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Review

The Participation of Students with Autism in Educational Robotics: A Scoping Review

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Abstract: Educational robotics (ER) is a growing interdisciplinary field that is attracting increasing attention in inclusive or special education settings. It provides a suitable educational environment for the participation of students with autism, through which they can utilize their main strengths and interests. Strengths-based vs. deficits-based approaches recognize the strengths and interests of autistic children as the starting point for their inclusion in school and the community. The scoping review was developed as the best knowledge-synthesis method for summarizing the pertinent research on the participation of students with autism in educational robotics for their successful inclusion. Forty-five studies were included and analyzed to address the main objectives, the mapping of contextual dimensions, and the specific characteristics of the educational robotic activities where the participation of students with autism occurred. The data were extracted into a charting framework, and a narrative analysis was adopted for the knowledge synthesis. According to the results, the research on the participation of children with autism is limited and has focused primarily on educational robotic activities, failing to adequately explore other dimensions that affect the successful participation and inclusion of students with autism in educational robotics.

Keywords: educational robotics; autism; inclusion; strengths-based approach; participation; intervention; training; attitudes; accessibility

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1. Introduction

Educational robotics (ER) is an interdisciplinary field of study that has attracted the interest of researchers from different fields. In a pedagogical context, ER introduces students to coding by constructing and programming educational robots (ERs), which thus evolves their learning into interactive, multidisciplinary, and collaborative experiences. ERs are tangible resources that interface with simple electronic systems to be constructed and programmed by students (Benitti 2012; García-Tudela and Marín-Marín 2023; Pivetti et al. 2020). Papert has argued that coding through ER in the early years of learning enhances student interest in computer programming, thus encouraging students to reflect on their own thinking (Papert 1993).

Research findings have highlighted the positive influence of ER in computational thinking (García-Tudela and Marín-Marín 2023; Govender and Govender 2023; Montuori et al. 2023; Pellas and Tzafilkou 2023) mathematical, geometry, and science concepts (Baccaglini-Frank et al. 2020), machine learning (Karalekas et al. 2023), STEM (Kalaitzidou and Pachidis 2023), and mechatronic concepts (Habib et al. 2021). Several research findings have demonstrated that ER learning experiences positively affect the development of social and cognitive skills (Caci 2004), creativity, critical thinking, problem-solving (Gubenko et al. 2021), and collaborative behavior, thus encouraging engagement, autonomy, and initiative-taking (Demetroulis et al. 2023; Gubenko et al. 2021).

Because of their positive outcomes in psychological and deductive dimensions, ER activities engage students from preschool through to graduate level in formal or non-formal learning environments of school classes, as well as in after-school activities, volunteer groups, robotics course units, or activities in specific educational settings (Antonelli et al. 2023; Chatzara et al. 2014; Gubenko et al. 2021; Jung and Won 2018; Montuori et al. 2023; Piedade et al. 2020; Zúñiga Muñoz et al. 2023).

ER has proven valuable for motivating and encouraging learning in not only regular but also special or inclusive education. In the creation of successful inclusive educational environments for autistic students, strengths-based vs. deficit-oriented approaches are increasingly being adopted (White et al. 2023). According to strengths-based approaches, students with autism are included on the basis of their positive characteristics and strengths. Although there are notable individual differences in the autistic spectrum, there are common characteristics that people with autism share. Some of these broadly recognized characteristics are strong attention to detail, deep focus on specific interests, and strong abilities in specific domains (Baron-Cohen 2004). The main learning-style characteristics are a preference for visual over verbal communication and more effective functioning in a predictable and structured learning environment with clear expectations and visual instructions, learning through repetition, and enjoying the use of computers and new technological developments in learning and entertainment (David Moore and Thorpe 2000; Hume and Reynolds 2010).

By taking advantage of their strengths and interests, ER creates a suitable environment for students with autism (especially those that have a special interest in using new technologies) in terms of bringing out their potential, recognizing their abilities, and building their self-esteem, as well as becoming accepted by their peers. Evidence-based research highlights the potential of programming ERs not only for individuals with high-functioning autism but also for mid-functioning individuals who need substantial support (Lahav et al. 2019; Nanou et al. 2022; Tsiomi and Nanou 2020).

Although the strong motivation of individuals with autism to use new technologies is broadly recognized, little is known concerning their participation in educational robotics (Chatzara et al. 2014; Galvez Trigo et al. 2019; Prummer et al. 2022). More attention has been received regarding the research on social robot interventions (Papakostas et al. 2021; Prummer et al. 2022). The cyber-physical systems that have given rise to social assistive robots (SAR) have been integrated into everyday life and are applied in education and autism rehabilitation (Chung 2021; Papakostas et al. 2021). SARs have taken on the role of presenters, teaching assistants, peers, or tutors, and they provide several benefits in social skills development—especially when SARs are carefully selected (Alhaddad et al. 2023; Costa et al. 2010; Dautenhahn and Werry 2004; Golestan et al. 2017; Kaburlasos et al. 2018; Moorthy and Pugazhenthi 2017; Papakostas et al. 2018, 2021; Pennisi et al. 2016; Yun et al. 2014). Literature reviews have synthesized the previous knowledge of SAR or ER interventions with regard to different types of disabilities. More specifically, previous literature reviews have been conducted on the following domains: (a) robot-based interventions for autism with the utilization of both SAR and ERs (Damianidou et al. 2020; Saleh et al. 2021), (b) robot-based interventions that encompass both SARs or ERs intended for a wide range of disabilities, including motor, sensory, and intellectual disabilities (Miguel Cruz et al. 2017), or (c) ER activities in several, but not exclusively, autistic and neurodevelopmental disabilities (Nanou and Karampatzakis 2022; Pivetti et al. 2020).

While ER offers an authentic environment conducive to the inclusion of students with autism, there is a lack of clearly defined knowledge regarding the qualified and quantified characteristics of their engagement in ER. This knowledge gap extends to both formal and non-formal educational settings, and there is also limited understanding of the factors influencing their participation. Participation is the best predictor for learning progress in individuals with autism (Froehlich et al. 2012; Iovannone et al. 2003). According to the family of participation-related constructs model, participation is affected by complex transactions between individual characteristics, as well as by contextual settings or the environment of the activities where the participation occurs. As such, apart from intrinsic individual characteristics, participation depends on cultural and social constructions such as tools, methodologies, and skills, which the individual activates. For participation to become satisfactory in terms of quality and quantity, individual characteristics interact with cultural and social constructions (Imms et al. 2017).

Our research aims to collect and synthesize the existing knowledge on the individual and contextual dimensions that affect the participation of students with autism in ER.

2. Materials and Methods

A scoping review was chosen as the most suitable methodology for systematically gathering, comprehending, and summarizing current knowledge regarding the participation of students with autism in ER. This approach aims to provide recommendations, evidence-based practices, and decision-making while identifying research evidence gaps (Kastner et al. 2012; Peters et al. 2020; Xiao and Watson 2019). Scoping reviews effectively map expansive research domains, encompassing all the relative research irrespective of the quality of the publications (Peters et al. 2020).

2.1. Methodology

The literature search for relevant studies was conducted in August 2023 in four electronic databases—IEEE Xplore, Scopus, WoS, and Google Scholar—in all types of publications and without any publication date limitation. The search terms used were the synonyms of autism (“Autism” OR “ASD” OR ”Autism Spectrum Disorders” OR “Developmental Disabilities” OR “ASC” OR “Asperger” OR “disabilities”) AND (“Educational Robots” OR “Educational Robotics” OR “Robots for Education” OR “Toy Robots” OR “LEGO-type robots”) AND (“education” OR “teaching” OR “intervention” OR “school” OR “support” OR training OR attitudes OR “participation” OR “collaboration” OR “involvement” OR “integration” OR “inclusion” OR “inclusive”).

To incorporate relevant studies, three basic eligibility criteria were applied:

1. The study should be written in English;
2. The study should refer to autism;
3. The study should be dedicated to ER experiments, educational activities, evaluated educational methods, attitudes or opinions of stakeholders, educators, therapists, or literature reviews on the participation of students with autism in ER.

The selection process for this scoping review is depicted in Figure 1. Initially, a total of 1720 references (n = 1720) were identified across all electronic databases. Following the elimination of 524 duplicates (n = 524), 1196 (n = 1196) underwent a thorough assessment for eligibility. To ensure the efficacy of the eligibility criteria, a random sample of the included references (n = 200/1196, 16.7%) was screened and evaluated by two reviewers. Cohen’s kappa statistic criterion was computed to gauge the agreement between two raters. With a calculated Cohen’s kappa value of k= 0.77, signifying substantial agreement, the reviewers independently screened the remaining references. Any discrepancies were deliberated with a third rater to determine the inclusion status for each reference.

Following the screening and evaluation of the 1196 references (n = 1196) based on the three eligibility criteria in topic (title, abstract, keywords), 1109 (n = 1109) were excluded as they did not meet the eligibility criteria. Subsequently, the 87 references that received three points from both raters were selected for full-text screening (n = 87). After a thorough examination of the full text, 42 (n = 42) studies were excluded, with 26 (n = 26) not pertaining to ER and 16 (n = 16) not addressing to autism. Ultimately, 45 (n = 45) studies were included for analysis. The flow diagram in Figure 1 succinctly outlines this process.

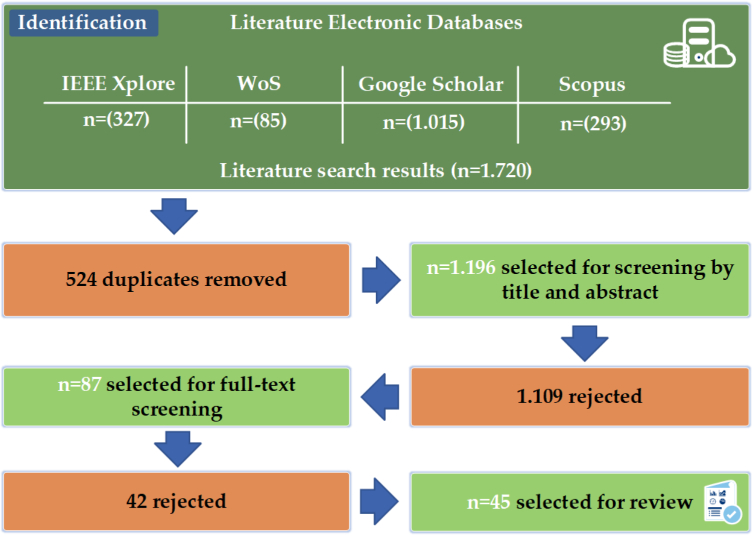


Figure 1. The selection process and each stage of the review.

2.2. Research Objectives and Questions

As presented in Figure 2, the relevant analyzed studies address two main objectives and specific research questions.

Objectives	Research Questions	Methodological Elements
Mapping the contextual dimensions that affect the participation of students with autism in ER	• What is the year and the country of publications? • What Educational Robotic technologies have been investigated? • What dimensions of the participation of students with autism in ER?	• Year of publication • Country of publication • ER technologies • ER participation dimensions
Mapping the nature of the ER activities in relation to the characteristics of students with autism who participate.	• What is the goal of ER activities? • What are the collaboration contexts of ER activities and how are they differentiated in relation to the goal of the activity or intervention? • What technologies have been used in ER activities? • What are the recommended psychoeducational methods that support the participation of students with autism in ER activities?	• Goals • Psychoeducational Methods • Outcomes • Results

Figure 2. The objectives and research questions.

The data have been extracted into a charting framework containing descriptive entries and specific thematic information (Peters et al. 2020). A narrative synthesis of the knowledge approach was adopted to combine evidence and draw conclusions across studies organized into a charting table containing author year, country, participants, context, outcome measures, and outcome areas.

3. Results

3.1. Mapping the Contextual Dimensions That Affect the Participation of Students with Autism in ER and Have Been Investigated by the Included Studies

3.1.1. Year and Country of Publication

The oldest among the 45 (n = 45) included studies dates to 1984, originating from the USA (Kimbler 1984). This scientific essay explored the utilization of robots for students with special needs in the classroom and referred to autism under the term "developmental disorders". Since then, research in this area has progressed at a slow pace. The next studies were published in 2004, two decades later, and from 2016 to 2023, only 11 (n = 11, 24.5%) studies were published. However, there has been a substantial increase in publication rate in the past six years, with 34 (n = 34, 75.5%) of the included studies published from 2016 to 2023, surpassing the cumulative output of the previous 34 years. Nonetheless, the findings underscore the limited extent of research on ER in educational settings for individuals with autism Pennisi et al. (2016), as highlighted in Figure 3.

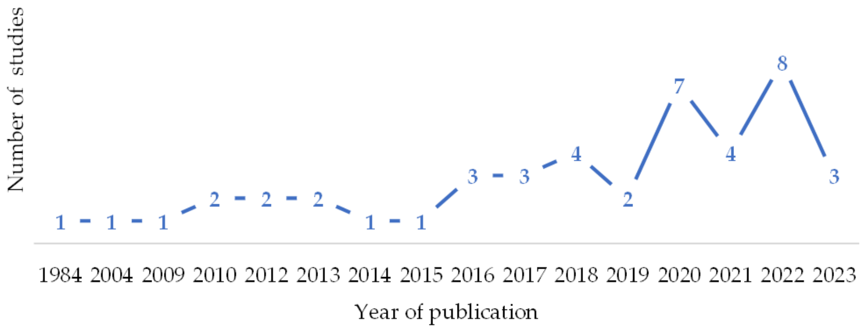


Figure 3. The number of included studies by the year of publication.

Although the first published essay that includes references to ER for developmental disorders was in the USA, most research has been conducted in European countries, especially in Italy in 2004 and Portugal in 2009. These two countries have published most of the included studies on ER for autism (n = 8, 17% and n = 5, 11%, respectively), as highlighted in Figure 4.

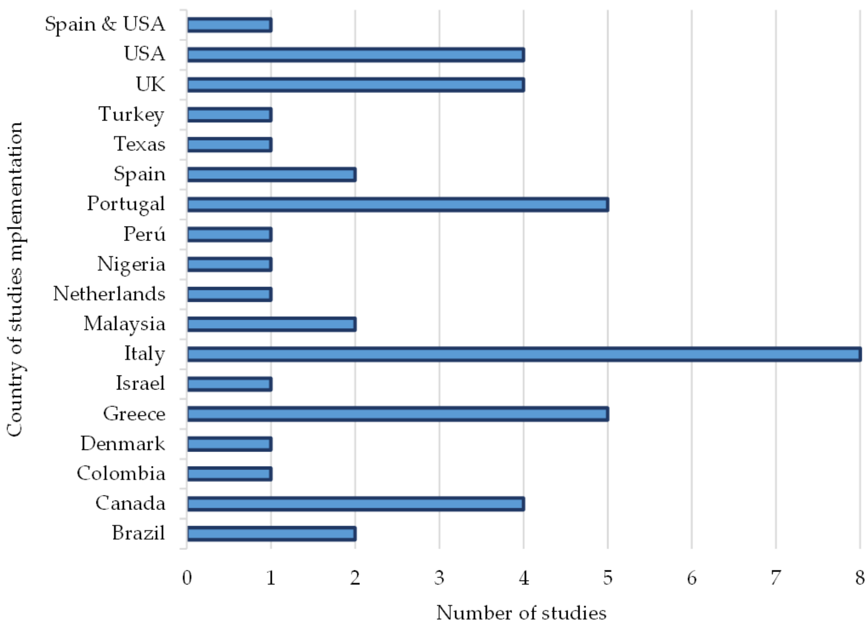


Figure 4. The number of studies per country of publication.

3.1.2. The Investigated Educational Robotic Technologies

Research has delved into 23 different educational robots, each garnering varying degrees of attention in the included studies, as illustrated in Figure 5. Notably, LEGO Mindstorms NXT held the highest frequency (n = 16, 25%), followed by EV3 (n = 10, 16%), Ozobots (n = 3, 5%), NAO (n = 4, 6%), LEGO WeDo (n = 2, 3%), and Bee/Blue-Bot (n = 8, 13%). Additionally, some studies have explored the application of DOC, Thymio, littleBits, and other affordable yet highly sophisticated robots capable of being controlled by children and meeting their needs (Kimbler 1984). The choice of specific ER technologies varies across studies, depending on the distinct research focuses and objectives.

The cost of ER kits and the humanoid robots examined in these research articles varies widely, spanning from a few tens of USD to more expensive solutions offering diverse functions and capabilities. Specifically, in the first cost tier, ranging from USD 50 to USD 200, we found Mio, DOC, Makeblock, LEGO WeDo 2.0, ArcBotics Sparki, Zowi, Ozobots, Wonder Workshop Dash, Sphero, Thymio, and Bee-Bot/Blue-Bot. In the second tier, priced between USD 201 and USD 600, we have ProBot, Tinkerbots, KIBO, littleBits, and EZ-Robot JD. Humanoid robots represent an advanced class, with RQ-HUNO costing USD 1300 and NAO USD 6500. It is noteworthy that the most widely recognized kits—ER kits LEGO Mindstorms WeDo, NXT, and EV3—have been discontinued and replaced by the LEGO Education SPIKE Prime set at an initial cost of USD 480.

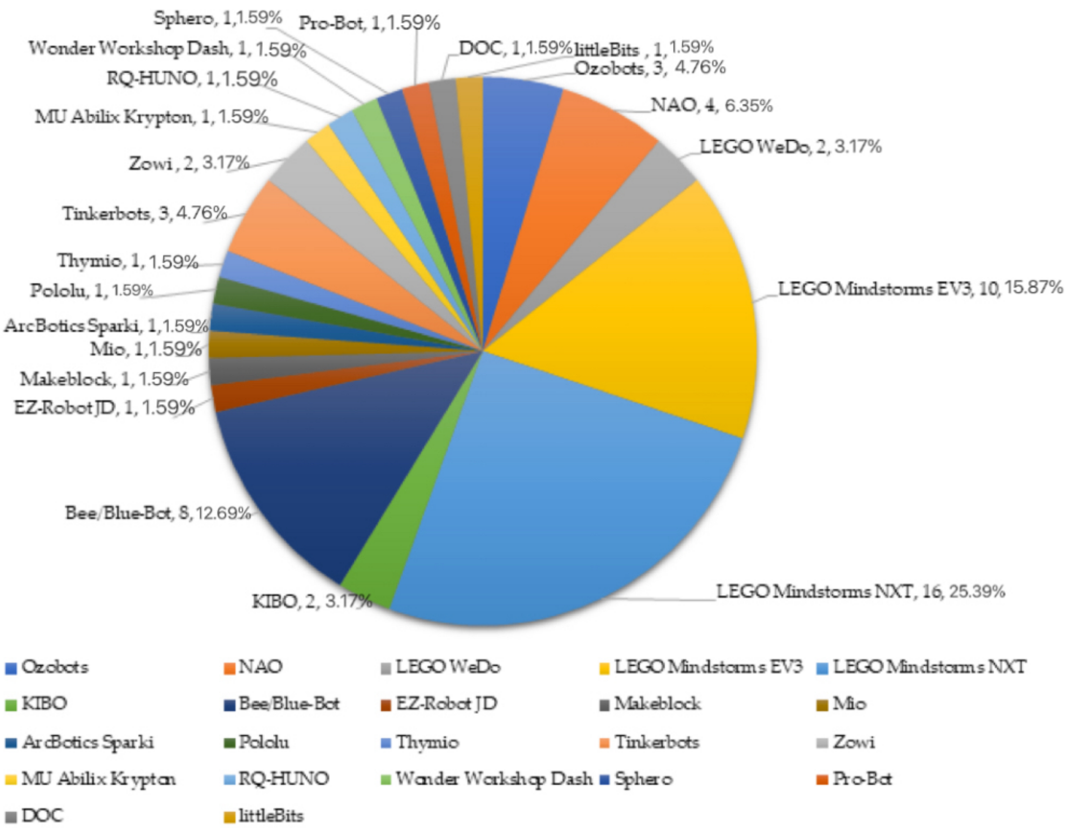


Figure 5. The investigated ER technologies.

3.1.3. The Investigated ER Participation Dimensions

The included studies shed light on four different dimensions of the participation of students with autism in ER: (1) Training methods on ER for autism (n = 7, 15.5%), (2) Attitudes or opinions about ER for autism (n = 5, 11%), (3) ER activities for autism (n = 31, 69%), and (4) Accessibility of ER for autism (n = 2, 4.5%). Most of the included research focuses on ER activities. The other dimensions—training methods, attitudes, and especially the accessibility of ER technologies for students with autism—remain extremely limited. It has been documented that the research on training methodology is in its infancy (Karademir Coşkun 2022; Schina et al. 2021), and the relevant research on attitudes and intentions for ER usage in special education and autism is especially limited (Di Battista et al. 2022). There is a commonly expressed difficulty concerning the accessibility and adaptability of ER for autistic or other disability needs (Di Battista et al. 2022 2020; Karademir Coşkun 2022).

Despite the highly limited research within each category, the spectrum of these categories reflects the multilevel dimensions that influence the participation of students with autism in ER. Notably, in the early part of 2022, the published studies focused on all dimensions—opinions (*n* = 2), training (*n* = 1), accessibility (*n* = 1), and intervention (*n* = 4)—as illustrated in Figure 6. An exploration of several interrelated dimensions is imperative for the successful participation of students with autism in ER. These dimensions encompass the training of teachers and special educators, the accessibility of the interface, and the intentions of teachers to use ER in the context of autism, as highlighted in various studies (Amante et al. 2023; Baccaglini-Frank et al. 2020; Kats 2021; Schina et al. 2021; Silva et al. 2023).

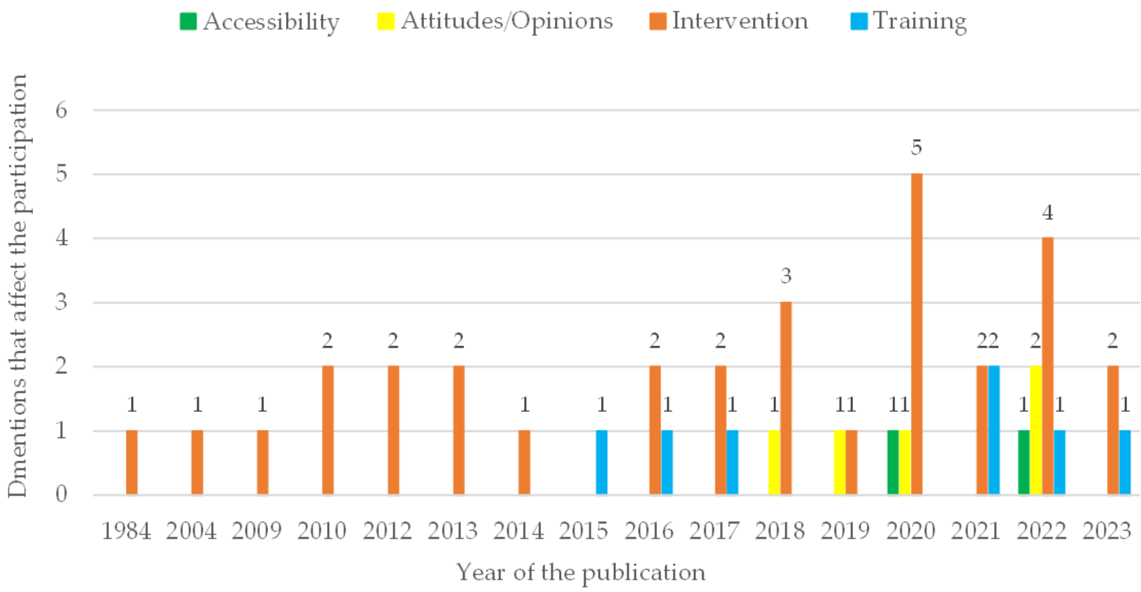


Figure 6. The investigated dimensions that affect participation in relation to the year of publication of the included studies.

3.2. *Mapping the Nature of ER Activities in Relation to the Characteristics of Students with Autism That Participate*

A thematic analysis was employed across the 31 studies (*n* = 31, 69%) to map the nature of the ER activities for autism and the psychoeducational methods that have been suggested and explored in the included studies. The analysis focused on discerning the goal, context, ER, participants involved, and the outcomes of the ER activity or intervention.

3.2.1. The Goal of ER Activities

Most of the included studies leveraged ER to enhance the social skills (42%), cognitive skills (19%), or both (19%) of students with autism. A smaller portion of activities focused on improving social status (*n* = 2, 7%), STEM (*n* = 2, 7%), learning inclusion (*n* = 2, 7%), and coding skills (*n* = 1, 3%), as depicted in Figure 7. In particular, over half of the ER activities (*n* = 61%) were directed towards improving social skills. This aligns with the recognized educational needs of individuals with autism (Papazoglou et al. 2021; Weiss and Harris 2001).

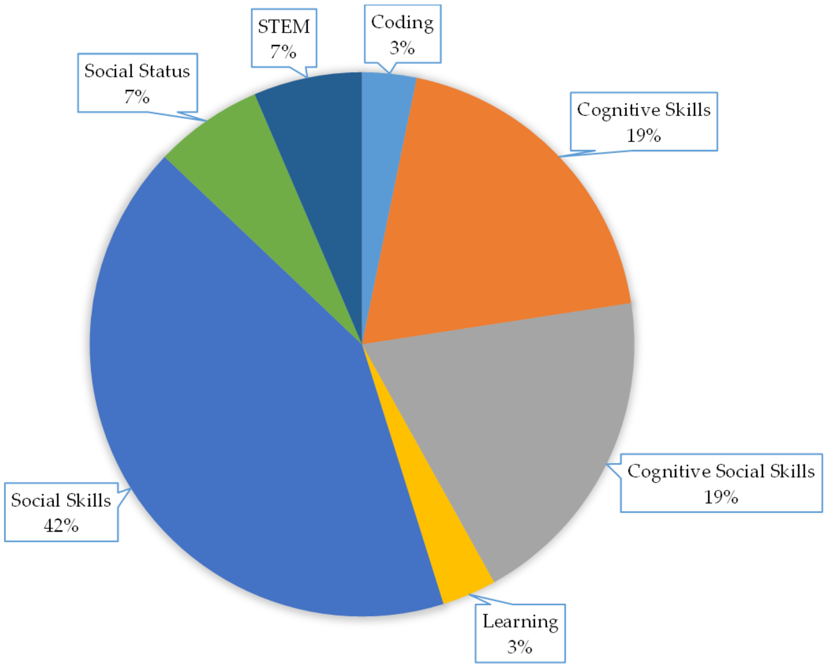
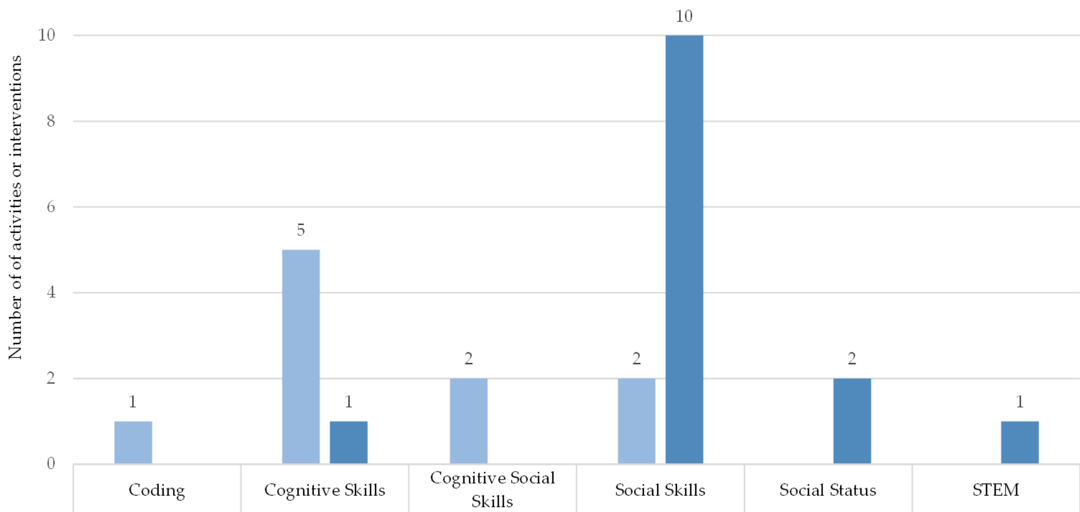


Figure 7. The goal of ER activities in the included studies.

3.2.2. The Collaboration Context in Relation to the Goal of ER Activities

The ER activities implemented in the included studies were executed in two different collaboration contexts: inclusive (IER) and special (SER). Most ER social skills activities were designed and implemented in an inclusive collaboration context (IER) with typical peers (*n* = 10, 32%), followed by a smaller portion (*n* = 2, 6.5%) in a special collaboration context. Similarly, ER social status activities were entirely implemented in an inclusive collaboration context within an inclusive school (*n* = 2, 6.5%), along with STEM ER activities (*n* = 2, 6.5%). By contrast, ER cognitive skills activities were predominantly implemented in special collaboration contexts (*n* = 5, 16%) as were ER coding activities (*n* = 1, 3.25%), as illustrated in Figure 8. Activities aimed at developing cognitive skills or coding were mainly realized in SER contexts.



	Coding	Cognitive Skills	Cognitive Social Skills	Social Skills	Social Status	STEM
SER	1	5	2	2		
IER		1		10	2	1

Figure 8. The goal of ER activities or interventions in relation to the context of the collaboration (IER inclusive vs SER special).

3.2.3. ER Technologies That Have Been Used in ER activities

In the included studies, researchers employed specific ER and interfaces tailored to achieve their intervention goals. Notably, LEGO Mindstorms was chosen to address not only social and cognitive skills but also social status and STEM education objectives. This is consistent with the widespread positive attitudes towards the use of LEGO-type robots, as they are regarded as particularly popular in educational settings (Arís and Orcos 2019; Silva et al. 2012; Souza et al. 2018; Wang 2001). LEGO Mindstorms was often utilized in combination with specific programming software, such as Choregraphe for the NAO robot, GeoGebra with LEGO Mindstorms, and ScratchJr software. In the specific domain of ER intervention for teaching coding to high-functioning autism (HFA) children aged 10.5 years old, kinder bot software was employed. Furthermore, an adaptive ER platform, the AI Jansen mechanism, utilized software as an instructor during assembly. Virtual educational robotic simulators, as exemplified by the Tselegaridis et al. study (Tselegkaridis and Sapounidis 2021), offer students the opportunity to work without hardware restrictions, as illustrated in Figure 9.

LEGO-type robots have been consistently employed in ER activities with the goal of developing social skills and social status in all studies conducted in various countries except for one in Portugal, where the Ozobots robot was utilized. Additionally, LEGO-type robots, accompanied by different software, have been utilized for STEM and coding development in research conducted in Italy and Brazil, respectively. The Bee or ProBot has predominately been used for cognitive skills development in studies in Greece and the UK. Furthermore, the NAO robot has been employed to foster social skills in research conducted in Portugal, as illustrated in Figure 10.

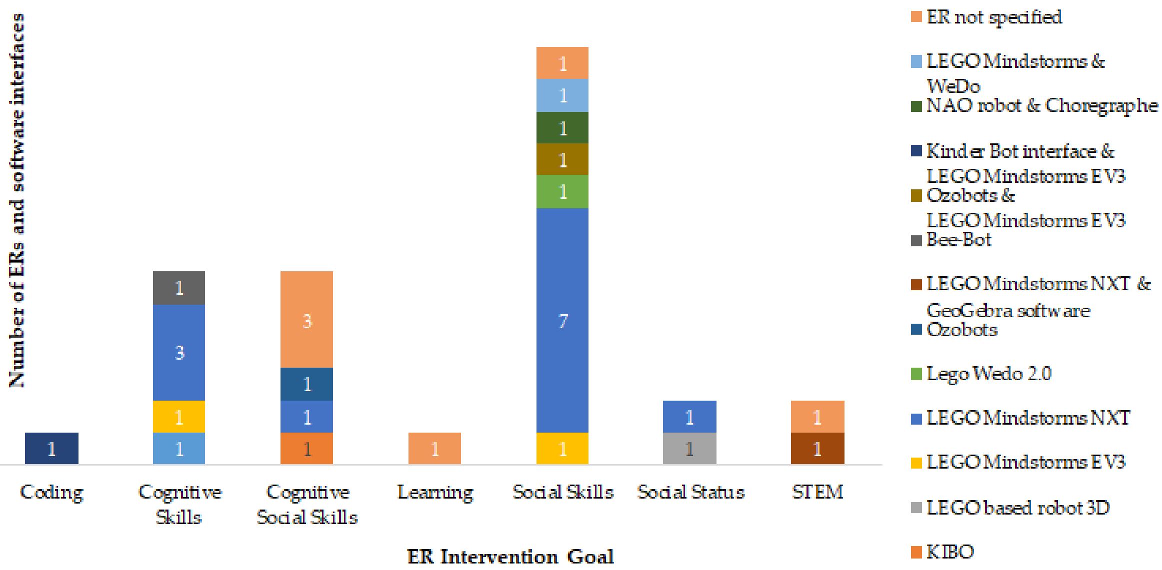


Figure 9. ER and software interfaces used in different ER intervention goals for individuals with autism.

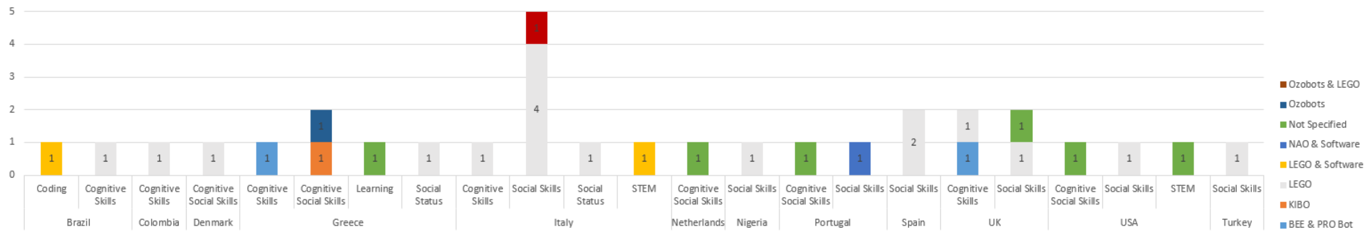


Figure 10. The correlation of ER activities and ER kits in different countries.

3.2.4. The Recommended Psychoeducational Methodologies and Strategies That Support the Participation of Students with Autism in ER Activities

A total of 267 subjects participated in selected ER research activities, including individuals, children, and adolescents. Specific adaptations characterized the nature of these ER activities to encourage participation. In the included studies (*n* = 31), although general strategies for ER were suggested, only 15 (50%) of these strategies were explicitly based on the strengths of autistic students. These strategies included elements such as visualization, clear routines, written rules or pictures outlining expectations of behavior in the classroom, turn-taking techniques, and social stories. The nature of the ER activities incorporating specific autism adaptations was based on the main learning characteristics of the autistic students, as described by the authors in (Barry and Burlew 2004; Hume and Reynolds 2010; Karagiannidis et al. 2014). These specific strategies were primarily applied in activities with the goal of social skills development, and half of them (*n* = 7) applied these strategies specifically for autism participation in an inclusive context, as illustrated in Figure 11.

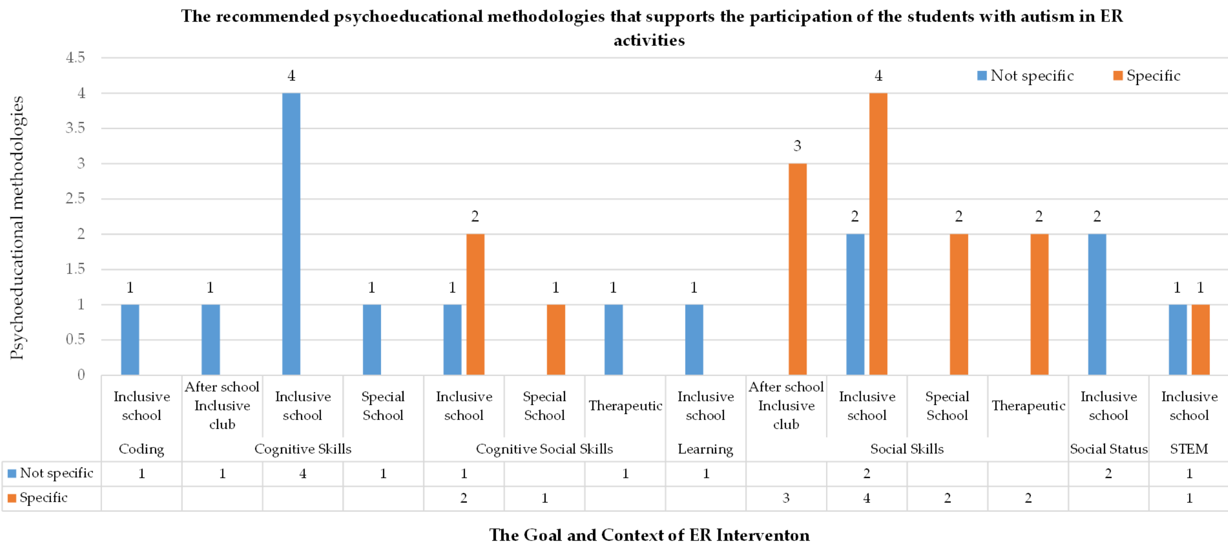


Figure 11. The recommended psychoeducational methodologies that support autism students in ER activities.

Universal design methodologies (Kats 2016 2021), along with other specific psychoeducational methodologies and strategies, are recommended to enhance the participation of individuals with autism in the learning process within a collaborative environment and engage them in programming (Fachantidis et al. 2020; Hansbøl 2015).

Cooperation scenarios (Kollar et al. 2006) recommend structuring the interaction process to facilitate the participation of students with autism in the ER learning environment. This structure is guided by specific collaboration scripts and rules defined to support teamwork (Caci 2004; De Franca Monteiro et al. 2020; Di Lieto et al. 2020; Fachantidis et al. 2020; Nanou et al. 2022; Papazoglou et al. 2021; Perez-Vazquez et al. 2022; Peribañez et al. 2023).

Teamwork strategies and rules are strongly recommended to be visualized and presented with visual stimuli or prompts to enhance the effective participation of children with autism (Albo-Canals et al. 2013; De Franca Monteiro et al. 2020; Fachantidis et al. 2020; Nanou et al. 2022; Papazoglou et al. 2021; Tsiomi and Nanou 2020).

Specific roles assigned to participants during group work in ER activities include the rotating roles of builder (builder, brick supplier, PC/tablet user) and coder (PC/tablet user, programmer, driver). These roles can be either rotated or permanent (Fachantidis et al. 2020; Nanou et al. 2022; Papazoglou et al. 2021; Tsiomi and Nanou 2020). To teach participation processes and interaction with peers, specific strategy training with visual prompts is employed (Ludi and Reichlmayr 2011; Nanou et al. 2022; Tsiomi and Nanou 2020).

ER activities have shown positive impacts in various domains, including: a) the improvement of social status (Di Lieto et al. 2020; Fachantidis et al. 2020; Papazoglou et al. 2021), b) the enhancement of participation and collaboration (Costa et al. 2010; Di Lieto et al. 2020; Nanou et al. 2022; Papazoglou et al. 2021; Peribañez et al. 2023; Prummer et al. 2022; Tsiomi and Nanou 2020; Wainer et al. 2010), c) inclusion (De Franca Monteiro et al. 2020; Di Lieto et al. 2020; Fachantidis et al. 2020; Papazoglou et al. 2021; Poletti 2023), and d) cognitive improvement (Albo-Canals et al. 2013; Arias and Madrid 2017; Arshad et al. 2020; Caci 2004; De Franca Monteiro et al. 2020; Lindsay 2011; Silva et al. 2012).

4. Discussion

This scoping review comprehensively maps the literature concerning the participation of students with autism in ER. The analysis encompassed 45 studies, achieving two primary objectives: (1) elucidating the contextual dimensions influencing the participation of students with autism in ER, and (2) elucidating the nature of ER activities with respect to the main learning characteristics of students with autism.

According to the first objective, research on the participation of students with autism in ER is acknowledged to be limited based on the selected studies. This research is distributed across four distinct yet interconnected dimensions that impact the participation of students with autism in ER, as illustrated in Figure 12. These dimensions include teacher attitudes toward the participation of students with autism in the ER, teacher training methods, the implementation of ER activities, and the accessibility of ER for students with autism. Given the asymmetrical development of research across these dimensions, there is a lack of interaction and feedback between the different yet complementary research findings (Kats 2021, 2016; Karademir Coşkun 2022; Keshav et al. 2018; Lopez and Louis 2009).

Figure 12. Research dimensions for autism participation in ER activities.

Regarding the second objective of the scoping review, the results reveal an asymmetry in the research development of the included studies. Most of the research investigates how the participation of students with autism in ER activities influences the development of their social skills and their social status. However, very few explore their cognitive skills, coding skills, or STEM knowledge development. These findings suggest that most researchers commonly find the ER environment to be conducive to improving the social skills or social status of students with autism. Social skills development poses a significant challenge in autism, and different intervention strategies, tools, and methods have been employed in a therapeutic context to address this challenge. Although these interventions have shown positive results based on individual characteristics, the generalization of acquired knowledge or skills remains a substantial challenge. It is uncertain whether individuals with autism can transfer the acquired social skills to new situations (Froehlich et al. 2012; Hernández-Torrano et al. 2022; Ozonoff and Miller 1995; Wainer et al. 2010). ER activities, as indicated by the findings of this scoping review, have been utilized by researchers to provide benefits for children with autism in developing their social skills. Adopting strengths-based approaches, students with autism share the same desire as their peers to interact and contribute to group activities (White et al. 2023). ER within an authentically collaborative environment provides significant benefits as the transfer process is included. Given that ER activities are extracurricular and serve as a "magnet" of interest for typical students, they create a context where students with autism could be taught how to develop their social skills and enhance their social status. On the other hand, research that is focused on using ER to enhance coding skills and STEM knowledge in students with autism is limited. The potential of students with autism in coding has not been adequately investigated in terms of both quality and quantity. Similarly, research on the accessibility of ER interfaces for children with autism is limited, with some ER control interfaces proving not to be accessible for children on the autistic spectrum (Galvez Trigo et al. 2022).

This scoping review additionally highlights the psychoeducational methods that support the participation of students with autism, as summarized in Table 1. These methods encompass cooperation scenarios, collaboration scripts and rules, teamwork strategies presented through visual stimuli or prompts, specific roles assigned to participants, and strategy training incorporating visual prompts. These psychoeducational methodologies align with the educational needs of students with autism to operate effectively in a structured environment (Barry and Burlew 2004; Hume and Reynolds 2010; Karagiannidis et al. 2014; Mesibov 2018).

Table 1. Psychoeducational ER methods recommended by the included studies and their appearances in them.

General ER Methods	Specific ER Methods for the Inclusion of Students with Autism	Inclusive Methods in the Class
Problem-solving method based on the declarative approach (3)	Modeling augmented reality with the mechanical assembly system (1)	Universal Design for Learning Principles (2)
Collaboration based on problem-solving exploration, demonstration, and interaction (6)	Collaboration script, specific roles in IER teamwork (architecture, supplier, builder), and SAS Strategy for successful collaboration (1)	Differentiation strategies integration of technologies and IER (1)
Rotate roles: Build (builder, brick supplier, PC/tablet user) Code (PC/tablet user, programmer, driver) (1)	Turn-taking wheels (1)	Project-based (1)
Guided instruction with simple orders (1)	General and special strategy training—Think Share Pair (TSP) cooperative strategy—Staring Manage Share (SMS) specific strategy for the cooperation of ASD with peers in ER–Self-regulated strategy Social story teaching approach (1)	-
Teamwork strategies—no definition of roles (4)	Visual instructions (2)	Learning by design (2)
-	Adjusted according to the needs of adolescents during each session (1)	Working stations (1)
-	Rules, Reminder Cards (1)	Structure challenging activities (1)
-	Structuring the process and the place (2)	-

Positive outcomes concerning the participation, peer collaboration, and improvement of social skills and the social status of students with autism, in parallel with cognitive benefits, have been documented by the participation of students with autism in the ER activities that have been investigated in the included studies (De Franca Monteiro et al. 2020; Nanou and Karampatzakis 2022; Nanou et al. 2022; Papazoglou et al. 2021; Silva et al. 2012; Silva-Calpa et al. 2021; Tsiomi and Nanou 2020). ER, in line with the vision of inclusion articulated by the Salamanca Statement (UNESCO, 1994), could be approached as an educational opportunity for differentiating instructions and establishing an authentically inclusive learning environment based on the strengths and interests of students with autism. According to the findings of this scoping review, it is recommended that more research be developed in different dimensions of the participation of students with autism in ER.

According to the results of the conducted research (Albo-Canals et al. 2013; Chatzara et al. 2014; Costa et al. 2010; De Franca Monteiro et al. 2020; Fachantidis et al. 2020; Lancheros-Cuesta et al. 2020; Nanou et al. 2022; Papazoglou et al. 2021; Tsiomi and Nanou 2020; Yun et al. 2014), as presented in Table 2, structuring the ER environment with visual instructions and creating a consistent schedule and routine are key factors to ensuring a predictable and secure environment suitable for the inclusion of students with autism (Baron-Cohen 2004; David Moore and Thorpe 2000; Hume and Reynolds 2010).

Finally, there are some limitations of this review that should be noted. First, the fact that we did not expand beyond the four electronic databases in our search means that some studies may not have been included. Second, only literature written in English was included. The lack of inclusion of non-English publications and limited country representation will limit the perspectives and experiences on ER for autism.

Table 2. Specific approaches for the inclusion of students with autism in ER activities recommended by the included studies.

Description of the method	Country	Type of robot	Result(s)
Augmented reality was used as an assembly instructor to support students with autism	Colombia	LEGO-type robot	Students with autism assemble the robot with a low number of failures and an estimated time of 10 to 15 min
Collaboration script with the definition of specific roles for building the robot (architecture, supplier, builder) and coding. SaS Strategy training (SaSS)	Greece	LEGO Mindstorms NXT	Social status improvement cooperative behavior and skills in building and coding
Turn-taking wheels	UK	LEGO Mindstorms NXT	Improved social interactions and peer collaborations were generalized in other domains. Children's parents reported improvement in their children's social status
Strategy training: (a) cooperative strategy: Think Share Pair (TSP) (b) Specific strategy for cooperation with peers: Staring Manage Share (SMS) (c) Self-regulated strategy, and (d) Social story teaching approach	Greece	LEGO Mindstorms NXT	The SMS strategy and the specific self-regulated strategies proved necessary in creating a climate of cooperation between typical and HF students. Difficulties with disrupting behaviors occurred with less intensity
Structured process and place with visual instructions and rules reminder cards	Greece, Spain, USA, Brazil, and Spain	LEGO-type Robot 3D, LEGO WeDo 2.0, Ozobots	Children with autism in structured environments overcame motivational and sensory processing barriers and improved participation, joint attention, and social skills

5. Conclusions

This scoping review demonstrated that research on the participation of students with autism in ER is limited. Interrelated dimensions that affect the participation of autistic students in ER have only just started to be investigated. Research gaps were identified in the investigation of autistic coding skills and the accessibility of ER interfaces. This scoping review highlights the key concept of participation in ER as a means and an outcome for the inclusion of autistic students in educational environments. Strengths-based approaches that take advantage of the potential of autistic students in ER and use of autism-adapted psychoeducational methodologies are strongly connected to the success of their inclusion. The findings of this review may help educators and researchers use strengths-based approaches to support the inclusion of autistic students in mainstream education using educational robotics.

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Abbreviations

The following abbreviations are used in this manuscript:

ASC	Autism Spectrum Condition
ASD	Autism Spectrum Disorder
ER	Educational Robotics
ERs	Educational Robots
HFA	High-Functioning Autism
IER	Inclusive Educational Robotics
SAR	Social Assistive Robots
SaSS	Search and Share Strategy (IER Strategy)
SER	Special Educational Robotics
SMS	Staring Manage Share (IER Strategy)
STEM	Science, Technology, Engineering, Mathematics
TSP	Think Share Pair (Cooperative Strategy)
WoS	Web of Science

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