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A Systematic Literature Review of Research-based Interventions and Strategies for Students with Disabilities in STEM and STEAM Education

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Abstract

Statistical studies performed mainly in the U.S. have depicted that students with disabilities (SWDs) are excluded from the educational process and are prone to several gaps and barriers in terms of special accommodations, learning opportunities, and socio-emotional support in Science, Technology, Engineering, Mathematics (STEM)-Science, Technology, Engineering, Arts, Mathematics (STEAM) education. To clarify this, we conducted a systematic literature review focused on interventions and strategies in STEM and STEAM education for SWDs based on 263 studies retrieved from the databases SCOPUS, Web of Science (WoS), and ERIC from 2013–2024. The studies cover proposals from early childhood to tertiary education. After the screening and appraisal stages, 39 interventions with 21 strategies were identified. The outcomes mostly reveal the following: (1) The studies are mainly focused on the U.S. and in students with autism, learning disabilities, or behavioral disorders between low and medium severity levels. (2) Interventions for autistic students use robotics and coding to foster cognitive, social, and communicative skills. (3) Interventions for deaf or hard-of-hearing students focus on creating a science identity and the issues with non-standardized STEM concepts in American sign language (ASL); in contrast, visually impaired students focus on assistive technologies and the accessibility of educational materials. (4) Little attention has been paid to other disabilities apart from autism, intellectual or learning ones, as well as the perspective of educators to support SWDs in classrooms. And (5) New machine learning, metaverse, and AI models are being used to assess the cognitive-emotional states of the SWDs. The conclusions and insights derived from this study can help educators and researchers to create new methodologies or strategies that sustain SWDs in STEM-STEAM education.

Keywords Students with disabilities · Inclusion · STEM education · STEAM education · Systematic literature review

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Introduction

Studies on Science, Technology, Engineering, Mathematics (STEM)-Science, Technology, Engineering, Arts, Mathematics (STEAM) education for students with disabilities (SWDs) claim that this group is underrepresented and suffers exclusion in their educational process. They do not have the same opportunities for participation, engagement, and retention rates as non-disabled students in STEM programs from K-12 levels to tertiary education (Cech, 2023; Griffiths et al., 2021; James & Singer, 2016; Lee, 2022; Shattuck et al., 2014). Some of the prior studies show that SWDs striving to enroll, graduate from schools and higher education institutions (HEIs), and have issues with employment opportunities, labor force, and access to postgraduate programs of master´s and doctorate (Cech, 2023; Lee, 2014; National Science Foundation, 2023). Conversely, the interest in education for SWDs has gained relevance and attention in the last two decades (Amor et al., 2019). It is not surprising that policymakers, governments, and transnational agencies like the United Nation (UN) or United Nations Education Scientific and Cultural Organization (UNESCO) have tried to find a solution to this context of SWDs. Thus, some policies and guidelines have been proposed, some of them mainly in the U.S., such as *the Perkins Act*, *the Individuals with Disabilities Education Act* (IDEA), the principles of *Universal Design Learning (UDL)* for instructional design (see studies Basham & Marino, 2013; Fovet, 2021; Schreffler et al., 2019), and more recently the *Convention on the Rights of Persons with Disabilities* (CRPD) by the UN (UN, 2023).

However, despite these initiatives, teachers have asked for assistance regarding teaching and engagement of SWDs in STEM-STEAM educational settings. Herein, literature reports that SWDs in these settings cope with several issues and barriers regarding accommodations, self-advocacy, teacher and faculty support, instructional design, emotional distress, and social isolation (Cech, 2023; Lee, 2014; Wang et al., 2024). Indeed, several Higher Education (HE) instructors admit not having the pedagogical expertise to create differentiated tasks or activities focused on SWDs that help to achieve the purposes or goals in the courses (Fovet, 2021; Melese & Tinoca, 2019).

Searching to clarify these points, this study aims to investigate and describe educational research-based interventions (instructional practices that have been researched and determined to be effective) and their strategies from 2013–2024 that help educators to identify and analyze the implications, issues, and challenges of STEM-STEAM education in the community of SWDs. This information can contribute to the pedagogical reflection about *how* to construct meaningful learning spaces that foster participation and inclusion for SWDs.

At this point, we expose two central points in this study. Firstly, we understand inclusive education as a synonym of special education that attends and meets the special needs or requirements of SWDs, and this is the primary focus of this study. Secondly, our attention is put on Science, Technology, Engineering, the Arts, and Mathematics (STEAM) initiatives wherein the Arts have been integrated to foster creativity and expression of the SWDs. Nevertheless, we also include the traditional STEM approach, where the focus is on the resolution of problems based on concepts and procedures from science and mathematics, which incorporate the strategies applied in engineering and the use of technology (Aguilera & Ortiz-Revilla, 2021; Shaughnessy, 2013). Hence, we prefer to use the terms STEM and STEAM education separately to describe the study's findings.

Background

We identified several prior reviews focused on SWDs and STEM-STEAM education. Scalise et al. (2018) describe assessment accommodations and UDL practices within the context of emerging technologies in STEM education. The authors emphasize the importance of implementing UDL principles, considering individual needs and preferences, and ensuring content accessibility. Moody et al. (2018) synthesize some key strategies for ASD students, which include early intervention and focus on individual skills; incorporating predictors for post-school success, such as career awareness, work experience, self-advocacy, social skills, and transition programs; Addressing deficits in social, communication, and behavioral skills through targeted support and accommodations; and designing STEM experiences in the UDL context. Knight et al. (2020) provide a review of research studies on teaching science to students with intellectual and developmental disabilities (ID/ASD). The authors pointed out several key points such as the importance of using evidence-based practices to teach scientific content, the significance of providing students with disabilities the opportunity to learn about science, and the need for additional research to evaluate effective instructional strategies for teaching science to students with ID/ASD. Schreffler et al. (2019) identified 17 empirical studies evincing effective UDL strategies in the postsecondary setting, with 15 studies showing positive outcomes. The researchers manifest a gap in systematic reviews addressing UDL in STEM fields.

Studies about SWDs through data retrieved from the *National Longitudinal Transition Study 2* (NLTS2) and *Dataset the Education Longitudinal Study of 2002* (ELS:2002) conducted by the U.S. Department of Education and standardized assessments mainly in the U.S. depict some key factors to bear in mind for SWDs in STEM-STEAM education (Gottfried & Sublett, 2018; Lee, 2014, 2022; Shattuck et al., 2014). For instance, the identification of SWDs is a hard issue in students with low or moderate learning disabilities. Thus, SWDs with this condition do not report that they need assistance or special accommodations for their disabilities. This causes several *hidden disabilities* to be presented in the classrooms, which in many cases are not detected and diagnosed. In addition, few financial aids have been deployed to diagnose SWDs (Santos et al., 2019). The prior studies highlight a big issue for SWDs: Their context and educational practices are invisible. This has been a reason to criticize and promote changes, e.g., in the National Science Education Standards in the U.S. (National Science Foundation, 2023; Rodriguez, 1997). National Science Foundation (NSF) in the U.S. has made an effort to create supporting practices for SWDs as well as to promote the development of educational projects that benefit them, e.g., *The Readiness Academy* (Tsinajinie et al., 2021) or

NSF-funded Research Experiences for Undergraduates (REU) (National Science Foundation, 2024). Similarly, the release of reports such as *Diversity and STEM: Women, Minorities, and Persons with Disabilities* (National Science Foundation, 2023) has helped to understand the context of SWDs.

Additionally, most of the studies identified in this SLR focus on students with low to moderate learning disabilities or students with autism spectrum disorder (ASD), see, i.e., (Pilotte & Bairaktarova, 2016; Wei et al., 2013, 2014, 2017). Seemingly, students with ASD are prone to study STEM-related majors and even students without disabilities currently enrolled in these majors could exhibit personal traits related to ASD (Baron-Cohen et al., 1997; Kumari & Sharma, 2020; Turner et al., 2021). Particularly, in the U.S., students with ASD have been enrolled in two-year community colleges at some point in their postsecondary education (Wei et al., 2014). The potential benefit of this fact is that SWDs in these colleges are twice as likely to be enrolled in four-year university programs as other ASD students who were not enrolled in these colleges (Wei et al., 2014).

We observed several trends in the prior studies that served as arguments for performing this study. Firstly, as described, many empirical studies are focused on SWDs with learning disabilities and ASD, which we think are common in educational settings. Nonetheless, SWDs have a variety of disabilities, and each disability has a way of coping effectively with it in classrooms. We think that literature lacks describing methodologies in STEAM education that encompass other disabilities or disorders such as physical, communicative, or socio-emotional. Secondly, some reviews and statistical studies mentioned synthesize the *overall characteristics* of SWDs in educational settings but do not expose educational methodologies and strategies designed by educators to support them. Even in top-cited reviews in STEAM education such as the ones in references (Chomphuphra et al., 2019; Li et al., 2020, 2022; Martín-Páez et al., 2019; Nguyen et al., 2021), it seems that the interest of researchers and educators in STEM-STEAM is focused on other topics such as, e.g., cognitive, affective, racial, ethnicity, or gender factors for non-disabled students, and not properly in the community of students with disabilities.

In this way, we search for complementing the previous studies, describing not only the overall characteristics of SWDs but navigating into the pedagogical particularities and insights of empirical studies in STEM-STEAM education for SWDs. This analysis can support educators and researchers to understand the panorama of SWDs and encourage them to create or enhance educational methodologies and instructional methods based on the evidence presented in this study.

Method

We performed a systematic literature review (SLR) based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Page et al., 2021) in the timeframe 2013–2024. These years mark the increase of interest in STEM-STEAM education for SWDs. Systematic reviews search for answering research questions to identify and reveal current gaps, contrast hypotheses, or expand the scope of topics in a particular knowledge area (Gough et al., 2017). The SLR followed the stages provided by Gough et al. (2017), which are summarized as follows: (1) Formulate research questions and conceptual framework; (2) Search and screen for inclusion with eligible criteria; (3) Code to match a conceptual framework; (4) Apply quality appraisal criteria; (5) Synthesize the studies using a conceptual framework or study codes; and (6) Interpret and communicate the findings. Figure 1 describes the PRISMA flow diagram tailored for the study.

Research Questions

For the study, we formulated a set of Research Questions (RQs), which are listed as follows:

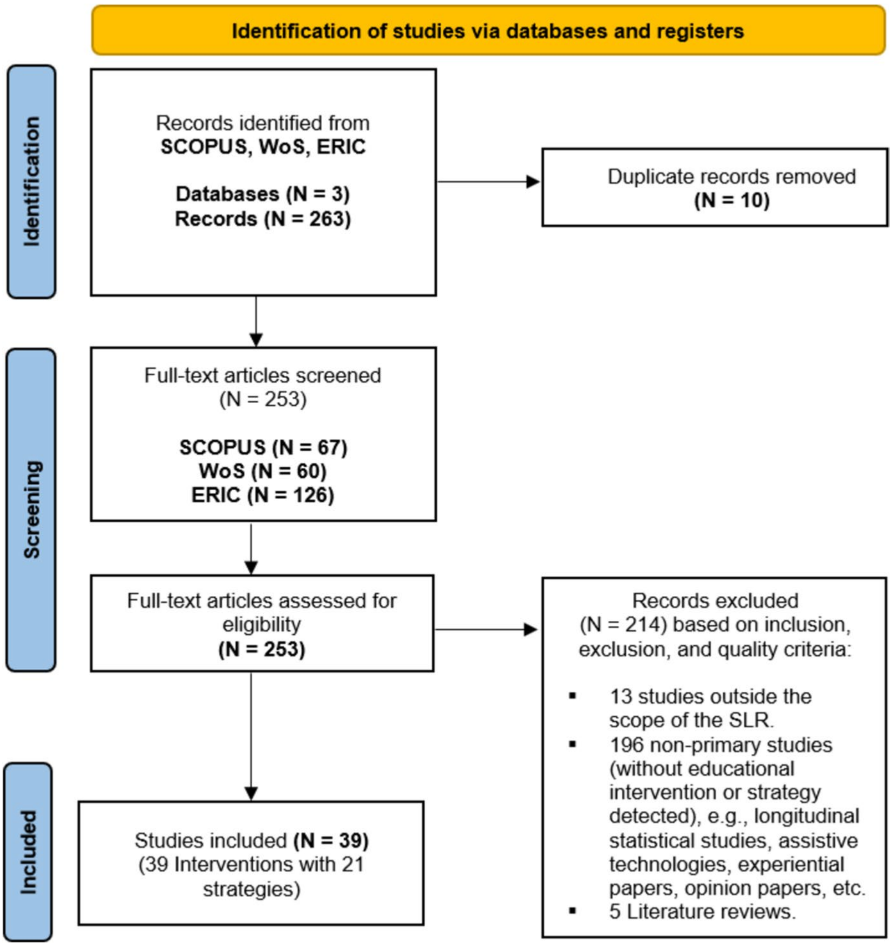

Fig.1 PRISMA flow diagram tailored for the SLR

RQ1. What are the bibliometric features and research trends of the studies on STEM-STEAM education for SWDs?
RQ2. What are the interventions and strategies for SWDs in STEM-STEAM education alongside their main educational outcomes and conclusions?
RQ3. What challenges and recommendations were identified in STEM-STEAM education for SWDs based on the studies identified?

For RQ1, we describe and inform the overall features of the studies in terms of bibliometric trends, e.g., top cited publications, journals, disabilities addressed, educational level, and topic clusters, among other features. In RQ2, we synthesize and describe educational interventions and strategies performed for SWDs with their learning outcomes in the cognitive, affective, behavioral, or psychomotor learning domains. Finally, in RQ3, we outline the current challenges of STEM-STEAM education for SWDs based on the studies analyzed and we indicate some recommendations and practical steps to implement them. In the SLR, we adopted an approach starting from the general characteristics in the included studies and navigating to their pedagogical particularities.

Searching Procedure

The search process was conducted in the scientific databases SCOPUS, Web of Science (WoS), and Education Resources Information Center (ERIC) with the respective string queries, inclusion, and exclusion criteria reported in Table 1. The search strings were based on the Individuals with Disabilities Education Act (IDEA) (Dragoo, 2017) in the following categories for disabilities: Autism, deaf-blindness, deafness, emotional disturbance, hearing impairment, intellectual disability, orthopedic impairment, specific learning disabilities, speech or language impairment, traumatic brain injury, and visual impairment including blindness. Similarly, we added the terms *disabled people*, *persons with disabilities*, or *people with disabilities*, which are used by the UN or World Health Organization [WHO] in documents such as the strategy for disability inclusion (UN, 2022), the WHO policy on disability (WHO, 2021), and the Convention on the Rights of Persons with Disabilities (CRPD; UN, 2023).

Query strings in Table 1 were obtained after a continuous refinement of their terms. For instance, our first strings only contained the words “persons with disabilities” or “people with disabilities” from which we only retrieved a few records. Then, we decided to add specific terms based on disabilities, disorders, or emotional disturbances such as “autism”, “learning disabilities”, “disabled people”, “ADHD”, “visually impaired”, and “blind”, among others, to extend the search process and comprise more interventions for SWDs. These disabilities, emotional disturbances, and disorders were taken from the study by Bianquin and Bulgarelli (2017), which relates to the disability categories indicated by the IDEA document. We used specific field codes such as TS or TITLE-ABS-KEY in the databases. The last search was performed on June 1, 2024.

Table 1 Description of searching criteria for the SLR

Aspect	Description
Timeframe	2013–2024
Databases	SCOPUS, WoS, ERIC
Searching Strings	▪ **WoS**: TS = (("disabled people" OR "persons with disabilities" OR "people with disabilities" OR "autism" OR "ADHD" OR "down syndrome" OR "learning disability") AND ("stem education" OR "steam education")) ▪ **WoS:** TS = (("visually impaired" OR "blind" OR "deaf" OR "mute" OR "motor disability" OR "hard of hearing") AND ("stem education" OR "steam education")) ▪ **SCOPUS**: TITLE-ABS-KEY(("disabled people" OR "persons with disabilities" OR "people with disabilities" OR "autism" OR "ADHD" OR "down syndrome" OR "learning disability") AND ("stem education" OR "steam education")) ▪ **SCOPUS:** TITLE-ABS-KEY(("visually impaired" OR "blind" OR "deaf" OR "mute" OR "motor disability") AND ("stem education" OR "steam education")) ▪ **ERIC**: ("stem education" OR "steam education") AND ("disabled people" OR "persons with disabilities" OR "people with disabilities" OR "autism" OR "ADHD" OR "down syndrome" OR "learning disability") ▪ **ERIC:** ("visually impaired" OR "blind" OR "deaf" OR "mute" OR "motor disability" OR "hard of hearing") AND ("stem education" OR "steam education")
Inclusion criteria	Primary studies on STEM or STEAM education for SWDs Studies in English
Exclusion criteria	Studies outside STEM or STEAM education for SWDs Not in English Not primary research, e.g., literature reviews, metanalysis, books, longitudinal statistical studies, etc Preprints or gray literature
Total records obtained	SCOPUS (67), WoS (60), ERIC (136). **Total** (263)

Screening, Eligibility, and Appraisal Criteria

Retrieved records in the databases ($n = 263$) were added to the software Mendeley in the format research information system (RIS) to check duplicates ($n = 10$) and complete missing information such as authors, DOI, abstract, keywords, or publisher. Each one of the 253 remaining articles was read completely and assessed according to a quality survey available in Appendix 1. The survey took into account: (1) inclusion and exclusion criteria in Table 1, (2) description of the context and methodology, (3) incorporation of a quantitative, qualitative, or mixed approach, (4) evidence of learning outcomes in the levels of cognitive (knowledge and its related skills), affective (attitudes, motivation), psychomotor (coordination, developed motion-skills), or behavioral (developed behaviors, e.g., socialization, communication, and organization skills), which are called domains of learning (Hoque, 2016; Mallillin, 2020), and (5) quality in the implications, further work, and conclusions of the study. For each approved article, several comments regarding its aim, study population, disability, methodology, outcomes, and a brief synthesis were added. When a borderline article was found, both authors reviewed it completely, and afterward, both researchers discussed its inclusion or exclusion based on the purpose of the review and the RQs proposed. Under this procedure, we achieved 100% agreement in the main corpus of the studies identified.

Data Extraction and Analysis of the Studies

After the previous procedure, from $n=253$ articles initially screened, $n=39$ articles passed the appraisal criteria. These articles were added to the software VOSViewer and the Python Crossref REST API to respond to the RQ1. VOSViewer is a software for bibliometric analysis based on network data that is focused on items and clusters with two overall functions: create maps and visualize them. The Python Crossref REST API is a tool that allows extracting bibliometric information such as citations, authors, publishers, type of study (journal article, conference proceedings, book chapter), or articles per year, among other features. The API was used with Python language to extract the bibliometric features of the studies. We selected these tools because they are well-known and open-access utilities to perform scoping and systematic reviews which have been used in diverse studies in the scope of this study (see, i.e., references Husaeni et al., 2022; Radević & Milovanović, 2024; Sarasola Sánchez-Serrano et al., 2020). With the previous software, we extracted the bibliometric features and trends of the studies. We noticed that several of the $n=214$ articles excluded were statistical studies (based on data mainly retrieved from the *National Longitudinal Transition Study 2* (NLTS2), and the *High School Longitudinal Study of 2009* (HSLS:09) in the U.S.), experiential reports, and evaluation of assistive technologies (ATs). Excluding these studies, we synthesized 39 interventions with 21 strategies. Each one of the interventions was classified by the educational level according to UNESCO in the document *International Standard Classification Education (ISCED)* (UNESCO, 2011), research approach, type of disability addressed, learning outcomes, and challenges reported.

Reporting the Results

Guidelines proposed by (Webster & Watson, 2002) were considered for writing the review in aspects such as identifying relevant literature, exposing results based on a concept-centric approach, presentation of tables and figures, and synthesis structure. Results are presented according to the described Research Questions (RQs). In the following link, readers can find detailed descriptions of the interventions and the educational strategies identified with the example information depicted in Fig. 2.

#	Citation	Disability-Disorder	STEAM Field	Research Approach	Participants-Educational Level	Outcomes-conclusions
1.	(Jackson & Hanline, 2020)	ASD	Reading/science textbook comprehension	Quantitative/ Single-case research design	Two 5-years-old children/Primary education	Concept maps enhance reading comprehension and language skills in young students with ASD by connecting new visual information with previous knowledge, but content should be carefully selected to avoid scaring students.

Strategy	Description	Disability-Disorder	Educational Level	Rationale for the strategy	Ref. evidence-based strategy
1. Explicit instruction, model-lead-test (MLT)	Students work directly with the instructor/researcher to learn one topic, e.g., in programming or robotics, and the purpose of the performed task. Topics are explicitly taught and capture the attention and interests of the SWDs.	ASD, Down Syndrome, ADHD, EBD	Primary	Explicit instruction (EI) aids in capturing the attention of ASD/Down syndrome students and helps them to follow procedures and complete sequences, e.g., in robotics or computer programming.	(Knight, Wright, & DeFreese, 2019; Knight, Wright, Wilson, et al., 2019; M. S. Taylor et al., 2017)

Fig.2 Example of information provided in the link by intervention and strategy

Interventions https://doi.org/10.5281/zenodo.14675637
Strategies https://doi.org/10.5281/zenodo.14675637

Results

RQ1. What are the Bibliometric Features and Research Trends of the Studies on STEM-STEAM Education for SWDs?

Bibliometric Trends

Figure 3 depicts the distribution of the articles per year with a relative peak of nine proposals in the year 2019 and a relative trend to increase this number from 2013 (see purple line). In 2019, several interventions included coding and robotics for students with ASD (Fisher et al., 2019; Knight et al., 2019a, b). According to the authors, robots can create links between learning and experimentation, which can foster the interest of the SWDs in STEM.

Robotics with coding is a method for students with ASD to cooperate with other peers and improve their social and communication skills, e.g., when they participate in competences like FIRST LEGO (Fisher et al., 2019). ASD students are more engaged during the construction of the robots instead of their programming (Fisher

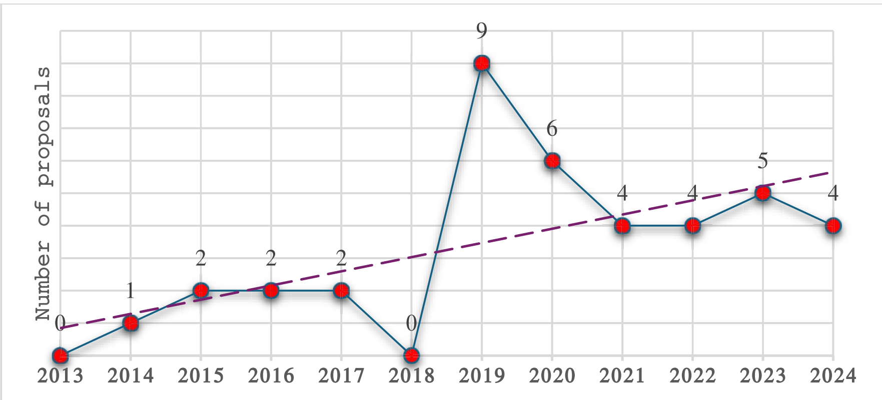

Fig.3 Distribution of the proposals per year from 2013–2024. N = 39. The trend line is marked in purple

et al., 2019). Proposals that use robotics have demonstrated impacts on learning and coding mastery several weeks after the intervention time (Knight et al., 2019a, b).

Another trend observed this year is the number of proposals oriented to deaf and hard-of-hearing students (Bao, 2019; Marchut & Gormally, 2019; Ross et al., 2019). These proposals point out two points: On one hand, there is a need to create a connection between the contents and the personal experiences of deaf students in science. On the other hand, the construction of a scientific identity through role models and inquiry laboratories. Marchut and Gormally (2019) have shown that deaf students develop a scientific identity only when they are in laboratory settings and not in the long term. The incorporation of inquiry laboratories (those that include inquiry around personal experiences and hypotheses about the phenomenon studied) strengthened the attitudes and identity of the students towards science. Role models (people with disabilities who are scientific and work in the STEAM field) can benefit the construction of this identity because SWDs can see their value and impact in STEAM fields (Ross & Yerrick, 2015). Table 2 shows the top 5 cited articles during the timeframe of the SLR.

The most cited article in Table 2 (Supalo et al., 2014) is a study of a set of Workshops offered to the community of blind or visually impaired students enrolled in a chemistry course. Some factors are mentioned that influence the students to enter STEM-related majors such as confidence and feeling part of a students' group. Taylor et al. (2017) depict how to teach coding to children with Down syndrome using tangible blocks and programming in Blockly to move a robot. Machine Learning (ML) models are used in the study carried out by Moon et al. (2020) that describes an automatic assessment system with machine learning (ML), which has been embedded into a virtual reality world that allows to evaluate the ASD students' emotions and flexibility.

For $n = 39$ interventions analyzed, 58.97% is for ASD, ADHD, or LDs students, 17.94% is for deaf or hard-of-hearing students, 15.38% is for blind or visually impaired students, and the remaining 7.69% is for overall disabilities. This trend is consistent with prior statistical and longitudinal studies (Gottfried et al., 2021; Wei et al., 2013, 2014). As mentioned, this trend could be due to students with ASD being prone to studying STEM-related majors, and students without disabilities currently in these could exhibit ASD traits. This is not odd if we consider that curricular activities in STEM tend to be individual with a central presence of problem-solving tasks and a minor development of social and communication skills. Also, in the case of SWDs with LD, STEM education emphasizes the development of cognitive skills, and this could be the reason why LDs are evident in classrooms when students repeatedly do not understand a subject or fail their exams. For instance, as we will see in Table 3, most of the methodologies identified in this SLR develop cognitive learning outcomes in contrast with affective, psychomotor, or behavioral ones. This leads us to assume that activities in STEM-STEAM education for SWDs are oriented primarily toward the cognitive learning domain.

Another noticed trend is the high number of proposals from the U.S. vs. the rest of the world. Around 90% of interventions come from the U.S., while the remaining come from countries such as the U.K., Canada, Nigeria, and the Republic of South Africa. This could be considered as a gap because we do not have a consistent

Table 2 Top 5 of cited articles during 2013–2024

Article Title	Citations	Authors	Journal	Year
1. Making Hands-On Science Learning Accessible for Students Who Are Blind or Have Low Vision	48	Supalo et al. (2014)	Journal of Chemical Education	2014
2. Computer Programming with Early Elementary Students with Down Syndrome	32	Taylor et al. (2017)	Journal of Special Education Technology	2017
3. Automatic assessment of cognitive and emotional states in virtual reality-based flexibility training for four adolescents with autism	28	Moon et al. (2020)	British Journal of Educational Technology	2020
4. Speaking up: a model of self-advocacy for STEM undergraduates with ADHD and/or specific learning disabilities	24	Pfeifer et al. (2020)	CBE—Life Sciences Education	2020
5. Teaching Digital, Block-Based Coding of Robots to High School Students with Autism Spectrum Disorder and Challenging Behavior	17	Knight et al., (2019a, b)	Journal of Autism and Developmental Disorders	2019

Table 3 Synthesis of the interventions. N = 39. Please refer to the appendix section for abbreviations, n.t: non-tertiary. Learning domains developed (C: cognitive, A: affective, Ps: Psychomotor, B: Behavioral)

#	Citation	Disability or disorder	STEAM Field	Educational Level	Learning Domains Developed			
					C	A	Ps	B
1	(Jackson & Hanline, 2020)	ASD	Reading, science	Primary education	X	X		
2	(Knight et al., 2019a)	ASD, ADHD, EBD	Coding, robotics	Primary education	X	X		
3	(Taylor et al., 2017)	Down syndrome	Coding, robotics	Primary education	X			
4	(Gkiolnta et al., 2023)	ASD	Coding, robotics	Primary education	X	X		X
5	(Kugler & Kárpáti, 2023)	ADHD, LD	Arts, Math	Primary education	X	X		
6	(Sari et al., 2023)	SLD	Arts, Math, Science	Primary education	X	X		
7	(Wright et al., 2021)	ASD	Coding, Robotics	Lower secondary education	X			
8	(Lindsay, 2020)	ASD, Cerebral palsy	Robotics	Lower secondary education	X	X		X
9	(Samuels & Poppa, 2017)	ASD	Math, Robotics	Lower secondary education	X	X		
10	(Choo et al., 2021)	MLD	Math, spatial ability	Lower secondary education	X			
11	(Chen et al., 2022)	ASD	Prototyping, tinkering	Lower secondary education	X			X
12	(Lu et al., 2022)	LD	Coding, arts	Lower secondary education	X	X		
13	(Murthi et al., 2024)	ASD	Engineering	Lower Secondary education	X	X		X
14	(Moon et al., 2020)	ASD	Physics	Upper secondary education	X	X		
15	(Michalek et al., 2020)	ASD	Robotics	Upper secondary education				X
16	(Gallup et al., 2016)	ASD	STEM general	Upper secondary education				X
17	(Knight et al., 2019b)	ASD, DD	Coding, robotics	Upper secondary education	X			
18	(Renken et al., 2021)	Deaf, hard-of-hearing	Genetics, biology	Upper secondary education		X		X
19	(Wegwerth et al., 2023)	Visually impaired, Blind	Chemistry	Upper secondary education	X			
20	(Mystakidis et al., 2024)	Deaf	Technology, Science	Upper Secondary education	X	X		X
21	(Dos Santos, 2022)	All disabilities (general)	Biology	Lower/Upper secondary education		X		
22	(Fisher et al., 2019)	ASD, EBD	Coding, robotics	Lower/Upper secondary education		X		X
23	(Supalo et al., 2014)	Visually impaired, Blind	Chemistry	Lower/Upper secondary education	X	X		
24	(Sokolikj et al., 2023)	ASD	Physics	Lower/Upper secondary education	X			

Table 3 (continued)

#	Citation	Disability or disorder	STEAM Field	Educational Level	Learning Domains Developed			
					C	A	Ps	B
25	(Hahn et al., 2019)	Visually impaired, Blind	Math	Lower/Upper secondary education	X	X		
26	(Adelakun 2020)	Visually impaired, Blind	Biology	Lower/Upper secondary education	X			X
27	(Moon et al., 2015)	All disabilities (general)	STEM general	Post-secondary education (n.t)		X		X
28	(Todd, 2015)	All disabilities (general)	STEM general	Post-secondary education (n.t)		X		X
29	(Pfeifer et al., 2021)	ADHD, SLD	STEM general	Tertiary education				X
30	(Pfeifer et al., 2020)	ADHD, SLD	STEM general	Tertiary education				X
31	(Smith & Rayfield, 2019)	LD	Engineering	Tertiary education	X			
32	(Bao, 2019)	Deaf, hard-of-hearing	Engineering	Tertiary education	X			
33	(Clark et al., 2022)	Deaf, hard-of-hearing	Chemistry	Tertiary education	X			
34	(Marchut & Gormally, 2019)	Deaf, hard-of-hearing	Biology	Tertiary education		X		X
35	(Marshall et al., 2016)	Deaf, hard-of-hearing	Engineering	Tertiary education	X			
36	(Kearney-Volpe et al., 2019)	Visually impaired, Blind	Programming, coding	Tertiary education	X			
37	(Ross et al., 2019)	Deaf, hard-of-hearing	Chemistry	Tertiary education	X			
38	(Zaghi et al., 2023)	ADHD	Engineering	Tertiary education		X		X
39	(Peleg et al., 2024)	Visually impaired, Blind	Chemistry	Tertiary education	X			

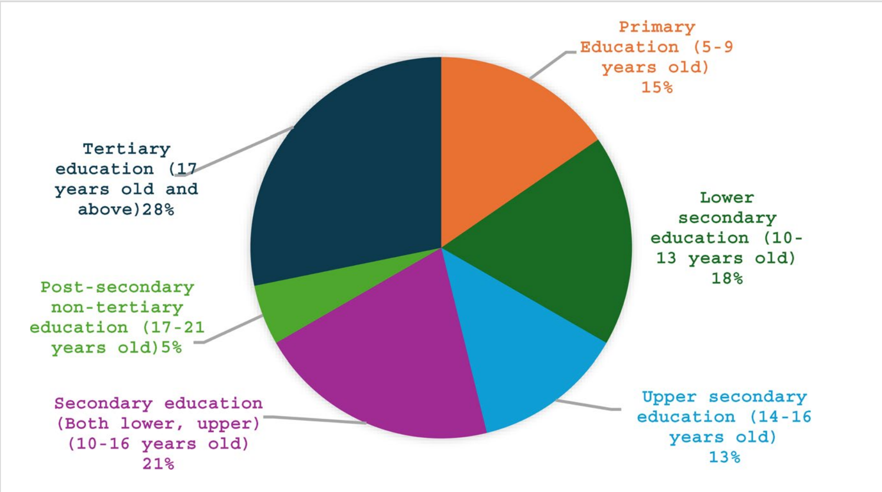

Fig.4 Distribution of the interventions by educational level and age range. N = 39

number of proposals from other countries, showing the context of SWDs in STEAM fields.

Figure 4 shows the distribution of the educational level and age range for the interventions in SLR. The main part of these studies was developed for adolescents from lower secondary education to post-secondary non-tertiary education (community colleges) (57%), while no proposals were identified for early childhood education (age under 5 years old). The age range of the participants in the proposals is from 5 to 35 years old. Figure 5 shows the distribution of proposals per STEAM field in reading (scientific book comprehension), coding and robotics, arts, physics, technology, chemistry, and general STEM (specific area not indicated). There, Fig. 5 illustrates a predominance of coding and robotics-based practices for ASD and ADHD students.

About the research approaches of the interventions (quantitative, qualitative, mixed, AI), 48.71% of the proposals have a quantitative approach, 33.33% a qualitative approach, 12.82% a mixed approach, and 5.28% an AI one. The quantitative proposals use a variety of methods to collect information and analysis strategies, among which the most important are the following: Single-case study, pretest–posttest, descriptive statistics of surveys, factor size, and ANOVA. In the case of the qualitative approach, studies combine participant and non-participant observation with thematic analysis, focus groups, semi-structured interviews, and video recording analysis. As for the mixed approach, studies combine descriptive statistics of surveys with thematic analysis of the interviews and participant diaries.

Topic and Cluster Trends

Figure 6 depicts the cluster map produced by the software VOSViewer for the studies' keywords. The map shows the co-occurrence of terms (keywords) in the studies.

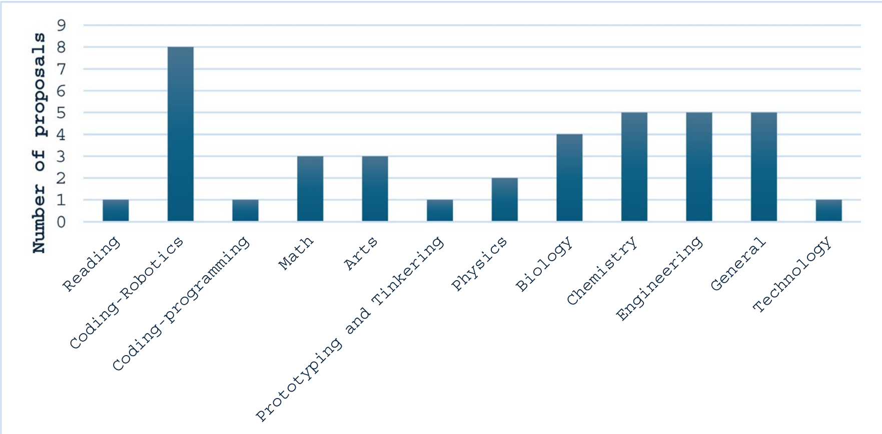

Fig. 5 Distribution of the interventions per STEAM field. N = 39

We merged some terms that either were repeated or were synonyms to create a compact cluster map.

Herein, interventions for ASD students are commonly related to *robotics, coding, or programming* (see green cluster), which confirms our hypothesis in the preliminary searches of the SLR: Interventions for SWDs are dominated by studies for developmental and learning disabilities.

Another cluster in Fig. 6 is regarding *high school, self-advocacy, and accommodations* (see red cluster). The studies related to these terms expose how accommodations such as adaptations in the instructional contents or time extension to deliver exams can help SWDs to be more motivated and engaged in STEM courses (Petz & Miesenberger, 2015; Scalise et al., 2018). As for self-advocacy, this term has a relationship with the capability to self-recognize a disability and utter accommodations

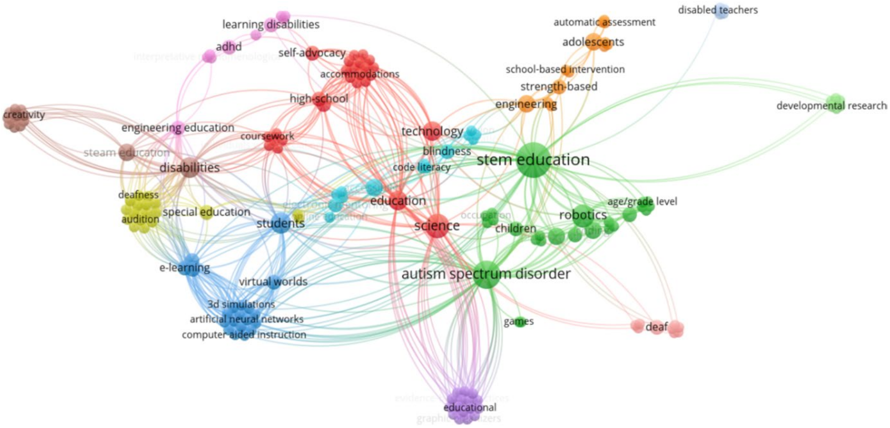

Fig. 6 Cluster map for the keywords in the studies

according to the special needs detected. Even some studies propose a protocol for accommodations with the help of instructors and institutions (see references Pfeifer et al., 2020, 2021). Accommodations and self-advocacy have been reported as factors for the academic success of SWDs in higher education (Pfeifer et al., 2021; Santos et al., 2019).

Another cluster in Fig. 6 is concerning *virtual worlds, 3d simulations, e-learning, and artificial neural networks* (see blue cluster). Mystakidis et al. (2024) have asserted that students with disabilities, e.g., deaf students, are prone to use virtual representations such as avatars or 3D models because students can express their beliefs and ideas through them. Similarly, Moon et al. (2020) and Sokolikj et al. (2023) explore virtual environments to improve representational flexibility (RF) in ASD students. RF refers to how individuals with ASD can adapt to new situations and can create alternative representations in information processing, which is associated with analytical thinking in STEM problem-solving tasks (Moon et al., 2020).

Concerning the orange cluster with keywords *engineering, strength-based, school-based intervention, adolescent, and automatic assessment*, Zaghi et al. (2023) indicate the importance of strength-based education for SWDs instead of the traditional approach focused on the issues evidenced by them. Fostering strengths of SWDs, for example, in ADHD students, can enhance their autonomy, competence, and relatedness. Other tiny clusters are presented with the keywords *disabled teachers* (see study Dos Santos, 2022), *developmental research, blindness, code literacy*, and *deafness*.

RQ2. What are the Interventions and Strategies for SWDs in STEM-STEAM Education Alongside their main Educational Outcomes and Conclusions?

Interventions

We synthesized thirty-nine interventions with their respective learning outcomes and conclusions in the link in subsection 3.5 (reporting the results). Table 3 shows a synthesis of the interventions and learning outcomes developed. The following sections describe a summary of the interventions and strategies identified.

Autism, Emotional Disturbance, Intellectual Disability, Specific Learning Disability Interventions for ASD, ADHD, or emotional and behavioral disorder (EBD) include the usage of robotics and coding through block-based programming. The intention is to promote the improvement of social and communication skills as well as abilities in programming and coding. Resiliency, self-determination, self-efficacy, and the changing of stereotypical behaviors have been reported as aspects to highlight with the methodologies (see references Gkiolnta et al., 2023; Knight et al., 2019a, b; Lindsay, 2020; Wright et al., 2021). Robots could be a personal projection in which ASD students can have interactions with other peers without violating social rules (Samuels & Poppa, 2017). The main part of these studies uses the single-case research design as an approach with a range of one to six students as participants. This evidences that these interventions are focused on a small number of students and the generalization in some cases is difficult in contexts where the rate of SWDs is higher. Despite this, the previous studies exhibit that interventions with robotics on ASD students can improve social skills and influence executive function during and after the interventions.

Similarly, the interaction of ASD students in the competitions of FIRST LEGO robotics has promoted the increase of social skills, emphasizing the support of the parents and teachers as a success factor as well as the integration of extracurricular activities (Fisher, 2017; Lindsay, 2020). Robots can increase kinesthetic arousal during their construction (Michalek et al., 2020). However, this result was achieved through a specific instructional method where some non-disabled adolescents served as peers for SWDs in the proposed activities. Taylor et al. (2017) expose a proposal for Down Syndrome students with robotics and block-based coding to teach the fundamentals of computer programming. The methodology aimed to improve inquiry and problem-solving skills and reduce consecutively the number of errors exhibited by the students between baseline and intervention phases.

In the case of science text comprehension, Jackson and Hanline (2020) provide a study about how to improve comprehension of science textbooks for ASD students. Through textbook readings and a protocol, the teacher inquires students with a set of questions about the text, searching to observe the grasping of the concepts. The mothers of the participants noticed an improvement in the answers to the questions during the shared readings.

For mathematics to develop spatial thinking ability, Choo et al. (2021) propose a methodology to help students acquire or develop spatial thinking for 2D and 3D models. The authors claimed that although 3D printing is a technology widely used in STEM education, students with math learning disability (MLD) struggle with this ability, especially, in spatial perception, mental rotation, and spatial visualization. The study shows how the methodology aided the students through pretests and posttests using the standardized Spatial Thinking Ability Test (STAT).

Regarding machine learning (ML) and AI, two works used them to track the representational flexibility (RF) of ASD students (Moon et al., 2020; Sokolikj et al., 2023). Through ML techniques based on audio and videos of the performance of ASD students in a Virtual Reality (VR) world, the researchers identified the different cognitive-emotional states of the students when they performed a Newtonian physics-related activity. The system is feasible to track the students and help them to improve their RF.

Three proposals explore the Arts to foster the engagement of ADHD and LD students. Lu et al. (2022) show how arts combined with PBL and Micro:Bit development boards can help students with LD to perform programming tasks during the intervention and post-intervention stages. Kugler and Kárpáti (2023) indicate how gathering arts, math (geometrical ability-Monge axonometry), and experience-based instruction can facilitate learning and provide meaning for students with ADHD and LD. Finally, Sari et al. (2023) expose a study where the arts have been combined with the traditional STEM approach to foster the learning of SLD students. After the intervention, most of the students performed well in activities with Math, Science, and Engineering. STEAM-based activities tailored to Individualized Education

Plans (IEPs) can positively influence academic achievements. All these interventions are between the primary and lower secondary school levels.

Deafness, Hearing Impairment Eleven proposals entail methodologies for blind, visually impaired, and deaf or hard-of-hearing students. In the case of proposals for deaf and hard-of-hearing students, Clark et al. (2022) and Renken et al. (2021) expose the difficulties that face students due to that many concepts in STEAM do not have standardized representation in ASL. This is a barrier and could be a cause of the low enrollment rate of deaf students in STEAM fields and dropout rates in bachelor degrees (Clark et al., 2022; Ross et al., 2019). To cope with this situation, Clark et al. (2022) have created a proper lexicon that fosters the teaching of organic chemistry concepts. With this method, the students increased their academic performance in the course. Marchut and Gormally (2019) have demonstrated that deaf students adopt an identity as scientists only when they are in laboratory settings. Therefore, this proposal emphasizes the need to construct a science identity for the long term, which can guarantee that more deaf students are enrolled in STEAM majors. Also, to construct the identity, the connection between personal experiences and instructional content should be strengthened (Franklin et al., 2018; Ross et al., 2019). The study carried out by Franklin et al. (2018) reports metacognitive strategies through concept mapping on environmental issues in a 2-week workshop. It incorporates the experiences of the students, which allows them to establish an identity and engage in the activities proposed. Besides, Mystakidis et al. (2024) describe how VR spaces like museum exhibitions in Metaverse can enhance self-confidence, sense of pride, and motivation, and be a catalyst for deaf students. These students can see that their work is comparable to or even better than their peers without disabilities.

Visual Impairment and Blindness Interventions for blind and visually impaired students focus on educational materials and their accessibility. Supalo et al. (2014) propose an accommodation in the laboratory equipment to collect the samples of a chemistry experiment. Active participation can engage and motivate the students in STEM because they feel part of a team, and their standpoints are considered crucial. Hahn et al. (2019) describe an intervention through mobile devices and tactile manipulatives to teach the comprehension of graphs (pie charts, scales, bar charts) to visually impaired students. These graphs are tough for these students. This methodology can be an opportunity to create educational content much faster than the traditional way using Braille. Adelakun (2020) shows a set of tactile educational materials to teach concepts in biology (cells and photosynthesis). Tactile diagrams can foster the participation and academic performance of the students. A similar proposal is described in (Wegwerth et al., 2023), where students used the *Kasi System* (a combination of tactile manipulatives and audio feedback) to comprehend the topics of molecules and equation balancing and their academic grades were improved through several interventions. Finally, no interventions for **orthopedic impairment and traumatic brain injury** were found.

Strategies

Twenty-one strategies have been elicited for STEM-STEAM education and were synthesized in the link in subsection 3.5. The strategies encompass those directly from interventions in classrooms, some with assistive technologies, and institutional support, which include the participation of DRC (Disability Resource Center), teachers, parents, and academic staff. Some of these strategies are aligned and consistent with evidence-based practices in the prior studies (Bustamante et al., 2021; Fleury et al., 2014; Kouo et al., 2021).

RQ3. What Challenges and Recommendations were Identified in STEM-STEAM Education for SWDs based on the studies Identified?

For Educators and Institutions

Promote methodologies in wider learning spaces. Several interventions use single-case design as a research approach. The participants oscillated from one to six students. Although we advocate that SWDs should count with differentiated instruction according to their special needs or requirements, it is necessary to implement these interventions in different and increasingly wide-ranging learning spaces. Depending on the disabilities of the students, peer-to-peer collaboration and monitored interaction with other students without disabilities in larger learning spaces could be contemplated. Maker and IDEAS spaces could be examples in this regard, see references (Chen et al., 2022; Masters et al., 2018; Scalise et al., 2018; Slaton, 2013).

Promote UDL principles, accessible educational resources, and accommodations for SWDs. Accessibility and affordability of educational resources through UDL principles have been reported as an issue in the community of SWDs (Fovet, 2021; Scanlon et al., 2021; Schreffler et al., 2019). Accommodations have a close relationship with the self-advocacy and agency of SWDs (Pfeifer et al., 2020), which are affected by the classroom contexts, enacted policies on classrooms, and teachers' language. SWDs have manifested to be excluded when accommodations and special requirements are not embraced by peers, teachers, or academic staff (Pfeifer et al., 2020). Special accommodations, educational requirements under UDL principles, and continuous dialog between STEAM Educators and institution coordinators are necessary to guarantee the inclusion of SWDs in classrooms.

Include family as a pillar for STEAM Education. Family plays an essential role in STEAM education as support for the educational pathway of the SWDs. Interventions with the families have been demonstrated to strengthen self-determination, resiliency, motivation, and self-advocacy in SWDs in primary and secondary education. However, few interventions were retrieved where the role of the family was essential in the methodology (see references Chen et al., 2022; Ehsan et al., 2018; Michalek et al., 2020; Murthi et al., 2024). In this sense, working with families can aid SWDs in strengthening cognitive and socio-emotional skills. In addition, parents can have a direct dialog with instructors to follow up on the progress of their children in cognitive, social, or communicative skills.

Training preservice and in-service teachers on how to sustain SWDs in classrooms. Several teachers consider that they do not have enough expertise in handling SWDs. Training in UDL principles and pedagogical approaches for SWDs should be provided to preservice and in-service teachers. But at the same time, the standpoint of the teachers (their voices) should be taken into consideration to overcome barriers and difficulties in attending SWDs by institutions from early childhood to tertiary education. We noticed that the main corpus of analyzed proposals is student-centered while barely one study exposes the voices of the teachers who have disabilities (Dos Santos, 2022). Further research should be forwarded to know the perception of teachers and their needs to support SWDs.

Promote a science identity and connect content with personal experiences. Science identity has proven to be a factor that determines whether deaf and hard-of-hearing students continue their educational formation in STEAM-related majors. Courses that strengthen an identity towards science, gather role models, and connect content with personal experiences are more valuable for SWDs. Further research that encompasses the shaping of a scientific identity is necessary to understand how SWDs construct or adapt scientific thinking and attitudes.

For Researchers in STEM-STEAM Education

Broad and complement the scope of STEAM Education for SWDs. Studies in the SLR exhibit two trends. On one hand, the main part of the studies is oriented toward neurodivergent students with ASD, LD, or behavior disorders. On the other hand, the main corpus of studies is promoted from institutions (universities and research centers) around the U.S., and there is no available information about STEAM Education for SWDs in other countries except in references such as (Adelakun 2020; Sakyi, 2017; Samuels & Poppa, 2017; Turner et al., 2021). Besides, three proposals include the arts to foster the motivation and engagement of students with LD and ADHD (Kugler & Kárpáti, 2023; Lu et al., 2022; Sari et al., 2023). It is necessary to broad the meaning of STEAM education including, e.g., the Arts more actively and allowing participation and inclusion of SWDs. Moreover, it is needed to include studies on other disabilities such as visually impaired, blindness, deaf, and hard-of-hearing, among others. Further research on deeper and severe disabilities is necessary as well as interventions that foster psychomotor learning outcomes. Also, research in other countries should be explored to understand the impacts and implications of STEAM Education in the pathway of SWDs from early childhood to tertiary education.

Practical Steps for Implementing Recommendations

We think the above recommendations can lead to deploying the methodologies and strategies described in this study. For the implementation of them, we have deemed some practical steps:

1. Identify SWDs in classrooms through follow-up procedures. These procedures can be initially created or tailored in cooperative work with physiologists and teachers with knowledge and expertise in special education in the institutions. Afterward, these procedures and guidelines can be shared and debated with all teachers across the institution involving parents' participation if this is feasible.
2. Share and debate educational practices for SWDs with colleagues. To create a community of teachers that meet the special requirements of SWDs, a willingness to share and discuss practices with teachers in the institutions is needed. Sometimes, teachers can reserve their practices for themselves, but debating and enhancing these practices with other colleagues with more expertise and contact with SWDs can help to identify aspects that otherwise had not been considered before. Appoint periodical meetings to share these practices with parents' participation and for universities with the cooperation of the Disability Resource Center (DRC). Invite people with disabilities to these meetings in the STEM-STEAM fields who can be role models for SWDs and inspire them. We insist on searching for help, especially if we do not have expertise with SWDs and special education.
3. Promote interdisciplinary work. We noticed that in several studies, educators encompass STEAM areas separately. Then, the initiative of a teacher could solely be viewed in one subject when his initiative could cover different courses across the curriculum with adaptation. Methodologies such as project-based learning, inquiry-based learning, or peer-mediated instruction and intervention (PMII) integrating non-disabled students as peers and combining robotics, programming, and the Arts in LEGO FIRST competitions or MAKER spaces can help to create proper environments for SWDs. For low-income schools, some alternatives for educational robots could be explored, embodying 3D printing and open-hardware prototyping boards such as Arduino. In the construction of these initiatives, revisit UDL principles.
4. Post methodologies and strategies as open educational resources (OERs). Educational materials created by teachers can support SWDs and other teachers across different countries. If the educational materials include webpages, review if these comply with the Content Accessibility Guidelines (WCAG) 2.0. In this sense, some examples of webpages with educational materials and helping guidelines are *dolearn* (https://do2learn.com/disabilities/FASDtoolbox/index.htm), the *IRIS resource locator* (https://iris.peabody.vanderbilt.edu/resources/iris-resource-locator/), or the site for teachers (https://teachershelpingteachers.info/classroom-resources/special-education/).

   Upload the materials in open repositories such as Zenodo or osf.io. Also, upload working documents or papers regarding methodologies and strategies in preprint education research communities such as EdArXiv. We think this procedure can help to disseminate methodologies and strategies for SWDs. We encourage teachers to disseminate their knowledge through these repositories or work jointly with universities to publish their initiatives.

5. Train teachers on pedagogical approaches for SWDs. Training teachers on approaches for SWDs with UDL is needed. Sign language and Braille courses should be considered. Training could consider partnerships between schools and universities or with external institutions whose focus is on special education. Besides, teachers must know about legislation and regulations regarding disability and SWDs in their countries. This could be achieved through online specialized courses.

Limitations

The SLR tailored rigorous protocols and procedures as much as possible to guarantee the relevance of the studies retrieved. However, there are some limitations to expose. Firstly, we considered studies in the selected databases during 2013–2024. Although these are relevant databases, we do not discard that several representative works would have been excluded from the revision. Similarly, some studies could be discarded in the search strings which include gray literature or articles in other languages, i.e., in Spanish. Secondly, the search strings tried to retrieve the highest number of studies according to the disabilities in STEAM education, including terms used by the UN and UNESCO, but including other terms such as "disabled person". Although we do not prefer to use this term, many studies include it. Additionally, as a limitation, we cannot add a complete set of words including all likely disabilities in the search strings, as well as all disciplines involved in STEM-STEAM education. Besides, we do not include specific terms in the search strings for the disability categories provided by the IDEA document such as "intellectual disabilities", "emotional disturbance", or "specific learning disability". We searched for specific disabilities or disorders that are common in the categories indicated altogether the terms "STEM education" or "STEAM education". We do not discard that through this procedure some disabilities, emotional disturbances, and disorders would have been excluded from the SLR. Also, we deemed a holistic approach in which the disciplines or subdisciplines in STEAM education are integrated into the interventions identified. Thirdly, the screening and assessment of the quality of the studies were based on the quality survey described. We tried to select the studies in the SLR under rigorous and objective criteria. We utilized different methods, programs, or APIs to gather and analyze the information objectively as much as possible. Finally, we assert that we do not have any disability, and this could bias or interfere with the findings of this study. Living without a disability evidently could affect our perception of what is going on with SWDs in STEM or STEAM settings. Nonetheless, through our journey as educators, we have taught students with disabilities with low or medium levels of severity, typically due to visual impairments, hard of hearing, or learning issues. Moreover, we have had the opportunity to tutor SWDs during their thesis construction in the academic programs we teach at the university level. Being part of these initiatives or participating in the educational process of SWDs, we got interested in this study.

Conclusions and Future Directions

In this study, we conducted a systematic literature review on the scope of STEM-STEAM education for SWDs. We evidenced that even though longitudinal studies and primary studies expose the exclusion context of SWDs, Researchers and Educators are addressing methodologies, strategies, or interventions that alleviate the situation and contribute to the improvement of cognitive, communicative, and socio-emotional skills of SWDs. However, we need to get over some ableism and invisibility practices that are in classrooms as explained by the authors in references (Cech, 2023; Kingsbury et al., 2020; Slaton, 2013).

We noticed some gaps in the focus of studies that their majority come from the U.S. and are orientated towards learning disabilities, ASD, ADHD, and behavioral or emotional disorders in a low or medium level of severity. Only a few studies that encompass other disabilities, e.g., visual impairments, or hard-of-hearing, were retrieved in the study. This is a challenge because it is necessary to understand how educators are creating methodologies or strategies for other disabilities, and how the disabilities are addressed worldwide in STEAM education. In the same way, some barriers and gaps were evinced in the revision in the following areas: Creation of educational materials and support for accommodations, self-advocacy, accessibility, ASL interpreters, non-standardized STEM terms in ASL, or integration of UDL principles. In addition, the construction and strengthening of a science identity by the SWDs was remarked as a key factor for some interventions, especially for deaf or hard-of-hearing students.

Another factor that we deem important is the role of educators in supporting SWDs. On the one hand, e.g., HEI educators have manifested a lack of pedagogical tools to create differentiated mechanisms or methodologies for SWDs. Moreover, this issue can influence the self-efficacy, self-advocacy, agency, and retention rates of the students in STEAM-related majors. On the other hand, it seems that the voices of the educators are missing in the studies, certainly because the main corpus of the proposals is student-centered. Little attention has been paid to the perceptions and beliefs of the educators in classrooms when they are addressing SWDs or even if they have some type of disability except for the study (Dos Santos, 2022). We think that the dialog between SWDs, STEAM educators, families, institutions, and policies can foster the creation of programs or initiatives that attend to disabilities in educational settings, promoting the real inclusion of SWDs.

Finally, as potential areas for research in future studies, we propose the following: (1) Investigate educational methodologies for STEM-STEAM education in other disabilities apart from ASD. (2) Research on educational materials contemplating UDL principles and Content Accessibility Guidelines (WCAG). (3) Promoting educational methodologies and strategies that came from developing or low-income countries to identify a panorama about SWDs in STEM-STEAM education worldwide. (4) Explore how role models can motivate and inspire SWDs in STEM-STEAM learning environments. And (5) Explore how communities of practice created by teachers and their role can enhance educational methodologies and strategies for SWDs.

Appendix 1

Survey questions for the screening process in the SLR

1. Is the study with the thematic lines of STEM-STEAM education and students with disabilities?
2. Is the study primary research?
3. Does the study describe the educational context and STEM-STEAM methodology applied to students with disabilities?
4. Does the study show a quantitative, qualitative, or mixed method of results analysis?
5. Does the study evidence learning outcomes at the cognitive, affective, psychomotor, or behavioral learning domains and/or any experience or lessons learned?
6. Are the discussion and conclusions of the study supported by the analysis of the results, and do they show the pros and/or cons of the methodology and/or aspects to be improved in the future
7. Has the study been cited by other authors?

Abbreviations ADHD: Attention Deficit Hyperactivity Disorder; EBD: Emotional Behavior Disorder; LD: Learning Disability.; DD: Developmental Disabilities.; VBM: Video-Based Modeling.; MLD: Math Learning Disability; IDEAS: Inventing, Designing, and Engineering for All Students.; ML: Machine Learning.; NLP: Natural Language Processing.; SLD: Specific Learning Disabilities.; ASD: Autism Spectrum Disorder.; VR: Virtual Reality.; ASL: American Sign Language

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Declarations

Competing Interests The authors declare that they have no competing interests.

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