., 1995)	Psychology	✓

designed by McDuff et al. (2016) that recognizes in real-time facial expression allowing easy integration of its software into multiple platforms. Through this tool, a range of frames related to facial expressions can be processed within 4 components: facial detection, face texture-feature extraction, facial action classification, and emotion expression modeling. Additionally, the LIWC tool (Linguistic Inquiry and Word Count) created by Tausczik and Pennebaker (2010) is a transparent text analysis program counting words in more than 80 psychologically meaningful categories. This tool examines attention, emotionality, social relationships, thinking styles, and individual differences. Moreover, Atlas. ti Software has been used as an assessment tool in the reviewed articles. This software tool is developed by Hwang (2008) and analyze qualitative data through texts, video and other digital formats. Furthermore, Tanprasert and Kauchak (2021) developed Flesch-Kincaid Grade Level, a posthoc metric measuring behavior. Finally, Coh-Metrix is a computer tool designed by Graesser et al. (2004) that analyses texts and offers over 200 measures related with language levels (Table 3C).

4. Discussion

ST and ER are conceptual and practical frameworks that their combination has arisen recently and have been developed since then. In this scoping review, we examined 82 out of 5272 articles published in 5 Databases in the last 20 years. In detail, we covered publications from 2004 to May 31, 2024. These articles were examined in terms of the student's skills and attitudes that the combination of ST and ER tried to reinforce and the curriculum subjects in which they are applied. Moreover, we explored the interventions in terms of the educational level, and the number of participants, the duration of the interventions, the type of data analysis, and the evaluation tools, robots used and the role of participants during the interventions.

Regarding RQ. 1, ST and ER were applied mostly are preschool and primary school. This may be attributed to the fact that children can begin their interaction with technological media from the early years of life, so they can become familiar with modern digital tools at an early age. Furthermore, free play and storytelling are usually ways of teaching preschool students. Preschool children are familiar with storytelling and perceive involvement with technology and robots as a playful activity (Hubbard et al., 2021). This playfulness encourages the hypothesis that ST and ER might have a positive impact on preschoolers regarding their learning, skills development and attitudes promotion (Conti et al., 2017). Therefore, it is concluded that the combination of ST and ER might be an appropriate teaching method particularly for younger students. Related to primary school, robots have been used in learning activities combined with ST to enhance the students' concentration, participation, and cooperation (Park, 2015). Concerning secondary schools, ST and ER's combination seems to be limited. Some researchers usually argue that ST and ER probably contribute to students' learning and engagement (Kory-Westlund and Breazeal, 2019a; Chul, 2010; Yue et al., 2019). While others, seem to have contrary opinions. For example, in a study conducted by Angel-Fernandez and Vincze (2018a) secondary school students find it difficult to cooperate while interacting with storytelling robots because they might consider it childish. However, other researchers argues that secondary school students have already secured the basic knowledge at earlier school levels, so at secondary level they can develop more complex skills such as computational thinking through storytelling robots (Brandhofer & Tengler, 2022; Szecsei, 2019). Based on the above, we need more effort to convince teachers to design appropriate activities for this particular age and simultaneously encourage secondary school students to participate. As for tertiary education, this scoping revealed that not enough studies have been conducted applying the

Table 3c
General purpose tools.

General Purpose	Tool Used	Domain	Validation
Facial Expression Recognition	Affdex Sdk (Software Development Kit), (McDuff et al., 2016)	Marketing, Gaming, E-Learning, Healthcare	–
Attention Focus, Emotionality, Social Relationships, Thinking Styles	Liwc Tool (Linguistic Inquiry And Word Count), (Tausczik & Pennebaker, 2010)	Language courses	–
Analyzing Texts, Video and other Digital Formats	Atlas. Ti Software, (Hwang, 2008)	Marketing, Healthcare, Education	✓
Posthoc Analysis of Behavior	Flesch-Kincaid Grade Level, (Tanprasert & Kauchak, 2021)	Language courses	✓
Language Level	Coh-Metrix, (Graesser et al., 2004)	Language courses	✓

combination of ST and ER at this educational level. According to Velentza, Fachantidis, and Pliasa (2021b), undergraduate students seem to enjoy their interactions with storytelling robots. Additionally, according to Granlund et al. (2018), ST and ER may facilitate the learning of a second language among university students. Furthermore, the results of robotic storytelling demonstrate that it can enhance the computational thinking skills of university-level students and promote their understanding of technology (Hu et al., 2022a,b, pp. 496–500). However, the data from the scoping review reveal that only 5 of the interventions target higher education students. Therefore, the possible benefits of ST and ER lack robustness and cannot be justified, so far, by the conducted studies. Hence, this condition requires that more ST and ER interventions involving older students are needed to obtain an overall picture and understanding of their impact on education.

Related to RQ. 2, this scoping review led to the conclusion that the field in which ST and ER combination is most prevalent is Language. Analyzing the context of Language, interventions focused mostly on foreign language learning, probably because narrative robots seem to contribute to vocabulary enhancement (Chen et al., 2020a) and reduce the effects of negative emotions caused by students' stress when trying to learn foreign languages (Costa et al., 2018; Pampaliari et al., 2023; Wu et al., 2008). Focusing on the results of studies on language, it appears that the use of ST and ER in Language learning can be an effective way compared to standard technological tools such as PowerPoint (Chen Hsieh & Lee, 2023b). Nevertheless, current research explores only a few areas of language, such as narrative skills. Moreover, no research was found that focuses on learning grammar, syntax, or vocabulary, which are important elements of language. Therefore, we conclude that the studies take a one-sided approach to the subject of language. In addition, almost half of the research was applied in the STEM framework, probably because robots are a prerequisite for STEM courses (Pei & Nie, 2018a). Anwar et al. (2019) claim that learning with robots introduces programming logic, so it was expected that storytelling robots would be chosen as a means of teaching STEM courses. Furthermore, the research did not reveal the application of the ST and ER combination in subjects such as geography, biology and history. Therefore, a gap is spotted in various domains of the use of ST and ER leading to the need to conduct interventions in them.

As for RQ.3, researchers led to conclusions about ST and ER interventions' potential contribution using mixed (qualitative and quantitative) research methods. To further explore the studies' findings, a meta-analysis could be performed leading to new findings further clarifying the effects of ST and ER on the educational process. Regarding the number of participants in interventions, this scoping depicts that most researchers used small sample sizes (1–20 participants). Only 4 studies of the 82 used 61–80 participants and 4 studies included 81–100 participants. Furthermore, related to the duration of interventions this scoping demonstrates that 43% of them lasted a few minutes to 6 h and 4% of interventions lasted more than a day. According to Elgarf et al. (2021a,b), the duration of an intervention is usually short because children need time to become familiar with the robot and the activity, thus reducing the intervention time. Despite the time the children acquire to become familiar with the robots, more long-term interventions need to be conducted in the future to clarify the effects of the ST and ER combination on education because the duration of interventions may affect the results (Sapounidis et al., 2022b). Finally, it was revealed that 30% of studies did not mention the duration, such a finding sets questions about the robustness of the studies' results.

In terms of RQ.4, it seems that it is very common to use humanoid robots in learning activities in various educational settings (formal, informal education, and special populations) as technological tools related to ST. The research data highlight that the most common humanoid-social robots used are NAO robots. This is probably due to the robot's ability to interact with students because they can participate in dialogues, express emotions through movements and gestures and are used as teaching assistants, especially in language learning (De Carolis et al., 2021; Budiharto et al., 2017; Serholt et al., 2020; Velentza et al., 2022). However, programmable robots are used too in combination with ST in education. The most common programmable robots used are Ozobots and LEGO robots. Since Ozobots are small robots that can be programmed with color codes, they are considered suitable for students in lower educational levels because of their simplicity of use (Pei & Nie, 2018b). This is probably the reason why many researchers prefer Ozobots in interventions with preschool or primary school children. In addition, the scoping indicated that many interventions used LEGO robots in STEM courses. This finding is probably explained by the fact that both Ozobots and LEGO robots are probably preferable for ST and ER interventions because are cheaper than humanoid and probably are already available at many schools worldwide (Souza et al., 2018). However, a gap in the criteria for selecting robots for each intervention (e.g. cost, measurement skill, educational level, etc.) arises. Therefore, it seems necessary to set selection criteria for the suitability of the robot according to the characteristics of the intervention. This will provide answers and guidelines for future research so that a rigorous selection of the right robot will be made.

In addition, several tools were explored in the extracted papers in this review. Thus, we explored them, grouped them, and let them at the researchers' disposal to facilitate future work. Looking at the scope of the tools, we have found that although most of the tools are validated, there aren't any focused exclusively on ST and ER. Only the Measuring Narrative Engagement tool developed by Busselle and Bilandzic (2009) was identified as being utilized to measure engagement in narrative in domains like marketing and psychology. Hence, the need for a validated tool that assesses the impact of the combination of ST and ER in assessing students' skills and attitudes like participation, motivation, and creativity is highlighted.

Regarding RQ.5, ST and ER may contribute to the development and enhancement of multiple skills (communication, creativity) and attitudes (participation, motivation). This scoping review demonstrates that most interventions (54% of articles) examined ST and robots' contribution to learning and engagement. Additionally, other interventions examined student collaboration and communication skills (17% of articles) while implementing ST and ER together in the learning process. These interventions concluded that students are more cooperative with each other, actively participate and enhance their communication skills during ST and ER activities. Also, according to Xu et al. (2015) collaboration and communication seem to be affected due to the ability of the storytelling robot to make gestures and express emotions. Thus, the mood of the participants is affected and the interaction with both the storytelling robot and peers is enhanced.

Regarding attitudes, motivation is addressed in only 9% of the interventions and participation is examined in only 7% of them.

Although many researchers claim that the ST and ER combination enhances students' motivation, there are no empirical data to justify the claim. This shortage might be enhanced by the limited evaluation tools that this scoping review detected. Finally, the scoping review reveals a low proportion (11%) of articles that discuss the enhancement of all skills and attitudes simultaneously. Hence, we suggest developing evaluation tools suitable for measuring together learning outcomes, skills, and attitudes in the framework of ST and ER to provide a holistic picture of their development.

Regarding the evaluation tools used in the reviewed papers, most researchers used qualitative tools to conclude. That may be attributed to the shortage of quantitative tools regarding skills and attitudes that are frequently examined. In addition to this, researchers used several different tools to measure the effects of ST and ER combination in educational settings. That may be, due to the lack of clear registration of tools related to ST in the framework of ER. Additionally, although social skills such as communication and collaboration are often evaluated, there are no tools focused on them. Moreover, no tools are measuring exclusively the cognitive outcomes related to the use of ST together with robotics.

Regarding RQ.6 and the children's role in the ER activities integrating ST, the students had an active (became programmers, scriptwriters, debaters and both programmers/scriptwriters) or passive role. Specifically, most studies (84%) revealed that students were active in the educational process by creating scenarios, programming the robot, and interacting with it. In detail, it was found that 29% of the interventions show that students had a role as programmers, 21% of the interventions show that students had a role as scriptwriters and 12% of the interventions show that students participated in the intervention as a combination of programmers and writers. In addition, the interaction between the children and the robots took place mainly through question-and-answer sessions in which the students played the role of debaters, which emerged in 22% of the interventions. Eventually, the review showed that in only 15% of the interventions, students were passive during the ST and ER educational process, and only one of the studies (1%) did not clarify the role of the students during the intervention.

By tracing the role of the students in the script creation process, it was found that they were creating the stories, but students were not examined in terms of the language and narrative skills they may have developed. Still, it emerges that in interventions where students act as scriptwriters, the potential development of creativity is not considered. It was also found that they were creating stories that were told only by robots. It is not clarified whether they had a role in narrating the stories with the robot. Furthermore, it was found that there is no precise model or "good practice" guide as to the roles that children assume during the intervention process. Particularly, the order in which pupils are asked to perform a task and the step-by-step sequence for the successful intervention outcome is unclear.

Based on the above, regarding the combination of ST and ER in education and its potential effects on students it is suggested: a. examining the potential positive impact of ST and ER on secondary and tertiary education, b. conducting interventions in courses where ST and ER have not been implemented, c. conducting interventions in language lessons focusing on the understanding of grammar and syntax rules, d. designing research with large sample sizes and long-lasting interventions to lead to safe conclusions related to ST and ER contribution to students' learning and holistic development, e. carrying out more quantitative studies to provide more data on the parameters and effects of the combination, f. clarifying the criteria for selecting robots according to the context of each intervention, g. the development of a model that will clarify step-by-step the methodology regarding the roles that children take on during the educational process with ST and ER.

5. Conclusion

Finally, considering the gap identified in the literature regarding a comprehensive overview of the ST and ER combination in educational settings, this article attempted to highlight the characteristics, parameters, potential effects, and gaps in the related field. Specifically, the review reveals gaps in the use of ST and ER when applied in secondary and university education because not enough interventions have been extracted at these educational levels to determine the effects of the combination on older students. In addition, the scoping review highlights the lack of long-term interventions that examine large sample sizes to evaluate the effects of ST and ER on teaching and learning. Still, the interventions reviewed did not specify the criteria for the robots they selected, thus identifying a gap in existing research. At the same time, there are several papers focused on language subjects but without clarifying the examined aspect of it, for instance, lexical skills, grammar, and syntax learning. Still, the research identifies a gap in terms of examining knowledge and engagement separately because interventions consider them in combination. The research also shows that the students' potential development of narrative attitudes and skills is not adequately addressed and there is a lack of step-by-step school curriculum for the implementation of the combination. Thus, this review provides useful insights into the combination of ST and ER activities as a contemporary educational tool to facilitate knowledge gain and develop useful skills and attitudes that help students navigate the complex social landscape.

6. Limitations

This scoping review focused on studies emerging from 5 databases, which means that studies relevant to the related research field might have been missed. Still, the target group of the interventions reviewed does not include gifted students, people with disabilities. Moreover, this scoping examined the impact of ST and ER combination on students in the framework of school curriculum only. Yet, scoping reviews are mapping a field and making useful suggestions for future studies and cannot evaluate the effectiveness of the combination. Thus, we recommend conducting a meta-analysis based on the studies' findings.

CRediT authorship contribution statement

Maria Palioura: Writing – original draft, Methodology, Investigation. **Theodosios Sapounidis:** Writing – review & editing, Supervision.

Appendix

Author	Year Publ.	Research Method	Robot System	School Subject	Educational Level	Part. Number	Skills & Attitudes Developed	Children's role
Federica Pelizzaria, Michele Marangib, Pier Cesare Rivoltella, Giulia Perettid, Davide Massaroe, Daniela Villanif	2023	Mixed Method	Programmable Cubetto Robot	Stem	Early Education	51	Learning-Engagement	Programmers
Romain Maure, Barbara Bruno	2023	Mixed Method	Humanoid Pixelbot Robot	Stem	Primary School	7	Participation	Programmers
Jia-Cing Liang, Gwo-Jen Hwang	2023	Mixed Method	Humanoid Nuwa Robot	Language (Efl)	Secondary Education	80	Learning-Engagement	Scriptwriters
Ralia Thoma, Nektarios Farassopoulos, Christina Lousta	2023	Mixed Method	Humanoid Tega Robot	Language	Mixed Ages	59	Learning-Engagement	Debaters
Ching-Yi Chang, Gwo-Jen Hwang, Ya-Lien Chou, Zi-Yin Xu, Hsiu-Ju Jen	2023	Mixed Method	Not Mentioned	Other Field (Health)	Primary School	47	Collaboration-Communication Skills	Passive
Xiaojing Shang, Zhujun Jiang, Feng-Kuang Chiang, Yicong Zhang, Dan Zhu	2023	Mixed Method	Programmable Lego Wedo1.0	Stem	Mixed Ages	133	Learning-Engagement	Programmers
Angela Balzotti, Berardina De Carolis, Stefania Massaro, Loredana Perla, Veronica Rossano	2023	Quantitative	Humanoid Pepper Robot	Other Field Nutrition	Primary School	14	All Skills	Debaters
García Vaquero, A.F., Diaz, M.A.	2023	Quantitative	Programmable Ozobot	Language (Efl)	Secondary Education	19	Motivation	Programmers
Sarah Matthews, Kathrin Kaiser, Janet Wiles	2022	Qualitative	Not Mentioned	Language	Mixed Ages	17	Collaboration-Communication Skills	Programmers
Weipeng Yang, Davy Tsz Kit Ng, Jiahong Su	2022	Quantitative	Not Mentioned	Stem	Early Education	108	Learning-Engagement	Programmers
Agnese Augello	2022	Mixed Method	Humanoid Nao Robot	Language	Secondary Education	271	Learning-Engagement	Scriptwriters
Karin Tengler, Barbara Sabitzer	2022	Mixed Method	Programmable Ozobot Robot	Language	Primary School	16	Learning-Engagement	Both Programmers/ Scriptwriters
Yuhan Hu, Isabel Neto, Jin Ryu, Ali Shtarbanov, Hugo Nicolau, Ana Paiva, Guy Hofman	2022	Qualitative	Not Mentioned	Language	Secondary Education	Not Mentioned	Collaboration-Communication Skills	Programmers
Gerhard Brandhofer, Karin Tengler	2022	Qualitative	Humanoid Nao Robot	Language	Primary School	106	Learning-Engagement	Both Programmers/ Scriptwriters
Germán E. Baltazarreyes, Brenda Jiménez, Edgar Omar Lopez, Nancy Mazon, Patricia Tlalpan, Pedro Ponce	2022	Mixed Method	Humanoid Nao Robot	Stem	Secondary Education	Not Mentioned	All Skills	Programmers

(continued on next page)

(*continued*)

Author	Year Publ.	Research Method	Robot System	School Subject	Educational Level	Part. Number	Skills & Attitudes Developed	Children's role
Anette Bentz, Bernhard Standl	2022	Mixed Method	Not Mentioned	Stem	Mixed Ages	34	Learning-Engagement	Scriptwriters
Elizabeth Miller, Shelley Staples	2021	Quantitative	Programmable Kebbi Air Robot	Language (Efl)	Secondary Education	52	Motivation-Positive Emotions	Programmers
Karin Tengler, Oliver Kastner-Hauler, Barbara Sabitzer, Zsolt Lavicza	2021	Quantitative	Programmable Ozobot Robot	Stem	Primary School	45	Learning-Engagement	Both Programmers/ Scriptwriters
Flor A. Bravo, Jairo A. Hurtado, Enrique González	2021	Qualitative	Programmable Robot (No Name)	Stem	Secondary Education	26	Motivation-Positive Emotions	Scriptwriters
Oliver Kastner-Hauler, Barbara Sabitzer	2021	Qualitative	Programmable Ozobot Robot	Stem	Primary School	43	Learning-Engagement	Both Programmers/ Scriptwriters
Ricardo Caceffo, Diego Addan Gonçalves, Rodrigo Bonacin, Julio Cesar Dos Reis, Jos'E A. Valente, Maria Cecília Calani Baranauskas	2021	Mixed Method	Programmable Mbot Robot	Language	Early Education	26	Collaboration-Communication Skills	Programmers
Elisa Rubegni, Monica Landoni, Laura Malinverni, Letizia Jaccheri	2021	Mixed Method	Not Mentioned	Stem	Secondary Education	45	Collaboration-Communication Skills	Scriptwriters
Anne T. Ottenbreit-Leftwich, Kyungbin Kwon, Thomas A. Brush, Michael Karlin, Minji Jeon, Katie Jantaraweragul, Meize Guo, Hamid Nadir, Fatih Gok, Parama Bhattacharya	2021	Mixed Method	Not Mentioned	Stem	Primary School	263	Learning-Engagement	Programmers
Karin Tengler, Oliver Kastner-Hauler, Barbara Sabitzer	2021	Qualitative	Programmable Ozobot Robot	Stem	Primary School	16	Learning-Engagement	Programmers
Maha Elgarf, Gabriel Skantze, Christopher Peters	2021	Quantitative	Humanoid Furhat Robot	Language	Primary School	32	Creativity	Scriptwriters
Dimitris Ziouzios, Dimitrios Rammos, Tharrenos Bratitsis, Minas Dasygenis	2021	Qualitative	Humanoid Robot Ei-Edurobot	Other Field (Climate Change)	Primary School	50	Participation	Passive
Anna-Maria Velentza, Nikolaos Fachantidis, Sofia Pliasa	2021	Mixed Method	Humanoid Nao Robot	Arts	University	225	Collaboration-Communication Skills	Passive
Chaolan Lin, Selma Sabanovic, Lynn Dombrowski, Andrew D. Miller, Erin Brady, Karl F. Macdorman	2021	Qualitative	Not Mentioned	Language	Early Education	Not Mentioned	Motivation-Positive Emotions	Passive
Maryam Alimardani, Stephanie Van Den Braak, Anne-Lise Jouen, Reiko	2021	Quantitative	Humanoid Nao Robot	Language	Early Education	41	Learning-Engagement	Passive

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Author	Year Publ.	Research Method	Robot System	School Subject	Educational Level	Part. Number	Skills & Attitudes Developed	Children's role
Matsunaka, Kazuo Hiraki								
Karin Tengler, Oliver Kastner-Hauler, Barbara Sabitzer	2021	Mixed Method	Programmable Beebot Robot	Language	Primary School	16	All Skills	Both Programmers/ Scriptwriters
Berardina De Carolis, Francesca D′ Errico, Veronica Rossano	2021	Quantitative	Humanoid Pepper Robot	Stem	Primary School	34	Learning-Engagement	Passive
Giovanna Castellano, Berardina De Carolis, Francesca D'errico, Nicola Macchiarulo, Veronica Rossano	2021	Quantitative	Humanoid Pepper Robot	Playing	Primary School	51	Learning-Engagement	Debaters
Elly A. Konijn, Brechtje Jansen, Victoria Mondaca Bustos, Veerle L. N. F. Hobbelink, Daniel Preciado Vanegas	2021	Quantitative	Programmable Woz Robot	Language	Primary School	63	Learning-Engagement	Scriptwriters
Samuel Fowler, Chelsea Cutting, Johnpaul Kennedy, Simon N. Leonard, Florence Gabriel, Wayne Jaeschke	2021	Quantitative	Programmable Mbot Robot	Stem	Early Education	107	Learning-Engagement	Programmers
Janika Leoste, Luis Pastor, José San Martín López, Carlos Garre, Paul Seitlinger, Pilar Martino, Elena Peribáñez	2021	Qualitative	Programmable Ozobot Robot	Playing	Primary School	4	Collaboration-Communication Skills	Debaters
Nataša Grgurina, Sabiha Yeni	2021	Mixed Method	Not Mentioned	Stem/ Language	Mixed Ages	151	Learning-Engagement	Programmers
Gayathri Manikutty Amrita Vishwa Vidyapeetham	2021	Qualitative	Not Mentioned	Stem	Secondary Education	46	All Skills	Both Programmers/ Scriptwriters
Mike E.U. Ligthart, Mark A. Neerincx, Koen V. Hindriks	2020	Mixed Method	Humanoid Nao Robot	Language	Primary School	27	Collaboration-Communication Skills	Scriptwriters
Elly A. Konijn, Johan F. Hoorn	2020	Quantitative	Humanoid Nao Robot	Stem/ Language	Primary School	86	Learning-Engagement	Debaters
Huili Chen, Hae Won Park, Cynthia Breazeal	2020	Mixed Method	Programmable Photon Robot	Stem	Primary School	76	Learning-Engagement	Debaters
Daniela Conti, Carla Cirasa, Santo Di Nuovo, Alessandro Di Nuovo	2020	Qualitative	Humanoid Nao Robot	Language	Early Education	81	Learning-Engagement	Passive
Mina Shibasaki, Youichi Kamiyama, Elaine Czech, Koichi Obata, Yusuke Wakamoto, Keisuke Kishi, Takayuki Hasegawa, Shinkuro Tsuchiya, Soichiro Matsuda,	2020	Mixed Method	Not Mentioned	Language	Early Education	31	Learning-Engagement	Passive

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Author	Year Publ.	Research Method	Robot System	School Subject	Educational Level	Part. Number	Skills & Attitudes Developed	Children's role
Kouta Minamizawa								
Zacharoula Smyrnaiou, Eleni Georgakopoulou, Sofoklis Sotiriou	2020	Qualitative	Not Mentioned	Stem	Mixed Ages	12	Learning-Engagement	Scriptwriters
Michele Garabedian Stork	2020	Qualitative	Programmable Sphero Robot	Stem	Secondary Education	16	All Skills	Both Programmers/ Scriptwriters
Carrie Tzou, Meixi, Enrique Suárez, Philip Bell, Don Labonte, Elizabeth Starks, Megan Bang	2019	Qualitative	Not Mentioned	Stem	Primary School	2	Learning-Engagement	Programmers
Marina U. Bersa, Carina González-Gonzálezb, Belén Armas–Torres	2019	Mixed Method	Programmable Kibo Robot	Stem	Early Education	172	Learning-Engagement	Programmers
Arash Soleimani, Danielle Herro, Keith Evan Green	2019	Mixed Method	Not Mentioned	Language	Mixed Ages	11	All Skills	Both Programmers/ Scriptwriters
Anna Zininaa, Liudmila Zaidelmana, Nikita Arinkina, Artemiy Kotova	2019	Mixed Method	Not Mentioned	Language	University	29	Learning-Engagement	Passive
Jacqueline M. Kory-Westlund, Cynthia Breazeal	2019	Mixed Method	Humanoid Dragon Robot	Language	Early Education	17	Learning-Engagement	Debaters
Jacqueline M. Kory-Westlund, Cynthia Breazeal	2019	Quantitative	Humanoid Tega Robot	Language	Mixed Ages	95	All Skills	Scriptwriters
Pirita Ihamäki, Katriina Heljakka	2019	Qualitative	Programmable Dash Robot	Playing	Early Education	20	Creativity	Debaters
Jauwairia Nasir, Utku Norman, Wafa Johal, Jennifer K. Olsen, Sina Shahmoradi, Pierre Dillenbourg	2019	Mixed Method	Programmable Cellulo Swarm Robots	Stem	Primary School	25	Learning-Engagement	Programmers
Steve V. Coxon, Rebecca L. Dohrman, Dustin R. Nadler	2018	Mixed Method	Programmable Lego Wedo 2.0	Stem	Primary School	65	Learning-Engagement	Programmers
Farhad Mehdipour, Mohsen Pashna, Aniket Mahanti	2018	Quantitative	Programmable Ai Empowered Robot	Stem	Primary School	Not Mentioned	Learning-Engagement	Programmers
Julian M. Angel-Fernandez, Markus Vincze	2018	Mixed Method	Programmable Thymio Ii Robot	Stem	Mixed Ages	196	Collaboration-Communication Skills	Debaters
Daniel C. Tozadore, Joao P H Valentini, Victor H. S. Rodrigues, Fernando M. L. Vendrameto, Rodrigo G. Zavarizz, Roseli A. F. Romero	2018	Mixed Method	Humanoid Nao Robot	Language	University	10	Participation	Both Programmers/ Scriptwriters
Fernando Garcia-Sanjuan, Sandra Jurdi, Javier Jaen, Vicente Nacher	2018	Mixed Method	Programmable Robot (No Name)	Playing	Primary School	8	Collaboration-Communication Skills	Debaters
Steve V. Coxon, Rebecca L. Dohrman, Dustin R. Nadler	2018	Qualitative	Programmablelego Wedo 2.0	Stem	Primary School	45	Learning-Engagement	Programmers

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Author	Year Publ.	Research Method	Robot System	School Subject	Educational Level	Part. Number	Skills & Attitudes Developed	Children's role
Ting-Ting Wu, Yueh-Min Huang, Rustam Shadiev, Lin Lin, Andreja Istenič Starčič	2018	Quantitative	Humanoid Nao Robot	Language	Primary School	52	Learning-Engagement	Passive
Lúcia Abreu, Ana Cristina Pires, Tiago Guerreiro	2018	Qualitative	Not Mentioned	Stem	Mixed Ages	20	Learning-Engagement	Both Programmers/ Scriptwriters
Daniel C. Tozadore, Joao P H Valentini, Victor H. S. Rodrigues, Fernando M. L. Vendrameto, Rodrigo G. Zavarizz, Roseli A. F. Romero	2018	Mixed Method	Humanoid Nao Robot	Language	University	10	Collaboration-Communication Skills	Debaters
Hae Won Park, Mirko Gelsomini, Jin Joo Lee, Tonghui Zhu, Cynthia Breazeal	2017	Mixed Method	Humanoid Robot Tega Robot	Language	Mixed Ages	54	Learning-Engagement	Scriptwriters
Allison Master, Sapna Cheryan, Adriana Moscatelli, Andrew N. Meltzoff	2017	Quantitative	Not Mentioned	Stem	Primary School	96	Motivation-Positive Emotions	Programmers
Jacqueline M. Kory Westlund, Sooyeon Jeong, Hae W. Park, Samuel Ronfard, Aradhana Adhikari, Paul L. Harris, David Desteno, Cynthia L. Breazeal	2017	Mixed Method	Humanoid Tega Robot	Language	Early Education	45	Learning-Engagement	Debaters
Scott Heath, Gautier Durantin, Marie Boden, Kristyn Hensby, Jonathon Taufatofua, Ola Olsson, Jason Weigel, Paul Pounds, Janet Wiles	2017	Quantitative	Humanoid Robot Opie	Language	Early Education	10	Learning-Engagement	Debaters
Mohammad Obaid, Gökçe Elif Baykal, Asım Evren Yantaç, Wolmet Barendregt	2017	Mixed Method	Humanoid Robo2box Robot	Stem	Mixed Ages	31	Participation	Programmers
Daniel C. Tozadore, Adam H. M. Pinto, Caetano M. Ranieri, Murillo R. Batista, Roseli A. F. Romero	2017	Mixed Method	Humanoid Robot Nao Robots	Language	Primary School	22	Learning-Engagement	Debaters
Renira Rampazzo Gambarato, Lilit Dabagian	2016	Qualitative	Humanoid Hitchbot-Ayrobot Robots	Stem	Secondary Education	44	All Skills	Debaters
Mohammad Obaid, Asım Evren Yantaç, Wolmet Barendregt, Güncel Kırlangıç, Tilbe Göksun	2016	Mixed Method	Humanoid Robot2box Robot	Other Field (Design Their Preferred Classroom Robots)	Mixed Ages	31	Participation	Both Programmers/ Scriptwriters

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Author	Year Publ.	Research Method	Robot System	School Subject	Educational Level	Part. Number	Skills & Attitudes Developed	Children's role
Iolanda Leite, Marissa Mccoyy, Monika Lohaniy, Daniel Ullman, Nicole Salomons, Charlene Stokesyz, Susan Riversy, Brian Scassellati	2015	Mixed Method	Humanoid Keepon Robot	Language	Primary School	40	Collaboration-Communication Skills	Scriptwriters
Jungho Park	2015	Qualitative	Not Mentioned	Language	Primary School	Not Mentioned	Collaboration-Communication Skills	Scriptwriters
Jacqueline Kory Westlund, Cynthia Breazeal	2015	Qualitative	Humanoid Dragon Robot	Language	Early Education	17	Learning-Engagement	Scriptwriters
Andri Ioannou, Emily Andreou, Maria Christofi	2015	Mixed Method	Humanoid Nao Robot	Playing	Early Education	4	Learning-Engagement	Debaters
Jacqueline Kory, Cynthia Breazeal	2014	Qualitative	Humanoid Dragon Robot	Language	Early Education	20	Learning-Engagement	Scriptwriters
Michele Scandola, Paolo Fiorini	2013	Mixed Method	Not Mentioned	Stem	University	20	Learning-Engagement	Not Mentioned
Marina Fridin	2013	Mixed Method	Humanoid Nao Robot	Free Play	Early Education	10	Motivation-Positive Emotions	Scriptwriters
Ji-Hun Sung, Young-Hoon Sung, Wae-Shik Moon	2013	Qualitative	Programmablelego Mindstorms Nxt	Stem	Primary School	Not Mentioned	Learning-Engagement	Passive
Melanie Veltman, Valerie Davidson, Bethany Deyell	2012	Mixed Method	Programmablelego Mindstorms Nxt	Stem	Secondary Education	36	Collaboration-Communication Skills	Programmers
G. Keren, A. Ben-David, M. Fridin	2012	Mixed Method	Humanoid Robot Nao Robot Linux	Free Play	Early Education	9	Learning-Engagement	Debaters
Masanori Sugimoto	2011	Mixed Method	Humanoid Robot (Gentoro System)	Language	Secondary Education	24	All Skills	Debaters
Ying-Tsuan Lu, Chih-Wei Chang, Gwo-Dong Chen	2007	Qualitative	Humanoid Robot Robosapien V2	Language (Efl)	Primary School	34	Motivation-Positive Emotions	Debaters
Chao-Fen Shih, Chih-Wei Chang, Gwo-Dong Chen	2007	Quantitative	Humanoid Robot Robosapien	Language	Primary School	20	Participation	Debaters

Data availability

Data will be made available on request.

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