MODESTUM EURASIA Journal of Mathematics, Science and Technology Education, 2026, 22(7), em2856
ISSN:1305-8223 (online)
OPEN ACCESS Literature Review https://doi.org/10.29333/ejmste/18741

STEM-based teaching strategies for children with autism spectrum disorder

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Received 04 February 2026 ▪ Accepted 23 May 2026

Abstract

This review article examines effective science, technology, engineering, and mathematics (STEM) -based teaching strategies designed to support children with autism spectrum disorder (ASD) in educational settings. With the growing global emphasis on STEM education, it is essential to create inclusive learning environments that address the needs of neurodiverse learners. The article synthesizes findings from recent studies on how structured, visual, and technology-assisted instructional strategies enhance academic achievement, conceptual understanding, engagement, communication, and skills. 24 studies were included in the systematic review based on inclusion and exclusion criteria. The results show that demonstration-guided practice, independent practice, and technology-based interventions were most commonly used in the reviewed studies. Additionally, most studies were conducted in Western and European contexts. The research indicates that STEM interventions for learners with ASD are effective in improving academic skills and subject knowledge in challenging subjects such as science and mathematics. The findings also show that STEM programs enhance social skills, including joint attention, peer communication, and group participation, contributing to social and behavioral improvements. Overall, the evidence suggests that STEM teaching is beneficial and effective for students with ASD in learning STEM topics. Further studies are needed to explore the effectiveness of STEM teaching to students with ASD in developing and underdeveloped countries and middle and high school education.

Keywords: STEM education, STEM teaching, children with autism spectrum disorder, special education, systematic review

INTRODUCTION

Students with autism spectrum disorders (ASD) are increasingly included in general education classrooms. They are expected to access core academic content, including science, mathematics, and STEM education (Knight et al., 2015; Zhunussova et al., 2025). Current initiatives aim to expand participation across subject areas. These efforts also emphasize the development of individual communication and social interaction skills (Abayeva et al., 2024; Sani-Bozkurt et al., 2017; Taylor et al., 2020)

Science, technology, engineering, and mathematics (STEM) education aims to promote scientific literacy for learners at all levels and encourage them to have careers in STEM fields. Earlier studies on STEM education and students with ASD indicate that deliberate, structured, and evidence-informed science instruction can yield meaningful learning outcomes in STEM fields, including science, technology, engineering, and mathematics, by

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Contribution to the literature

- For effective teaching of STEM topics to learners with ASD, scholars and teachers recognize that instructional practice is central to supporting students with ASD at all levels.
- However, few studies comprehensively review existing research on the learning outcomes of STEM instruction for these learners.
- Therefore, the findings from this article offer new insights into studies published on STEM education and learners with ASD.

promoting vocabulary, understanding of concepts, inquiry skills, and task-related competencies for students with intellectual disabilities (IDs) and ASD. Thus, STEM education serves as a core instructional approach to support learners with ASD at various school levels in terms of academic achievement and basic social skills (Apanasionok et al., 2019). Additionally, STEM education supports learners in developing vocabulary and concepts that align with their needs. Many students with ASD need to acquire symbolic representations and conceptual frameworks to support reasoning and communication (Apanasionok et al., 2019). Empirical evidence from earlier studies shows that evidence-based STEM instructional practices, such as explicit instruction, task analysis, prompting, and data-based decision-making, meaningfully and significantly support learners' skill acquisition in vocabulary, concepts, and inquiry processes (Apanasionok et al., 2019).

These practices in STEM teaching show that evidence-based instruction supports the learning outcomes of students with ASD in STEM education (Knight et al., 2019). For meaningful learning outcomes, researchers have indicated that well-designed and implemented STEM activities should be used in teaching contexts with learners with ASD. Additionally, studies have found that both students and teachers report positive experiences with STEM interventions for ID/ASD (Apanasionok et al., 2019). Several reviews caution that findings may not generalize to all students with ASD, especially those with more severe disabilities.

For effective teaching of STEM topics in ASD learners' contexts, scholars and teachers acknowledge that instructional practice plays a central role in supporting students at all levels who have ASD. Specifically, studies have shown that a systematic instruction approach has been found to be effective in yielding positive and meaningful learning outcomes for students with ASD (Apanasionok et al., 2019; Knight et al., 2019). Systematic instruction characterizes organized content, explicit objectives, modeling, and guided practice in teaching STEM topics to students with ASD/ID. For example, the study by Apanasionok et al. (2019) reported that most studies they reviewed (n = 23) produced positive and significant learning outcomes in science vocabulary, concepts, and related skills. Knight et al. (2020) support this pattern in their review studies that synthesize publications on teaching science content and science practices to students with ID and ASD.

From this point of view, instructional strategies present benefits in illustrating what kind of instruction can support learning outcomes in ASD (Knight et al., 2019). This kind of information can provide benefits to scholars to determine and choose for long-term implementation in STEM education contexts for learners with ASD (Apanasionok et al., 2019). In addition, an understanding of effective instructional methods and techniques can provide researchers with nuances in implementing methods and techniques for STEM teaching to learners with ASD (Apanasionok et al., 2019; Knight et al., 2019). While evidence supports the effectiveness of STEM teaching, there are insufficient studies that report specific teaching methods and techniques used in STEM instruction for learners with ASD. Therefore, research gaps remain in synthesizing outcomes related to methods and learning results to promote learners' achievement and skills.

Systematic reviews are especially important and valuable for reviewing and synthesizing the literature on ASD and STEM interventions. They also help produce stronger and more generalizable conclusions, contributing to scholars' knowledge for educating learners with ASD (Apanasionok et al., 2019). Despite the growing body of research on students with ASD in STEM education, there are still few studies that review related research in STEM fields or synthesize findings on learners' learning outcomes in STEM teaching. This lack of comprehensive reviews on learners' learning outcomes in STEM teaching contexts highlights a critical gap in the literature. Previous reviews have often had a limited scope, focusing on a single subject (e.g., Knight et al., 2020) or broader special education contexts without specifically addressing STEM teaching. Additionally, no comprehensive synthesis has examined the learning outcomes of interventions designed for learners with ASD in STEM education. Furthermore, the emergence of new technologies for teaching STEM topics to learners with ASD has produced new findings and learning outcomes relevant to the effective implementation of STEM education for these students. Recent research underscores the need to identify and clarify specialized instructional methods and techniques for students with ASD in STEM education.

Although numerous studies have examined STEM education and students with ASD, very few comprehensively review existing research on the learning outcomes of STEM instruction for learners with ASD. For example, previous systematic reviews have generally focused on a single technology (e.g., augmented reality [AR], see Cheng & Bololia, 2023) or a single method (e.g., video modeling [VM], see Wright et al., 2020). For scholars, studying how STEM instruction should be structured for students with ASD remains largely unexplored in the literature and represents a significant research gap. Because of this reason, STEM practices from an interdisciplinary perspective need to be examined. Additionally, more new systematic reviews and evaluations are needed to determine and explore the effectiveness of STEM teaching methods and techniques for students with ASD, as well as to examine the impacts of STEM teaching on academic learning outcomes for ASD learners.

To address these research gaps and problems, this study aimed to review and synthesize specific instructional methods and techniques to provide new insights into effective STEM teaching for learners with ASD. To achieve this, publications from the Scopus database were selected to answer the research questions, covering ten years from 2016 to 2025. This research seeks to answer the following questions:

- What interventions have been developed to teach STEM topics to learners with ASD?
- What are the results of research regarding interventions used to teach STEM topics?

LITERATURE REVIEW

Although many studies have examined STEM teaching and students with ASD, very few have reviewed the existing research on STEM and students with ASD. For example, Cheng and Bololia (2023) reviewed studies on the effects of AR on basic social skills in children with autism. Their review included 13 studies that used AR-based social interventions with students with autism. The results indicated that research recognized a favorable role for AR technology in fostering social skills in children diagnosed with autism. Additionally, their findings suggested that AR may be effective in improving social skills in children with autism. Furthermore, their findings indicated that AR technologies may be efficacious in supporting the recognition of facial expressions in children with autism.

Knight et al. (2020) synthesized research from 2009 to 2018 on teaching science to students with IDs and ID/autism. They reviewed 12 studies and evaluated the evidence base for instructional practices used to teach science content and practices to these students. Their results showed that all 12 studies supported student learning of at least one scientific practice. Additionally, they identified three instructional practices as evidence-based for teaching both science content and the science practices:

(1) multiple exemplar training,

(2) task analytic instruction, and

(3) time delay.

A study by Apanasionok et al. (2019) was conducted to identify current practices in teaching science to students with ID and ASD, examine the effects of these practices, and explore students' and teachers' experiences with the interventions. They searched six databases and included thirty studies that reported results on science interventions and twenty studies on student and teacher experiences with the interventions. They found that most studies focused on science vocabulary, concepts, inquiry skills, and comprehension skills. The majority of interventions used components of systematic instruction (n = 23). Five studies focused on self-directed learning and two on comprehension-based instruction. Students and teachers generally reported positive experiences with the interventions. The findings suggest that components of systematic instruction, in particular, may be effective in teaching science content to students with ASD.

Wright et al. (2020) reviewed the use of VM to teach STEM skills to students with autism and ID. They analyzed ten studies and found insufficient evidence for using VM to teach science, technology, and engineering skills. However, they found that VM was effective for teaching mathematics to individuals with autism and IDs. Thus, their results indicated that VM is effective for teaching some STEM skills to students with ASD and/or ID. Zeng et al. (2024) reviewed studies that used technology-mediate interventions to improve STEM achievement in students with ASD. They included forty-four studies. Their results showed that technology-mediated interventions were effective for students with ASD in STEM education. In particular, they found that technology-mediated interventions were effective when computer or mobile devices supported the intervention. Their results also revealed that most technological software focused on knowledge within a particular STEM field, such as mathematics or technology, along with appropriate instructional strategies. Recently, Zhunussova et al. (2025) systematically reviewed science education research for students with ASD published between 2015 and 2024. They included articles from Scopus, ERIC, and Web of Science databases, totaling fifteen studies. Their results showed that most of the papers used single-subject research designs (56.25%). Of the studies, 31.25% were conducted in special education environments. Among the sciences, life sciences (43.2%) were the most frequently researched field. Instructional durations were generally short (62.5% were 20 minutes or less), and frequent repetitions were used. Complete success was achieved in 66.7% of the interventions. Technology-supported interventions and systematic

Table 1. Search terms used in the database query for STEM education and ASD

Search terms	Keywords used
STEM teaching	STEM education, STEM instruction, mathematics instruction, math content, mathematics teaching, engineering education, engineering instruction, teach engineering, science education, science instruction, science learning, science teaching, science content, teach technology, technology instruction, technology education, biology education, teach biology, chemistry education, teach chemistry, physics education, teach physics
Autism spectrum disorder	Autism spectrum disorders, autistic disorder, autism, ASD, autis, asperger

teaching approaches were particularly effective. Effect size analyses indicated that most interventions were highly effective.

An examination of the results from the previous reviews mentioned above shows that most studies indicate structured and systematic teaching methods are the most effective strategies for students with ASD (Apanasionok et al., 2019; Knight et al., 2020). Specifically, methods such as task analytic instruction, time delay, and multiple exemplar training are used in STEM education (Apanasionok et al., 2019; Knight et al., 2020). Additionally, the use of technology emerges as a common success factor across all sources in these studies. Research findings highlight that AR (Cheng & Bololia, 2023), VM (Wright et al., 2020), and computer- or mobile device-supported interventions (Zeng et al., 2024) are effective in developing STEM skills and supporting social interaction among students with ASD (Cheng & Bololia, 2023). All of these studies also demonstrate that applications implemented within STEM education generally have positive and significant effects on students' academic achievement and social skills (Apanasionok et al., 2019; Knight et al., 2020). In addition, both teachers and students reported positive experiences with these interventions (Apanasionok et al., 2019).

METHOD

In this study, to answer the research questions and identify documents that meet the inclusion and exclusion criteria, the PRISMA guidelines (Moher et al., 2009) for reporting systematic reviews were used.

Focus and Inclusion Criteria

This review was concentrated on research assessing educational interventions for instructing STEM subjects to students with ASD. Thus, studies involving children and young adults were limited to those including undergraduate students with ASD. For this purpose, included studies describing interventions developed and implemented for students with ID and ASD, and excluded studies that did not report results of any intervention in STEM fields for learners with ASD. If a publication reported learning outcomes from interventions, we included it in the data collection. In this study, we also included studies with only one group and no comparison group. Additionally, included studies had to report findings on students' changes in STEM knowledge and skills or focus on learners with ASD.

Search Strategy

Scopus was used to search for related documents for data collection and analysis. The database was searched in March 2026. The rationale for choosing only one database is its focus on education, psychology, and science. Scopus was selected because it includes publications that explore the relationships among psychology, sociology, and technology. Keywords for the search strategy were developed using terms related to STEM education and ASD. **Table 1** lists the terms used during the database search for STEM education and ASD. Search terms were organized into two groups. The first contains terms related to STEM education, and the other contains terms related to ASD. Because the STEM field encompasses a wide range of disciplines, the search strategy was intentionally expansive to reduce the likelihood of overlooking potentially pertinent studies. Therefore, the authors sought to include as many keywords as possible during the data search in the database. During the search, we separated search terms within each list using "OR" and combined the two lists using "AND." The data collection was exclusively centered on research papers published in English. We restricted the publication date data to the years 2016 through 2025. Furthermore, database searches were restricted to peer-reviewed journal articles exclusively.

Data Collection

After searching for articles in the database, the authors exported the search results to an Excel file. Duplicate publications were then removed by one of the researchers. Next, two researchers reviewed the titles, abstracts, and keywords of all results based on the inclusion and exclusion criteria. The excluded articles did not meet the review standards. The following criteria were used for the inclusion of publications.

- Conducted with students diagnosed with ASDs
- Related to a STEM field, including physics, chemistry, biology, or environmental science
- Provides data on students' academic, social, or behavioral development

- Empirical research (experimental, quasi-experimental, single-subject, etc.) is included in the review.
- Includes an instructional activity or intervention and presents data on its effectiveness

During the data analysis, reliability between the two researchers was found to be 99.8%. After this, the full texts of all articles were downloaded from the database and the journals' websites. For a few articles, the researchers disagreed with inclusion; to resolve this, they discussed the criteria in light of the inclusion and exclusion guidelines.

Data Analysis

During the data analysis, basic characteristics of the reviewed studies, including the country, participants, duration of the activity or intervention, STEM fields, teaching strategy, dependent variable, data collection tools, and the main results, were identified. Articles on STEM teaching and students with ASD reviewed in the present study are summarized using narrative synthesis.

RESULTS

The results for the nine categories identified as analysis criteria for each study examined in this research (country, number of participants, duration of implementation, STEM field, teaching strategy, dependent variable, independent variable, data collection tools, and main findings) are presented in the **Appendix A**.

Study Characteristics

Countries

When examining the countries where STEM studies were conducted, it was found that the vast majority of the 24 studies (17 studies) were conducted in the USA. Studies were also conducted in Europe, the Middle East, and Asia. In Europe, these include Portugal (Silva et al., 2025), the UK (Apanasionok et al., 2021), Greece (Gkiolnta et al., 2023), and Turkey (Denizli-Gulboy et al., 2024; Kiyak & Toper, 2023); in Asia, South Korea (Park & Bouck, 2022); and in the Middle East, Saudi Arabia (Alabdulaziz & Alamoudi, 2026).

Participants

In terms of the participants' educational levels in the studies reviewed, the vast majority of the research (11 studies) was conducted with primary school pupils (Alabdulaziz & Alamoudi, 2026; Apanasionok et al., 2021; Denizli-Gulboy et al., 2024; Gkiolnta et al., 2023; Greene & Bethune, 2021; Hutchison et al., 2020; Knight et al., 2018; Ledbetter-Cho et al., 2023; Ma & Xin, 2023b; Root, 2019). In addition to this, middle school (Cox & Root, 2018; Kiyak & Toper, 2023; Martin et al., 2020; McKissick et al., 2018; Silva et al., 2025) and high school students (Clees & Clinton, 2025; Kim et al., 2025; Knight et al., 2020; Park & Bouck, 2022; Yakubova et al., 2025), with the number of studies being five, and this number is equal for both school levels. At the university level, only two studies (Kellems, 2016; McMahon et al., 2016) have been conducted, and at the pre-school level, only one study (Ingelin et al., 2021) has been carried out.

Duration of the intervention

An examination of the duration of STEM activities in the studies reveals that these activities vary in terms of both the duration of individual sessions and the total duration of implementation. An analysis of the results in **Appendix A** shows that in the majority of studies, the duration of individual sessions was kept quite short (generally between 10 and 30 minutes). In some studies, sessions were limited to very short durations, such as 1-3 minutes (Kellems et al., 2016), 4 minutes (Alabdulaziz & Alamoudi, 2026) or 5-7 minutes (Denizli-Gulboy et al., 2024). In many studies, however, sessions of 15-20 minutes (Apanasionok et al., 2021; Ingelin et al., 2021) or 30-40 minutes (Greene & Bethune, 2021; Hutchison et al., 2020) have been implemented. This finding indicates that STEM interventions are kept brief, considering the attention spans and cognitive load capacities of students with special educational needs.

Another finding regarding STEM interventions is that the frequency of implementation generally varies between 2 and 5 days per week. For example, Denizli-Gulboy et al. (2024) conducted sessions five days a week, while Greene and Bethune (2021) conducted them four days a week. This finding highlights the importance of systematic repetition and continuity for the skills in the STEM field to become permanent. Furthermore, in terms of total duration, studies have implemented both short- and long-term interventions. For instance, studies such as Silva et al. (2025) focused on developing a specific skill within a short period of 4 weeks, while Hutchison et al. (2020) implemented a 7-week program. In long-term interventions, for instance, Martin et al. (2020) conducted a 20-week program, Apanasionok et al. (2021) implemented a full school year's program, and Knight et al. (2018) carried out comprehensive and extensive STEM programs spanning two years.

STEM fields

By STEM subject area, more than half of the studies (approximately 14) focused on mathematical skills. These studies addressed fundamental topics ranging from early number sense (Ingelin et al., 2021; Root, 2019) and fractions (Alabdulaziz & Alamoudi, 2026; Park & Bouck, 2022) to more complex topics such as algebraic equations (Clees & Clinton, 2025) and problem-solving (Ma & Xin, 2023b). Nine studies focused on science lessons, covering topics such as cell structures

(McKissick et al., 2018), life cycles (Knight et al., 2018), internal organs (Denizli-Gulboy et al., 2024), and states of matter (Kiyak & Toper, 2023). Furthermore, only two of the studies focused on technology. Among these, studies such as "robotics and coding" (Hutchison et al., 2020; Knight et al., 2020) applied technology as a skill to be acquired directly within their practices. In many studies, technology (virtual reality [VR], AR, VM) was used as an independent variable in the teaching of science or mathematics (McMahon et al., 2016; Silva et al., 2025).

Among these studies, the field of engineering has been examined in three studies, either integrated with other STEM fields (Knight et al., 2020; Gkiolnta et al., 2023) or within comprehensive programs such as Maker Education and the engineering design process (EDP) (Martin et al., 2020). These findings show that the number of studies focusing solely on engineering skills is quite small and limited. In summary, these results indicate that research on STEM and learners with ASD has predominantly focused on mathematics-related topics, while engineering has generally been integrated with technology and robotics studies, and science studies have primarily focused on conceptual teaching.

Instructional strategy and method

An examination of the teaching strategies used in the studies showed that a significant proportion favored evidence-based systematic teaching methods such as model-lead-test (MLT), constant time delay (CTD), and discrete trial teaching (DTT). These methods have contributed to academic success, particularly in teaching scientific terms (Denizli-Gulboy et al., 2024; McMahon et al., 2016), defining mathematical concepts (Root, 2019), and acquiring basic coding skills (Knight et al., 2020). Furthermore, the results indicate that, in addition to academic success, students gain skills through these teaching methods and techniques and can generalize these skills in different situations.

Furthermore, technological tools such as VM, video prompting (VP), AR, and VR have been central to the teaching strategies and methods used in these studies. The research results indicated that VM and VP strategies improved students' independent working skills and enabled them to solve complex mathematical operations, such as algebraic equations, on their own (e.g., Clees & Clinton, 2025; Kellems et al., 2016). In science-related subjects, the use of AR and VR has helped students visualize abstract concepts, such as internal organs and cell structure, and has increased engagement with the subject.

In addition, strategies such as maker education, the EDP, and schema-based instruction (SBI) have been shown to help students improve their knowledge, STEM self-efficacy, and understanding of EDPs (Martin et al., 2020). The SBI approach has also been found to enhance students' ability to explain their reasoning when solving mathematical problems (Cox & Root, 2018; Ma & Xin, 2023b).

It has been established that strategies supported by robotics and coding programs (Gkiolnta et al., 2023; Hutchison et al., 2020) contribute to reduced autism symptoms, increased social interaction skills, and decreased problem behaviors in children with autism. In light of these findings, it is evident that the teaching strategies examined in these studies yield highly effective results for skill acquisition, retention, and generalization.

Dependent variables

When the dependent variables used in the studies are examined, the research can be said to have three focuses. First, studies in mathematics focus on learners' conceptual understanding and skills in areas such as accuracy in solving fraction problems, solving algebraic equations, and early number sense and measurement skills. Second, in science-related studies, "science terminology/vocabulary," "naming of cell structures or internal organs," and "level of understanding of science concepts" were identified as dependent variables.

Thirdly, it was found that studies were also conducted in the technology and engineering focus areas, where students grasped basic coding logic and could create original codes in the variables of "coding and generalization" and "understanding the EDP." Fourthly, when the research was examined in terms of behavioral outcomes, some studies focused on "frequency of problem behavior," "increased social interaction skills," "decrease in autism diagnostic indicators," and engagement. Additionally, some studies focus on participants' (students') ability to use the coding or science terms they have learned in different environments and with different materials, that is, their generalization skills (Denizli-Gulboy et al., 2024; Knight et al., 2020). Finally, studies have investigated students' self-efficacy, particularly after using "Maker" programs and engineering designs, with variables such as "STEM self-efficacy" and "career interest" as dependent variables.

Independent variables

When the independent variables of the research are examined, researchers combine technology-focused tools with traditional systematic teaching methods. The most common independent variables used in the studies are VM, AR, VR, and robotics applications. Additionally, structured methods such as MLT, CTD, and DTT are also included as independent variables in the research. Furthermore, SBI, conceptual model-based problem-solving (COMPS), and virtual manipulatives were identified as key independent variables in mathematics education. Finally, real-time feedback provided via

telemedicine (Kiyak & Toper, 2023) or adapted e-books (Kim et al., 2025) appears as an independent variable.

Data collection tools

When examining the data collection tools used, it is observed that researchers primarily relied on observation methods to track student behavior and skill levels. For example, researchers used observations and video recordings to measure students' class participation, social interactions, and problem behaviors (Gkiolnta et al., 2023; Hutchison et al., 2020; Yakubova et al., 2025). In addition, to confirm the accuracy of the data, researchers collected inter-observer agreement data (Root, 2019) and conducted semi-structured interviews (Kiyak & Toper, 2023; Martin et al., 2020).

As quantitative data collection tools, researchers used standardized tests to measure learners' knowledge gains (Apanasionok et al., 2021; Ingelin et al., 2021). Some researchers tracked academic progress with rubrics (Cox & Root, 2018), performance records, and criterion-referenced tests (Ma & Xin, 2023; Yakubova et al., 2025). They also used task analysis checklists (Kellems et al., 2016; Knight et al., 2020) and social validity questionnaires (Denizli-Gulboy et al., 2024; Knight et al., 2018; McMahon et al., 2016). Researchers measured students' progress using clinical scales, DHD scales, and comprehensive scales such as AQ-child (Hutchison et al., 2020) and VABS-II and BASC-3 (Silva et al., 2025) to assess adaptive functioning. Furthermore, researchers used clinical scales, DHD scales, and comprehensive scales such as the AQ-child (Hutchison et al., 2020) to assess students' progress. The findings of this study demonstrate the effectiveness of STEM education for individuals with autism across four categories: academic, social, and methodological.

Effects on Academic Achievement and Concept Acquisition

The majority of studies in the literature indicate that STEM interventions are highly effective in improving the academic skills and content knowledge of students with autism.

Science

Studies on STEM education and autism in science education have shown that computer-assisted instruction (CAI) (McKissick et al., 2018) and video-based methods (McKissick et al., 2018) have made positive contributions to teaching science topics—such as cell structure and digestion—that are considered challenging for individuals with ASD, improving both achievement and conceptual understanding. Additionally, research in science education has demonstrated that combining AR with systematic instruction (such as fixed-delay) yields positive outcomes in teaching the names of internal organs (Kiyak & Toper, 2023).

Overall, studies have focused on achievement and understanding in science topics such as cell structures, internal organs, states of matter (Kiyak & Toper, 2023), the solar system (Kiyak & Toper, 2022), food and digestion (Kim et al., 2025), energy, and weather (Greene & Bethune, 2021).

Research examining STEM education and autism has shown that CAI (McKissick et al., 2018) and video-based methods positively affect middle school students' understanding. For example, McKissick et al. (2018) investigated the effect of a CAI intervention package to teach three middle school students with ASD and ID the structure and function of five key elements of an amoeba. Results showed a functional relation between the CAI intervention and an increase in the number of correct responses during probe sessions.

Similarly, Denizli-Gulboy et al. (2024) found that systematic instruction (CTD) combined with an AR application positively affected the ability to name internal organs. In another study, Kiyak and Toper (2023) examined the effects of the simultaneous prompting procedure and observational learning in teaching science facts to middle school students with ASD. Their results indicated that students acquired the target science facts and observational learning skills and maintained them over time.

Mathematics

The modified SBI (MSBI) strategy has been shown to improve students' ability to solve ratio and proportion problems and explain their solution process (Cox & Root, 2018). Technology-supported tools, such as VM (Alabdulaziz & Alamoudi, 2026; Yakubova et al., 2025) and virtual manipulatives, have facilitated learning of abstract topics like fractions (Alabdulaziz & Alamoudi, 2026) and equivalent fractions (Park & Bouck, 2022), and have reduced error rates. Research indicates that studies focus on enhancing students' understanding of mathematical concepts such as ratios and proportions (Cox & Root, 2018), fractions (Alabdulaziz & Alamoudi, 2026; Park & Bouck, 2022), early number sense, and real-life calculations (Root, 2019) among students with ASD.

For example, Cox and Root (2018) used the MSBI strategy with two middle school students in the USA. The results showed that MSBI had a positive effect on word problems involving ratios and proportions, improving the students' ability to flexibly solve mathematical word problems and explain their answers. Furthermore, a study by Yakubova et al. (2025) revealed the effectiveness of an online, synchronous VM multicomponent intervention (guided practice, self-monitoring checklist, and prompting) on the acquisition of mathematics and geometry skills in an autistic high school students. In addition, Ma and Xin (2023) found

significant improvements in problem-solving abilities among students with ASD who used COMPS with the concrete-representational-abstract (CRA) sequence for teaching addition and subtraction in mathematics. In a recent study, Clees and Clinton (2025) evaluated the effectiveness of point-of-view video self-prompting (VSP) with narration, delivered via an iPad, in teaching four secondary students with high-incidence disabilities to solve algebraic equations requiring the distributive property, and found that three of four participants' data evidenced a functional relation between the VSP intervention and solving the targeted algebraic equations.

Engineering and technology

Some studies have reported that robotics and coding-focused programs help students learn and motivate them to continue learning. For example, Hutchison et al. (2024) evaluated the effects of a robotics program for children with ASD, considering various relevant factors such as the severity of ASD symptoms, presence of attention-deficit/hyperactivity disorder (ADHD) symptoms, degree of challenging behaviors, quality of relationships, and sensory sensitivity. The study included 12 elementary students who participated in a 7-week after-school program for students with ASD. The results showed a decrease in participants' diagnostic ASD markers and an increase in engagement as the sessions progressed, with no significant change in participants' ADHD symptoms, challenging behaviors, or sensory sensitivities.

Social and behavioral outcomes

The results of the reviewed studies indicate that STEM-focused teaching strategies have positive effects on academic performance, social interaction, and behavior management. These include:

Social skills and interaction

Relevant studies have found that robotics activities and VR environments enhance students' social skills, such as shared attention, peer communication, and group participation. For example, Silva et al. (2025) concluded that VR-based learning environments may support improvements in cognitive, behavioral, and social skills in the context of design science research in STEM education, though they noted limitations in causal inference. The findings of Gkiolnta et al. (2023) demonstrated an increase in the social and communication skills of two elementary school students during robot programming and coding.

Student engagement and motivation

Research has shown that STEM activities, especially robotics and maker programs, increase student engagement and enhance self-efficacy and career interest in STEM fields. For example, Martin et al. (2020) reported positive outcomes from involving middle school students with ASD in an inclusive maker program, including significant improvements in technology and engineering self-efficacy, technology and engineering interest, vicarious experience, science appreciation, and understanding of the EDP. The results also showed that all students participated in the EDP, pursued a wide range of interests, successfully created their projects, and communicated with peers about those projects.

Reduction in problem behaviors

The review of the studies indicates that no increase in stereotypical or problem behaviors was observed among students during STEM activities, and significant decreases in such behaviors were found. For example, Knight et al. (2019) found no increase in problem behaviors among three high school students with ASD during the implementation of robotics and computer programming instruction. Gkiolnta et al. (2023) observed a decrease in problem behaviors among two elementary school students during robot programming and coding. Silva et al. (2025) reported positive improvements in students' behavioral skills in the context of Design Science Research in STEM education, though limitations exist regarding causal inference. Gkiolnta et al. (2023) also demonstrated an increase in the social and communication skills of two elementary school students during robot programming and coding. In contrast, Hutchison et al. (2024) reported a non-significant change in challenging behaviors among 12 elementary students after a 7-week robotics program.

Teaching Strategies

The teaching strategies and methods used to implement STEM education for individuals with ASD, as described in the reviewed articles, are as follows:

Systematic and direct instruction

The "demonstration-guided practice-independent practice" format (Cox & Root, 2018; Ingelin et al., 2021; McMahon et al., 2016; Root, 2019) has been used as a core component in nearly all studies. Additionally, methods such as simultaneous prompting (Kiyak & Toper, 2023) and fixed-time delay (Denizli-Gulboy et al., 2024; Greene & Bethune, 2021) have been frequently used in the instruction of science and mathematics skills.

Technology-based interventions

VM (Alabdulaziz & Alamoudi, 2026; Yakubova et al., 2025), VP (Kellems et al., 2016), AR (Denizli-Gulboy et al., 2024; McMahon et al., 2016), CAI (McKissick et al., 2018), science eBooks (Kim et al., 2025), and VR (Silva et al., 2025; Yakubova et al., 2025) are widely used to individualize instruction and provide visual support.

Maker education

In more informal settings, interest-driven and discovery-based strategies based on EDPs have been found to support the creativity and self-efficacy of students with autism (Martin et al., 2020).

Findings on Generalization and Retention

Another key finding from the systematic review concerns the retention of skills learned in STEM education over time and their generalization to different materials and individuals. For example, Cox and Root (2018) found that middle school students maintained high performance in acquiring and retaining math content and practices after instruction using MSBI, both during the intervention and in the follow-up phase when visual supports continued. Kiyak and Toper (2023) reported that, following a synchronous hinting procedure delivered via telehealth (Zoom), students acquired the target science knowledge and observational learning skills, maintained these skills over time, and generalized them to different individuals. All of these findings demonstrate that STEM education has a positive impact on students with autism across multiple areas and supports their cognitive and social development.

DISCUSSION AND CONCLUSION

The main aims of this review were to identify what interventions have been developed to teach STEM topics to learners with ASD and the results of research regarding interventions. Firstly, the results of this research show that the vast majority (17 studies) of STEM education studies designed for individuals with ASD were conducted in the USA. Regarding the educational level of the participants, the studies were mostly conducted with elementary school students (11 studies). The results showed that STEM activities were generally implemented for short periods of time, typically 10-30 minutes, and the frequency varied between 2 and 5 days a week.

In terms of the STEM areas focused on, more than half of the studies examined focused on mathematical skills (from basic numbers to algebraic equations), followed by science, with studies in technology and engineering being more limited. Regarding teaching strategies and methods, the research found that evidence-based systematic teaching methods such as MLT and CTD were preferred. This finding is very parallel to that of Apanasionok et al. (2019), who found that systematic instruction was used in the majority of the studies they reviewed that were conducted in science education. Also, this finding supports the results of Spooner et al. (2011), who reported that systematic instruction is effective for learners with developmental disabilities in science education.

Furthermore, the results show that technological tools such as VM, AR, and VR are used to concrete abstract concepts for learners and to improve independent study skills. Additionally, studies have been found to focus not only on academic achievement (math and science concepts) but also on behavioral and affective outcomes such as improved social interaction skills, reduced autism symptoms, decreased problem behaviors, and STEM self-efficacy.

The findings of the studies reviewed in this research indicate that STEM interventions for learners with ASD are highly effective in improving the academic skills and content knowledge of autistic students in challenging subjects such as science and mathematics. The studies suggest that VM, AR, and CAI provide learners with essential visual support. This is because the strong visual information processing abilities of autistic individuals, when combined with these technologies, facilitate their learning. Specifically, presenting abstract mathematical concepts (e.g., fractions) using virtual manipulatives or CRA sequences helped students make abstract concepts more concrete, reducing error rates (Alabdulaziz & Alamoudi, 2026; Yakubova et al., 2025).

The findings also show that STEM applications enhance social skills such as shared attention, peer interaction, and group participation, which are related to social and behavioral gains. Additionally, a decrease in problematic behaviors and an increase in class participation were observed during these activities. This result may be due to the use of systematic and direct instruction in the studies, along with structured formats such as "demonstration-guided practice-independent practice" and fixed-time break methods, which allowed students to develop complex academic skills through a systematic approach. Furthermore, presenting activities such as robotics and "maker" programs in an engaging and hands-on manner may have led to more active participation in the learning process (Hutchison et al., 2024; Martin et al., 2020). Thus, it has been concluded that the skills students acquire through these applications are maintained over time and can be generalized to different materials or individuals.

Recommendations

There is limited evidence in the literature regarding preschool and undergraduate levels. The lack of studies in these age groups indicates a significant gap in the literature. In particular, the focus on functional skills such as "daily calculations" in studies with adults suggests that STEM education is primarily used to support independent living skills in this group. From this perspective, studies are needed to support learners with ASD in preschool and undergraduate age groups. Additionally, most research on STEM integration and learners with ASD in special education, as well as the development of evidence-based practices in this field, is largely based on Western or USA-centric academic

knowledge. Therefore, further studies are needed in both developed and developing countries. In the USA, systematic teaching methods (MLT and CTD) and the use of technological tools (VR and AR) in special education have a more established research history. Researchers in developing and underdeveloped countries should focus on using systematic instruction and technological tools to contribute new insights to the special education field. Additional research is also needed on the impact of STEM implementations throughout middle and high school education. More research is needed to establish the effectiveness of STEM implementations across these age and school levels.

Due to the breadth of STEM teaching content, some relevant articles may not have been identified during database searches, especially for studies targeting a variety of educational goals. Although it is possible that some similar studies were missed, the systematic review method was designed to identify studies using a range of processes to reduce the risk of omission.

Author contributions: LAB: conceptualization, formal analysis, investigation, methodology, writing – original draft; **SKA:** supervision, validation, writing – review & editing; **AAM:** data curation, formal analysis, supervision, validation, visualization, writing – review & editing; **AKT:** data curation, formal analysis, project administration, supervision, visualization, writing – review and editing; **BYK:** data curation, formal analysis, project administration, supervision, visualization, writing – review and editing; **SMU:** project administration, supervision, writing – review and editing. All authors approved the final version of the article and agreed with the results and conclusions.

Funding: This research is funded by the Committee of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No. BR28712661 – National system for comprehensive continuous support of students with autism spectrum disorder).

Ethical statement: This study is a systematic review of published literature and did not involve direct interaction with human participants. Therefore, informed consent and ethical approval were not required. All data analyzed were extracted from peer-reviewed publications indexed in the SCOPUS database.

AI statement: No AI tools, technologies, or generative AI models were used in the completion of this research and writing.

Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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APPENDIX A

Table A1. Results for the reviewed studies

Studies	Country	n	DS	STEM field	TS	DV	IV	DCT	MS
Hutchison et al. (2024)	USA	12 elementary school students	7 weeks (2 days per week, 40-minute sessions)	Technology	Structured and unstructured exploration	Student engagement and ASD diagnostic indicators	Robotics and coding program	Observation, AQ-child, ADHD scales, BPI-S, sensory questionnaire	A reduction in ASD symptoms and an increase in engagement
Martin et al. (2020)	USA	109 middle school students	20 weeks (1-2 times per week, 45 min-2 hours)	Science, technology, and engineering	Interest-based "maker" education and the EDP	STEM self-efficacy, career interest, and understanding of EDP	IDEAS maker program	Pre- and post-test surveys, EDP assessment, observation, interviews	Increased technology/ engineering self-efficacy and understanding of the EDP
Silva et al. (2025)	Portugal	44 students	4 weeks (8 sessions, 30 min per session)	Science, technology, and mathematics	VR learning environments and UDL principles	Cognitive, social, and behavioral skills	Immersive VR-based STEM environments	VABS-II, BASC-3, SSIS, observation, usability surveys	Improvements in adaptive functioning and positive trends in skills
Cox and Root (2018)	USA	2 middle school students	2-3 times per week (first session 30 min)	Mathematics	MSBI	Flexibility in mathematical problem-solving and communication	MSBI presented with visual aids	4-point researcher rubric	Increased problem-solving and explanation skills
McKissick et al. (2018)	USA	3 middle school students	Daily (sessions 12-17 min)	Science	CAI	Science vocabulary	CAI intervention package	Attendance slide shows and social validity surveys	An increase in the number of correct answers and skill acquisition
Knight et al. (2018)	USA	9 elementary students	Two years (4 weeks per unit, 10-60 minutes per lesson)	Science	Scripted and unscripted lessons, constant time delay, system of least prompts, model-lead-test (MLT) procedures	Science learning outcomes, number of sessions required and lesson duration	Lesson plan format (scripted vs unscripted)	6-item assessments, social validity	Both lesson plans were found to be effective. The unscripted ones were considered more efficient.
Knight et al. (2020)	USA	3 high school students	NA (interviews 2-5 min)	Technology and engineering	Explicit instruction method	Code acquisition, generalization, and creation of original code	MLT procedure	Task analysis, reliability data, and social validity	Learned the basic codes, generalized the skill, and created original codes
Root (2019)	USA	1 elementary student	NA (10 min)	Mathematics	Explicit instruction	Acquisition and generalization of mathematic concepts	Explicit instruction	Number of correct identifications, test reliability, IOA	Independent definition of concepts.
McMahon et al. (2016)	USA	4 undergraduate students	3 days a week (sessions 12-15 min)	Science, technology	AR and MLT procedure	Number of correct answers on science vocabulary tests	AR-based vocabulary instruction	Vocabulary tests and social validity survey	Learned the science vocabulary
Apanasionok et al. (2021)	UK	17 elementary students	12 weeks	Mathematics	Systematic instruction	Early numeracy skills	Teaching program	TEMA-3 test, staff surveys, and interviews	Significant improvement in early numeracy skills.
Greene and Bethune (2021)	USA	3 elementary school students	4 days a week (30-35-minute sessions)	Science	Systematic instruction in a group format	Science knowledge (word recognition, definition matching, etc.)	Systematic instruction integrated into group lessons	Response measurements and teacher social validity survey	Increase in science knowledge

Table A1 (Continued).

Studies	Country	n	DS	STEM field	TS	DV	IV	DCT	MS
Ingelin et al. (2021)	USA	3 pre-school pupils	3 days a week (sessions 15-20 mins)	Mathematics	Number chats and systematic instruction	Percentage of correct answers in the early number sense test	Adapted number chats	TEMA-3 and video-recorded assessment sessions	Increased number sense skills
Alabdulaziz and Alamoudi (2026)	Saudi Arabia	40 elementary school students	Every two weeks (4-minute VM clip)	Mathematics, technology	VM and concrete manipulatives	Accuracy rate on fraction problems	Self-Monitoring & manipulatives	Worksheets and social validity questions	Improved accuracy rates
Kellems et al. (2016)	USA	9 undergraduate students	Various tasks (1-3 min)	Mathematics	Video modeling and prompting	Percentage of steps correctly completed in math tasks	VP package delivered via iPad Mini	Task analysis checklist and interviews	Significant gains and maintained skills
Park and Bouck (2022)	South Korea	3 ninth-grade students	8 weeks	Mathematics	Virtual manipulative-based instructional sequence (V-A)	Accuracy in solving equivalent fraction problems	Virtual manipulative-based (VA) intervention	Learning sheets, reliability checklist, and interviews	Acquired the skills and sustained some skills
Gkiolnta et al. (2023)	Greece	2 elementary school students	Weekly for two months (20-minute sessions)	Technology, engineering, mathematics	Structured activities using the 'codey rocky' robot	Social/ communication skills and problem behaviors	Robot-assisted programming and coding activities	Observation data forms and video recordings	An increase in social skills and a decrease in problem behaviors
Denizli-Gulboy et al. (2024)	Turkey	4 elementary students	5 days a week (3 sessions per day, 5-7 min per session)	Science	AR application and CTD	Percentage of AR usage and organ naming	Systematic instruction using the 'our body in 4D' app	Data collection forms and social validity surveys	AR is effective in vocabulary instruction, generalized skills
Ledbetter -Cho et al. (2023)	USA	5 elementary student s	15 weeks	Mathematics	Video-assisted activity schedule (VAS) and video modeling (VM)	Academic performance and frequency of problem behaviors	VAS and VM intervention	Task analysis data sheets and video recordings	Improved academic performance and decreased problem behaviors
Kim et al. (2025)	USA	3 high schools	10 weeks	Science	Shared reading and adapted science e-books	Science comprehension level and task engagement	Use of adapted e-books	Multiple-choice questions and instant-time sampling	Improved reading comprehension and increased engagement
Kiyak and Toper (2023)	Turkey	3 middle schools	Twice daily on weekday s	Science	Real-time feedback via telemedicine	Percentage of correct answers in daily quizzes	Simultaneous prompting procedure via Zoom	Paper-and-pencil data system and semi-structured interview	Increased learning, retained and generalized knowledge
Clees and Clinton (2025b)	USA	Four secondary students	NA	Mathematics	Independently use an iPad to self-deliver video prompts	Percentage of steps correct within each algebraic solution protocol, and percentage of problems correct on novel, untaught problems	Introduction of point-of-view VSP delivered via an iPad	Observational data of procedural steps & Problem-solving accuracy data	Improvement in solving the targeted algebraic equations
Yakubova et al. (2025)	USA	Two elementary school	NA	Mathematics	VM, virtual manipulatives, digital math games, self-monitoring, least-to-most prompting	Math skills	VM, virtual manipulatives, and mathematical games	Observations, independence across trials the degree to which participants completed responses without prompts	Effectively bolster mathematical skills

Table A1 (Continued).

Studies	Country	n	DS	STEM field	TS	DV	IV	DCT	MS
Yakubova et al. (2025) using	USA	1 high school student	NA	Mathematics	Virtual video modeling multi-component intervention	Mathematics and geometry skills	Online multicomponent intervention	Trial-level accuracy records, probe-based assessment sheets, phase-specific skill checklists, maintenance/ generalization indicators	Improvement in the acquisition of mathematics and geometry skills
Ma and Xin (2023)	USA	4 elementary school students	NA	Mathematics	Conceptual model-based problem-solving	Problem-solving abilities	COMPS with the CRA sequence	Criterion-based word-problem solving assessments, session-by-session performance records, criterion tests	Significant improvements in students' problem-solving abilities

Note. n: Number of participants; DS: Duration of the study; TS: Teaching strategy; DV: Dependent variables; IV: Independent variables; DCT: Data collection tools; MS: Main results