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Teaching science to students with special educational needs: a systematic review of science teaching-learning approaches in regular and special education settings.

In this systematic review, a series of didactic proposals and experiences that have been developed over recent years in formal education are presented with the common purpose of ensuring that students with special educational needs learn science. The main characteristics that define this line of research are also discussed. Initially, only 54 publications on the topic were identified, which underlines the scarce research over the last 20 years and the small percentage of papers published in research journals and conference proceedings within this area. From among those publications, our review is focused on the 27 that report the implementation of didactic interventions: 11 at specific special education centres and 16 at regular educational centres. Explicit instruction was considered a fundamental strategy in the first group that was identified, while varied experiences and methods were among the most relevant approach in the second group. In addition, both educational environments involve learner-centred teaching approaches, in which the learner takes an active and participatory role in the learning process, with the implementation of inquiry-based and hands-on activities, in line with the general results of research in Science Education that does not specifically deal with SSEN. Ensuring that all learners have the opportunity to access and to learn science requires more specific and complementary studies that reinforce and consolidate the evidence of these results, and that promote research on those approaches, taking into account the diversity of learners in classrooms for the benefit of all.

Keywords: Science education; inclusion; special education; systematic review

Introduction

The importance of developing competences within scientific-technological areas has become a priority issue in modern society and therefore in our educational systems. However, a significant proportion of students appear to encounter serious difficulties, not only in developing those competences, but also in accessing scientific knowledge itself. Many of them are identified as Students with Special Educational Needs (SSEN), who have traditionally followed different educational pathways from other students.

Educational differentiation is based on both exclusive educational spaces for SSEN and the design of specific curricula whose learning objectives have almost exclusively been focused on teaching basic content in the area of language and mathematics (Scruggs *et al*., 2008), and on the development of functional skills, so that SSEN may more easily adapt to the environment in which they are living (Bobzien, 2014). This restriction of access to scientific knowledge and learning is reinforced by the perceptions of many professionals and family members who are still reluctant to endorse the possibilities that SSEN have of achieving academic and professional success in scientific and technological areas (Bryant Davis, 2014) and the impact that learning has on their daily lives.

The inclusive education movement emerged, with the aim of providing quality education for all learners and overcoming these and other constraints that SSEN and other vulnerable or at-risk groups have faced. Its launch formed part of the World Declaration on Education for All, celebrated at Jomtien, Thailand, which served to promote educational settings where all children can learn together (UNESCO, 1990). Four years later, the Salamanca Declaration reasserted the commitment to promote inclusive educational models that ensure that all learners, especially SSEN, follow regular educational programs, even though it may be required the use of additional support (UNESCO, 1994).

Inclusive education is therefore a commitment to diversity, not only with SSEN, but with all learners, to create flexible teaching-learning spaces of benefit to all. However, this aspiration has not been completely achieved. The reality is that, although the percentage of SSEN who share educational spaces with other students with no special educational needs is increasing, it does not mean that access to science and learning science is guaranteed (Kaya & Kaya, 2020).

The textbook-centred models traditionally used for science teaching in regular schools, based on memorization, and decontextualized approaches to scientific knowledge (Villanueva *et al*., 2012), limit meaningful learning, lead a large number of children to reject these knowledge areas, and seriously trouble many SSEN, due to the challenge of tackling activities relating to reading and writing (Mastropieri *et al*., 2006).

Added to all these obstacles are the difficulties that teachers encounter in teaching science to SSEN, regardless of whether they are in special or regular settings.

In the first case, special education teachers do not usually have training in specific science-related content, while in the second case, the difficulties that teachers face tend to have stronger links with lack of experience in interacting and teaching in various educational spaces where SSEN are present (Villanueva *et al*., 2012).

Despite all the limitations that prevent SSEN from learning science, educational approaches of proven efficacy have been studied, although more research appears necessary to see whether the evidence may be strengthened. Progress on the subject that concerns us here must first be ascertained, in order to direct future research efforts towards results with greater validity.

Identifying progress will also give teachers and policy-makers a clearer idea of the most promising lines of action, inspiring them to improve and to complement their teaching practice, as well as to take decisions that address the limitations that schools, teachers, and students continually face during the science teaching-learning process.

Thus, our objective is to develop a systematic review of the literature, so as to identify the approaches that are proposed for an educational response mindful of science learning for SSEN, both in regular and in specific special education classrooms. A review that also provides insight into the defining characteristics of articles published on science education in relation to SSEN. This study is part of a wider project developed in Spain, specifically in the autonomous region of Castile and Leon, which is focused on the promotion of educational spaces within which all students can participate and learn science, especially those with special educational needs.

Other systematic reviews have likewise been developed, although addressing only some specific types of SSEN: Courtade *et al*. (2007) focused on students with severe cognitive disabilities and Apanasionok *et al*. (2019) on intellectual disability and autism spectrum disorder. In both cases, components of systematic instruction were the most commonly used approaches, highlighting modelling and errorless learning in the former; and simultaneous prompting procedures and embedded instruction in the latter.

Methodology

The current paper presents a systematic review with the major objective of collating "evidence that fits pre-specified eligibility criteria in order to answer a specific research question" (Green *et al*., 2008, p. 3). After reviewing the numerous research results, we can interpret reality in a rigorous and reliable process that leads us to make coherent evidence-based decisions (Petticrew & Roberts, 2006).

A guaranteed requirement of the compilation process is that it must be replicable. This systematic review has therefore been developed taking into account the execution phases established by the Evidence for Policy and Practice Initiative (EPPI) Center (Bennett *et al*., 2005) and the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement checklist of the elements that must be included in a final systematic review document (Liberati *et al*., 2009).

Design

This systematic review is intended to identify educational proposals for science learning for SSEN in regular and special education settings. The electronic search strategy was divided into two different phases to achieve this objective.

The first phase of the search was focused on two databases: Web of Science Core Collection and SCOPUS. A selection that assures the quality and the relevance of the selected publications, because all the journals indexed in both databases meet a series of specific criteria and requirements, such as peer review and practice based on ethical principles.

The basic search was chosen for the main database search process, and the terms were entered in the topic option, in such a way that the results returned by the databases contained the search terms in the title, in the abstract, and/or in the keywords. This process was divided into two sections led by two sets of terms, broadening the search and increasing the validity of the review (Bennett *et al*., 2007):

- “Science Education” OR “Science Curriculum”.
- “STEM Education” OR “STEAM Education”.

Although our research question is only focused on science learning, we considered it appropriate to include STEM and STEAM teaching approaches among the search terms, because new currents within science education are founded on these approaches (National Research Council [NRC], 2014; Zollman, 2012). In this way, we were able to ensure that the science teaching proposals understood from an integrated perspective were included in the sample.

The search was completed by independently matching both groups with the terms Disability, “Special Education”, and Inclusion, as seen in Table 1:

SEARCH	ROW 1	SEARCH	ROW 2
1	“Science Education” OR “Science Curriculum”	1.1	AND Disability
		1.2	AND “Special Education”
		1.3	AND Inclusion
2	“STEM Education” OR “STEAM Education”	2.1	AND Disability
		2.2	AND “Special Education”
		2.3	AND Inclusion

Table 1. Search process. Entering and combining keywords in databases.

These combinations were first introduced into SCOPUS, and later into the Web of Science Core Collection under the following search restrictions:

- Papers published between 2000 and 2020.
- Papers written in Spanish, English, and Portuguese.
- Papers published in journals and conference proceedings.

The pre-established parameter of years was set with the objective of observing educational trends related to inclusion issues. It was based on the hypothesis that international reports and recommendations on the need to create learning spaces within which all students can participate (UNESCO, 1990, 1994) have influenced the development of new studies on the actions that could contribute to achieving that objective. In addition to English, papers in both Spanish and Portuguese were included, in order to broaden the initial sample of articles, bearing in mind that the study was part of a larger project aiming to improve formal science education in Spanish schools, and that similar studies were available in Portuguese, a language known by the authors of the study.

Inclusion and exclusion criteria

With all items retrieved from the databases, certain inclusion and exclusion criteria were established, in order to achieve the objective of this study. The main selection requirement for the inclusion of articles within the sample was related to the research objective(s). The papers had to contain an analysis of one of the following options: the teaching-learning processes of science, its assessment, and the promotion of positive attitudes towards this discipline, as long as the object of the study was focused on SSEN or the teachers responsible for their learning.

Our international search made it necessary to define the SSEN with greater exactitude, in order to avoid semantic conflicts that might cause problems when identifying and classifying studies, since the term special educational needs can be understood in different ways, depending on the context (Villanueva *et al*., 2012).

Based on current Spanish educational legislation, it is understood in this review that SSEN are people who, due to a disability or a serious behavior, communication- or language-related disorder require specific attention, either temporarily or permanently, to achieve developmentally appropriate learning goals (physical, intellectual, and sensory disabilities; language, and communication disorders, and autism spectrum disorder, and severe personality and behavioral disorders) (Ley Orgánica, 2020).

According to this legislation, SSEN are situated within a larger category identified as Students with Specific Educational Support Needs, which includes, apart from SSEN, other subcategories, such as, Attention or learning disorders, that is, students with Learning Disabilities (*e.g*., dyslexia or dyscalculia) and students with Attention Disorder and/or Hyperactivity (ADHD). These subcategories were excluded from this review as in Spain, neither learning disabilities nor ADHD are considered disabilities nor serious disorders, and are therefore not included in the SSEN group. However, the papers whose population under study was defined as students with special educational needs (or similar), without further specification, were included in the sample, as we understand that the variability of subjects comprised in this term will also include students with the characteristics that were sought for this review.

Finally, the research objectives must have some reverberation within regular or specific formal education settings (infant, primary or secondary education) for inclusion in the sample, and all students over the age of 16 years old were excluded. The impact of the research can be directly generated in these contexts, through actions developed at the educational centres with teachers or students; or indirectly, through activities developed outside schools, but with the ultimate goal of improving teaching-learning processes within previously defined educational contexts.

Related to the exclusion criteria, it was on the one hand agreed to exclude those articles from which the previously described inclusion categories could not be inferred, despite a complete reading of the text; and, on the other hand:

(1) papers in which the Science discipline was not given a central role even though a STEAM teaching approach was used;

(2) papers that reported work with students over 16 years old, the age up until which schooling remains compulsory in Spain, although the age range included younger subjects, for example, a sample of students between 14 and 18 years old;

(3) papers whose objectives were not related to the science teaching-learning processes with SSEN, although the results may contribute indirectly to the topic; and

(4) papers on the conceptualization of disability, even if within the curricular area of science.

In this study, a first researcher applied the inclusion and the exclusion criteria and a second researcher, who reviewed 20% of this first sample, applied the same inclusion and exclusion criteria. A high level of agreement (90%) was reached on both sides. The cases that resulted in disagreement were jointly analyzed and, finally, a consensual decision was taken to complete the main sample of articles sourced from the databases.

The second phase of the search yielded new articles of interest that were identified from the citations and references found in the articles selected in the main database search. After ensuring that all the new articles were indexed in the databases that had initially been employed, the two researchers jointly applied this inclusion process to the papers, following the quality parameters and the inclusion criteria that had initially been defined, to ensure their suitability. In this Systematic Literature Review only backward search was employed.

The search sequence and the article selection process are shown in Table 2, identifying a total of 54 articles, among which we can find theoretical documents, reviews and studies that implement strategies to facilitate SSEN learning access to science. This set of articles of a different nature yielded an overview of the treatment and impact of science teaching for SSEN within the research and the educational community over the last 20 years.

Once the situation regarding the study theme had been contextualized, a new filtering phase was performed with the aim of finding a more limited and precise answer to the research question. Therefore, only those articles related to studies published in journals that implemented interventions with impact on teaching and/or learning processes formed part of the final study sample; a process that reduced the sample to 27 articles. All the information on the educational context, the population, the nature of the didactic approach that had been implemented, the research questions and design, and the results was codified and extracted for analysis.

LITERATURE SEARCH Stage 1	EXCLUSION CRITERIA Stage 1	EXCLUSION CRITERIA Stage 2	LITERATURE SEARCH Stage 2	EXCLUSION CRITERIA Stage 3
Searched 2 databases using search terms and initial requirements. Database 1 N=618 Database 2 N=509	Excluded studies after reading the title, keywords and abstract. Repeated articles	Excluded studies after reading the whole text. N=75	Retrieved referrals from final selected studies N=61	Excluded studies after reading the whole text. N=47
Cumulative N=1127	Cumulative N =115	Cumulative N =40	Cumulative N =101	Final N=54

Table 2. Selection process for the inclusion of each publication in the sample.

Results

Analysis of the results of the complete sample

The 54 articles represented a sufficiently large sample to approach the main characteristics that could be said to define the production of articles on science education with SSEN.

This initial analysis showed that, although the trend in the number of articles has been increasing over the last 20 years, it has been following a non-linear trend (Figure 1). In addition, the number of journals in which these studies have been published numbered 40, the aims and the scope of which can be categorized into seven different groups (Table 3).

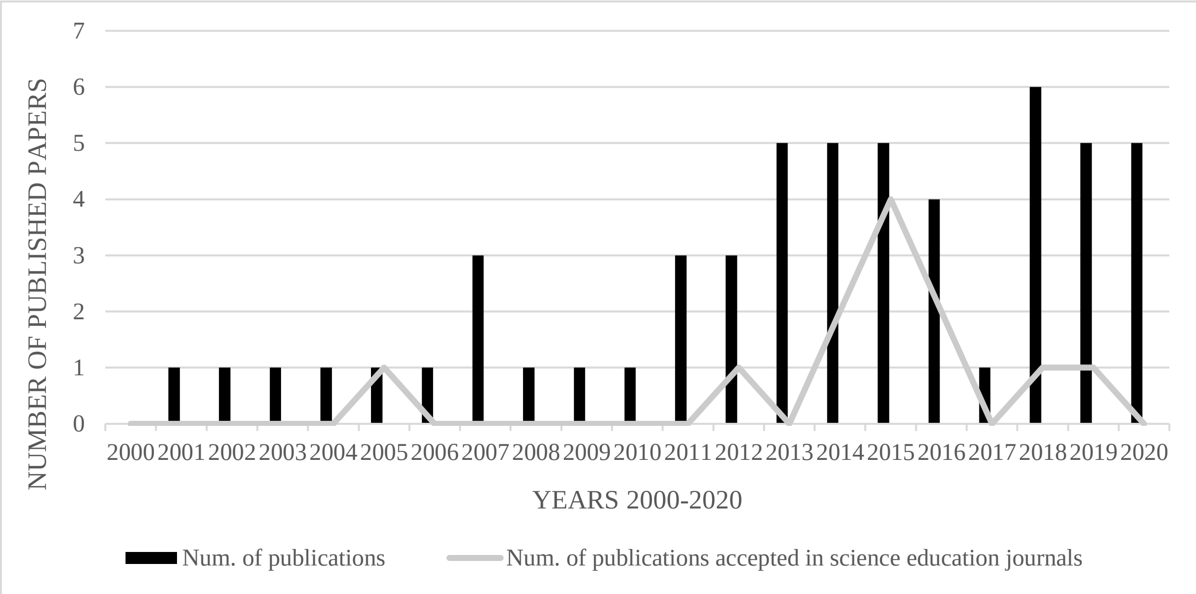

Figure 1. Relationship between total number of published articles and total number of articles published in science education journals.

GROUP 1. Journals on Education Address any issue related to education.
GROUP 2. Journals on Special Education Focused on the education of students who require exceptional support for learning (SSEN, giftedness, learning disabilities, *etc*.).
GROUP 3. Journals on Science Education Focused on science-teaching objectives.
GROUP 4. Journals on Inclusion Focused on the diversity and inclusion of any person (women, migrants, at risk of exclusion, *etc*.).
GROUP 5. Journals specialized in a specific group that are not only focused on education. Comprehensive focus on all the dimensions of a specific group of people, for example, people with autism spectrum disorder.
GROUP 6. Others Journals that do not fit into any of the groups described above.
GROUP 7. Conference Proceedings Articles published through different conferences.

Table 3. Categorization of the journals in the sample.

When applying this classification, it can be observed that the articles on science teaching journals only represented 22% of the total and their publication trends were irregular (Figure 2).

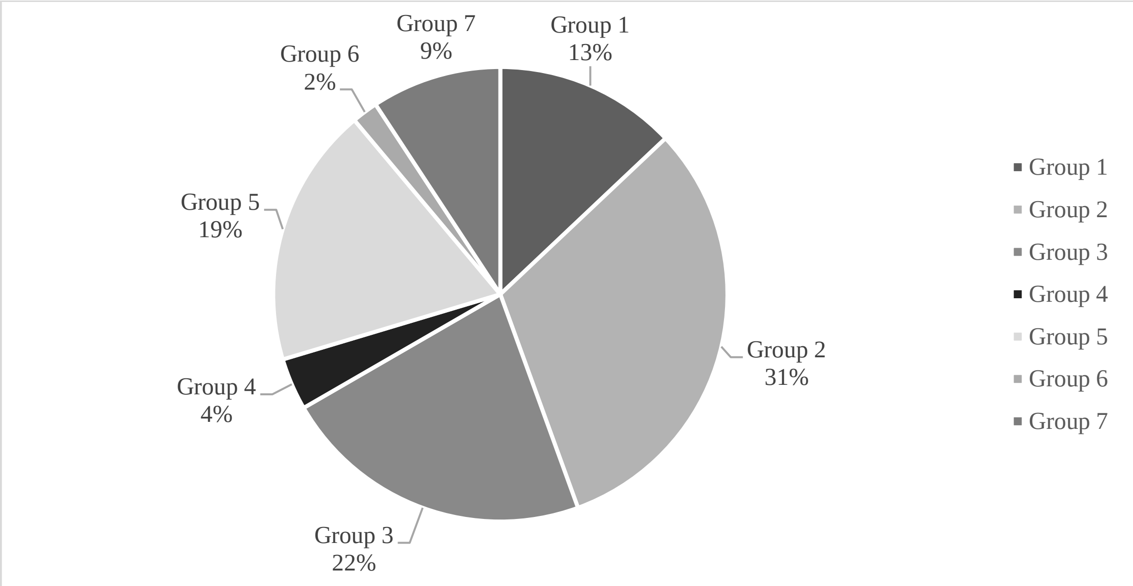

Figure 2. Percentage of journals belonging to each of the previously identified categories.

Analysis of the final selected studies

The 27 studies focused on applying interventions with the objective of facilitating the learning of science for SSEN was split into two large groups, based on the type of educational setting in which they were developed. On the one hand, 11 studies were developed in specific special education centres or classrooms between 2005 and 2020, of which seven are from North America, three from Europe and one from Asia. On the other hand, 16 studies were developed in regular educational centres between the years 2002 and 2020 in North America (11), South America (two), Australia (one), and Europe (two). It should be noted that 81.8% of the articles in the first group were concentrated between the years 2014 and 2020. While the publication dates of the articles within the second group were more evenly distributed over the years (Figure 3).

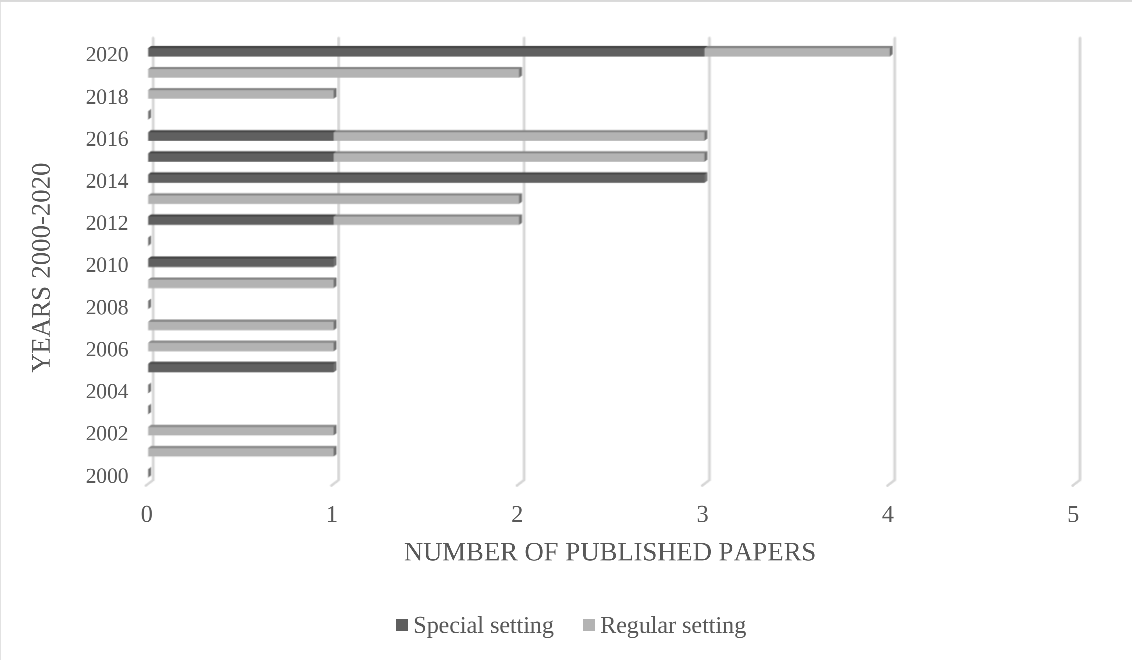

Figure 3. Temporal distribution of the studies.

Both groups were similar regarding the educational stages in which they were developed. In the first group, six of the 11 papers described interventions in secondary education classrooms (students between 11/12 and 16 years old or enrolled in Middle school or High school), two in primary (students between 6 and 11 years old or enrolled in Elementary school), one in pre-school (students between 0 and 5 years old or enrolled in Kindergarten), and another two in which neither the school year nor the age of the sample was specified. In the second group, secondary education also has a greater weight with respect to the rest, with 14 articles, one of which included infants in its sample, and another that included pupils from primary education.

With respect to the characteristics of the students under study, we found that those enrolled at specific special education centres were mainly living with intellectual disability or autism spectrum disorder. However, there was greater variation of student profiles within the samples used for the studies on regular educational settings: emotional or behavioral disorders, sensory disability, autism spectrum disorder, language disorders, and intellectual disability. In addition, four of the studies referred to the specific sample under the name of: students with disabilities or students with educational needs, with no further clarification (Tables 4 and 5).

Didactic strategies used in specific special education settings.

From the analysis of this specific set of articles, didactic interventions have been categorized in four different categories: active learning or explicit instruction, active learning and open instruction, self-directed learning and multisensory and digital support.

Active learning and explicit instruction. In general terms, the relevance of assigning active roles to students when they are learning science is evident in the analysis of the interventions developed in specific special education settings. Active participation that took place through inquiry and hands-on activities yielded better academic results than textbook-centered teaching approaches, without having a negative impact on student behavior (McCarthy, 2005).

The importance of creating controlled and structured learning spaces in which explicit instruction assumes a leading role is also stressed in these studies. In the case of the study developed by Apanasionok *et al*. (2020) and Jimenez *et al*. (2014), the use of guided inquiry was reinforced with the application of explicit instruction strategies such as most-to-least prompting and example and non-example procedures, as well as with the division of complex tasks into smaller steps. These interventions also made use of scripts, in which the teaching process was carefully detailed: ranging from how to present scientific content to the sorts of questions that students may be asked. This useful material for teachers was reinforced by Jimenez *et al*. (2014) through the use of guided notes, although no significant improvements were noted in the acquisition of scientific content among students.

Finally, Knight *et al*. (2012) used explicit instruction of scientific vocabulary to facilitate student participation in the inquiry process. In turn, the teaching-learning of science in the study developed by Im and Kim (2013) was approached with the use of hands-on activities in structured spaces in which manuals and field notebooks were used to address written expression and comprehension.

Active learning and open instruction. In contrast to the previous group of articles that advocated the convenience of creating highly structured spaces and instructions, Essex (2020) proposed exploring scientific phenomena in more open and less structured teaching-learning spaces, with equally positive results for academic performance among students.

Self-directed learning. Self-monitoring checklists and notebooks were the strategies assessed by Miller and Taber-Doughty (2014) to facilitate self-directed participation among students during the inquiry process. The ultimate goal of their study was for students to apply these competencies in everyday problem solving.

Multisensory and digital support. This category includes the use of tablets and digital whiteboards (Özgüç and Cavkaytar, 2016), as well as the integration of scientific texts in digital format (Knight *et al.*, 2015) and concept maps (Jackson and Hanline, 2020). The aim was to remove reading comprehension barriers that hindered the access of students with autism spectrum disorder to written scientific knowledge. The latter was combined with a specific program based on shared reading and explicit instructions.

In Table 4 (A-E), the main characteristics of the sample of academic papers are summarized, in which the educational strategies are linked to both the results and the population under study, as well as the research design, and the nature of the research.

ARTICLES	RESEARCH DESIGN	MAIN DIDACTIC APPROACH	EFFECTS ON TEACHERS AND STUDENTS	RESULTS
Courtade *et al.*, (2010)	Single-subject multiple-probe design	Teacher collaboration and training	Teachers Teaching performance and knowledge transfer Students Inquiry competence and knowledge transfer (Quantitative data)	Teachers Improved teaching performance and transfer of knowledge across other scientific content areas. Students Improved inquiry competence and identification of the use of science terms within and outside science lessons among some students.
Miller & Taber-Doughty, (2014)	Single-subject multiple-probe design	Self-directed learning	Students Inquiry competence and knowledge transfer (Quantitative data)	Acquisition and independent performance of inquiry skills. Knowledge transfer for functional problem solving.
			Student perspectives	Showing interest in science investigations. Assessment of the strategy as useful.
Özgüç & Cavkaytar, (2016)	Action research	Digital support	Teachers Teaching performance Students General impact on student performance levels (Qualitative and quantitative data)	Teachers Improved technological pedagogical content knowledge. Increased teacher collaboration and expectations. Students Improved academic performance. Transfer knowledge to daily life. Increased collaboration, interaction among students, participation and responsibility taken among students. Emergence of new behavioral problems.

Table 4. A. Analysis of the studies developed in specific learning settings. Intellectual Disability

ARTICLES	RESEARCH DESIGN	MAIN DIDACTIC APPROACH	EFFECTS ON TEACHERS AND STUDENTS	RESULTS
Jackson & Hanline, (2020)	Single case study	Multisensory support and specific program.	Students Science knowledge (Quantitative data)	Improved science knowledge and reading comprehension.
Knight *et al.*, (2012)	Single-subject multiple probe	Explicit instruction.	Students Science vocabulary and knowledge transfer (Quantitative data)	Improved acquisition of science descriptors. Better knowledge transfer to a new set of objects and within science experiments than to images.

			Teacher and student perspectives	Teachers Willingness to incorporate explicit instruction in other contexts. Students Positive assessment of the experience.
Knight *et al*., (2015)	A-B-C-D research design	Digital support.	Students Science knowledge (Quantitative data)	Improved outcomes of three students.
			Teacher and student perspectives	Teachers Assessment of the strategy as beneficial and useful for all. Students Assessment of the experience as pleasant and useful.

Table 4. B Analysis of the studies developed in specific learning settings. Autism Spectrum Disorder.

ARTICLES	RESEARCH DESIGN	MAIN DIDACTIC APPROACH	EFFECTS ON TEACHERS AND STUDENTS	RESULTS
Apanasionok *et al*., (2020)	Not defined	Active learning and explicit instruction	Students Science knowledge (Quantitative data)	Improved science knowledge.
			Teacher perspectives	Assessment of the experience as useful with lasting results. Identification of constraints related to time and staff ratios.
Essex, (2020)	Ethnography	Active learning and open instruction	Teachers Teaching performance Students Science knowledge and knowledge transfer (Qualitative data)	Teachers Improved competence and confidence. Students Improved science knowledge and understanding. Transfer of knowledge to other curriculum areas.
Jimenez *et al*., (2014)	Single-subject multiple probe	Active learning and explicit instruction (Scripted Lesson (SL) with guided notes, GNs)	Students Science knowledge (Quantitative data)	Slight improvement in using SL with NG for teachers.
			Teacher perspectives	Preference for SLs without GNs; Both options together were considered complicated and time-consuming.

Table 4. C. Analysis of the studies developed in specific learning settings. Intellectual Disability and/or Autism Spectrum Disorder.

ARTICLES	RESEARCH DESIGN	MAIN DIDACTIC APPROACH	EFFECTS ON STUDENTS	RESULTS
McCarthy, (2005)	Not defined	Active learning and explicit instruction	Students Science knowledge and behavior (Qualitative and quantitative data)	Significant improvement in scientific knowledge of students taught through active rather than passive learning. No statistically significant behavioral results between active and passive learning. In qualitative terms, however, active learning students required less attention and direction from the teacher without affecting behavior.

Table 4. D. Analysis of the studies developed in specific learning settings. Serious Emotional Disturbance.

ARTICLES	RESEARCH DESIGN	MAIN DIDACTIC APPROACH	EFFECTS ON STUDENTS	RESULTS
Im & Kim, (2014)	Not defined	Active learning and explicit instruction	Students Language proficiency and inquiry competence (Quantitative data)	Improved expression fluency, observation, measurement, classification, data transformation and variable control. Non-significant improvement in expectation, inference, data interpretation and constructing hypotheses.

Table 4. E. Analysis of the studies developed in specific learning settings. Sensory disability: Deafness and Hearing Loss.

Didactic strategies developed in regular learning spaces.

The didactic interventions and/or specific supports for SSEN to learn science in regular educational spaces can be classified into two groups:

(1) specific interventions for SSEN.

(2) common interventions for all students.

The first group included six studies that were defined by focusing the didactic approaches on a small and specific group of students, without assessing the impact it causes within the classroom as a whole. Following the same procedure used in the previous group, the interventions have been categorised into groups:

Active learning. The work of Szczytko *et al.* (2018) comes within this category, who assessed the impact of an outdoor inquiry-based environmental program that included practical scientific experiments, walks, group reflections, and exploration of nature.

Self-directed learning. Strategies that enable learners to guide their own learning process were discussed in the study developed by Jimenez *et al.*, 2009. In their work, KWHL (what we Know, Want to know, How to find out, what was Learned) graphs were introduced, together with multiple exemplar training and time delay so that students could independently complete an inquiry sequence.

Multisensory and digital support. Under this category, some studies were grouped in which specific supports were integrated to compensate the difficulties that students encountered when learning science. These studies concerned the use of podcasts based on the principles of Universal Learning Design, to facilitate the understanding of exam questions among students with reading difficulties (McMahon *et al.*, 2016); tactile models so that blind and low-vision students could appreciate the structure of DNA (Delou *et al.*, 2016); and explicit computer-assisted instruction for learning scientific terms (Smith *et al.*, 2013).

Specific programs. Lowe *et al.* (2019) sought to compensate the difficulties that students with language disorders usually presented in relation to science vocabulary management, through a phonological –semantic vocabulary intervention.

The second group included ten papers, in which interventions were described that were designed to respond to the learning needs of SSEN, through common teaching approaches for all students:

Active learning. Lynch *et al.* (2007) and Palincsar *et al.* (2001) tested a guided inquiry sequence in a science classroom. In the first case, the sequence was designed under the principles of the Theory of Conceptual Change. In turn, Palincsar *et al*. (2001) implemented two sequences of guided inquiry, repeating cycles of investigation on a specific phenomenon, over two consecutive years. Working with teachers and students, they identified opportunities and challenges experienced during the first year and improvements based on previous experience were implemented with much better results during the second year. Likewise, Mastropieri *et al*. (2006) used hands-on instruction and peer tutoring to address the diversity of a classroom.

Teacher collaboration and training. These studies recognized the importance of well-trained teachers and collaboration, in order to boost scientific learning among students. Swanson and Bianchini (2015) analyzed the effectiveness of jointly planning teaching units based on inclusion and inquiry, in order to facilitate the learning of science among all children. van Garderen *et al*. (2012) assessed a professional training based on teacher collaboration, in order to support them to implement inquiry-based instruction, formative assessment, and Universal Design of Learning. Finally, Cawley *et al*. (2002) focused on a training programme committed to collaboration between educational professionals (teachers from different disciplines and educational research teams) with the intention of designing and implementing a science project based on hands-on activities.

Variability and teaching flexibility. These didactic strategies were selected to provide the teaching-learning process with the flexibility, support, and accessibility required to create an inclusive learning environment where all students could learn. Kaya and Kaya (2020) implemented inclusive science classes based on the principles of Universal Learning Design and the Theory of Multiple Intelligences. Along the same lines, a wide range of teaching strategies was also present in a study from the team of Next Generation Science Standards (2013), referenced by Lee *et al*. (2014), in which multiple forms of representation, action and expression, and motivation were employed, in order to offer students different experiences that facilitated the acquisition of scientific knowledge.

Additionally, Santana and Sofiato (2019) employed different and varied methodologies, multisensory resources, languages, and research activities within a regular class, involving a student with intellectual disability, with the aim of teaching the same scientific concepts to all the students. An intervention in which specific strategies and activities for SSEN were also implemented that in many cases proved beneficial for the other classmates.

Finally, Fleer and March (2015), from a cultural-historical perspective, observed science learning classes in which storytelling was the guiding thread. After analyzing the classes and interviewing teachers and families, the authors identified how science learning were supported through making students aware of everyday scientific concepts; experiencing hand-on activities; using imagination and science storytelling; and involving families within the teaching-learning process.

In Table 5 (A-E), the main characteristics of the sample of academic papers are summarized, in which the educational strategies are linked to both the results and the population under study, as well as the research design, and the nature of the research.

ARTICLES	RESEARCH DESIGN	MAIN DIDACTIC APPROACH USED	EFFECTS ON TEACHERS AND STUDENTS	RESULTS
Jimenez *et al*., (2009) (*)	Single-subject experimental design	Self-directed learning	Students Inquiry competence, science knowledge and knowledge transfer (Quantitative data)	Positive results in self-directed inquiry lessons and its generalization to other settings. Generalization of scientific concepts learnt after introducing new variables.
Santana & Sofiato, (2019) (*)	Not defined	Variability and teaching flexibility	Students Science knowledge (Qualitative data)	Improved academic performance and participation in science classes. Specific strategies for SSEN were beneficial for all students.
Smith *et al*., (2013) (*) (**)	Single-subject multiple-probe across participant designs	Digital supports	Students Science vocabulary and knowledge transfer (Quantitative data)	Improved identification of science terms and the generalization of their use.
			Teacher and student (with and without disability) perspectives	Teachers Beneficial tool for inclusive experience. More interest in using technology within their classrooms. Students SSEN assessed the strategy as effective. No SSEN assessed the assistance provided to other students as pleasant.

Table 5. A. Analysis of the studies developed in regular learning settings. Intellectual Disability (*) and Autism Spectrum Disorder (**).

ARTICLES	RESEARCH DESIGN	MAIN DIDACTIC APPROACH USED	EFFECTS ON STUDENTS	RESULTS
Delou *et al*., (2016) (*)	Not defined	Multisensory support	Students Science knowledge (Qualitative data)	Improved understanding of science concepts.
Fleer & March, (2015) (*)	Naturalistic study design	Storytelling	Science learning and personal development (Qualitative data)	Identification of relevant didactical strategies: linking everyday scientific concepts, use of imagination and science storytelling. Involving families within the learning process through similar scientific exercises at home.
Lowe *et al*., (2019) (**)	Within-subject repeated-measures design	Specific programs	Students Science vocabulary (Quantitative data)	Significant improvement in knowledge of words and their use.

Table 5. B. Analysis of the studies developed in regular learning settings. Sensory disability: Blindness and Low-Vision (*). Language Disorders (**).

ARTICLES	RESEARCH DESIGN	MAIN DIDACTIC APPROACH USED	EFFECTS ON STUDENTS	RESULTS

Cawley *et al*., (2002)	Not defined	Teacher collaboration and training	Students Science knowledge and behavior (Quantitative data)	Comparable academic success between SSEN and no-SSEN. No negative influences on students' behavior during inclusive lessons.
			Classroom social climate	Positive classroom coexistence. Inclusive settings provided SSEN much higher level of social acceptance than self-contained class.
Kaya & Kaya, (2020)	Mixed-research design	Variability and teaching flexibility	Students Attitudes towards science (Qualitative and quantitative data)	Significant improvement and lasting results for attitudes towards science.
NGSS, (2013)	-	Variability and teaching flexibility.	Students Scientific knowledge	A description of how to support access to and understanding of knowledge of science for all students.
Szczytko *et al*., (2018)	Quasi-experimental study. Mixed-method	Active learning	Students Behavior, attention span and science knowledge (Qualitative and quantitative data)	Improved attentional spans and reduced disruptive behaviors. Maintained measures of nature of science, science efficacy, and science grades.

Table 5. C. Analysis of the studies developed in regular learning settings. Samples consisting of different types of SSENs.

ARTICLES	RESEARCH DESIGN	MAIN DIDACTICAL APPROACH USED	EFFECTS STUDIED ON	RESULTS
Lynch *et al*., (2007)	Quasi-experimental study	Active learning	Students Science knowledge (Quantitative data)	Significant improvement for SSEN and no-SSEN taught by a guided inquiry unit.
Mastropieri *et al*., (2006)	Randomized field trial design	Active learning	Students Knowledge of science and attitudes towards science (Quantitative data)	Better content knowledge results for students taught by peer tutoring and hands-on science activities than by teacher-directed instruction. Assessment of peer tutoring and practical science activities as positive, but no more positive attitudes.
McMahon *et al*., (2016)	Latin square comparative design	Digital supports	Students Student performance in science content tests (Quantitative data)	Significantly better results using the podcast and the teacher reading out aloud than without assistance. No significant difference between listening to the podcast read out aloud and the teacher reading out aloud.
Palincsar *et al*., (2001)	Not defined	Active learning	Students Science knowledge (Qualitative and quantitative data)	No-significant improvement after the first intervention. Teacher experience as a key element in improving the learning of all students after the second implementation.

Table 5. D. Analysis of the studies developed in regular learning settings. Sample not defined.

ARTICLES	**RESEARCH DESIGN**	**MAIN DIDACTICAL APPROACH USED**	**EFFECTS STUDIED ON**	**RESULTS**
Swanson & Bianchini, (2015)	Not defined	Teacher collaboration and training	Teachers Co-planning (Qualitative data)	Strengths: High engagement and participation in discussions on content and activities. Limitations: Discussions focused on science education without much attention to special education aspects.
van Garderen *et al*., (2012)	-	Teacher collaboration and training	Teachers Teaching performance	A description of a professional training to prepare teachers to support science learning for all students.

Table 5. E. Analysis of the studies developed in regular learning settings. Teachers.

Discussion

The systematic review presented above provides insight into research on science learning and SSEN and the lines of action that mark the way forward in educational settings. We can extract some interesting questions from it, worthy of further study. In the first place, considering that the need for everyone to learn science has been vindicated since the 1990s (NRC, 1996; Rutherford & Ahlgren, 1990), the small number of publications aimed at studying this topic is surprising, despite the slightly increasing trend observed over the last two decades. A fact that, along with the small percentage of studies published in specialized science teaching journals (22%), leads us to think that this area of knowledge continues to occupy an elitist position (Essex, 2018) that hinders the universalization of its learning. A position that is reinforced when scientific learning objectives are focused on preparing future professionals within science and other related fields (Essex, 2018), instead of seeking the scientific literacy of all students to ‘recognize not only the main concepts, hypotheses and theories of science, but to use them in solving problems, understanding the world and making decisions’ (Sañudo-Guerra & Perales-Ponce, 2014, p. 30).

The objective of promoting scientific literacy through the formal education of all students and its achievement implies a transformational process within both regular and special education classrooms. A transformation that is undoubtedly linked to the role of the teacher, often poorly prepared to face such a key role in overcoming the barriers to learning science that SSEN can encounter.

In second place, we may highlight the standstill in the production of studies focused on regular learning spaces when the trend shows us increasingly diverse classrooms, in which SSEN still encounter obstacles to the development of their maximum academic and personal potential. Despite the calls from various international organizations in relation to the promotion of inclusive learning spaces in which all students can enjoy learning together (UNESCO, 1994, 2019), inclusive education has not produced sufficient studies to dispel all doubts over its viability and to provide practical answers to its true implementation, in all areas, especially in science education (Nilholm, 2021). Thus, the difference between the studies developed in regular environments only exceeded the studies in specific spaces by 18.6% in the final sample of articles applied in school classrooms. In addition, it is interesting to observe that the production of articles on science teaching-learning has remained steady over the last 20 years within regular environments where there are SSEN, contradicting the hypothesis on this point that was initially proposed in this review. However, the studies on specific centres grew, grouping 81.8% of the academic papers within the final sample between 2014 and 2020. This increase was also noted in the systematic review of Apanasionok *et al*. (2019), in which 22 of the 30 articles were published in and after 2010, and only eight during the previous seven years.

The reasons that are restricting progress on inclusion issues appear to be related to the lack of consensus on what inclusive education is and what it implies. Göransson and Nilholm (2014), after a review of the literature, identified four different approaches to the concept: (a) inclusion as the placement of students with disabilities in mainstream classrooms; (b) inclusion as meeting the social/academic needs of students with disabilities; (c) inclusion as meeting the social/academic needs of all students; and (d) inclusion through the creation of communities, which underlines the lack of common objectives linked to this concept. The approaches to improve the science learning of SSEN, used in the sample of articles developed in regular settings found in this review, give an idea of the concepts of inclusion that are handled. One approach to the concept was focused on compensating specific needs of SSEN that make it difficult for those students to participate actively and to learn, without considering the other students within the class (McMahon *et al*., 2016; Smith *et al*., 2013); another approach was focused on the impact that certain common teaching methodologies and strategies have on the group-classroom as a whole, with special attention to SSEN (Lynch *et al*., 2007; Palincsar *et al*., 2001); and finally, the interventions of the third approach were based on cultural-historical conceptualizations of inclusion (Fleer & March, 2015).

The fact of adopting conceptualizations where educational inclusion is understood as going beyond the special needs of a specific group entails the introduction of profound change in the methodologies used up until now to guide the teaching-learning processes (Sharma *et al*., 2012). As with programming, both planning and the implementation of strategies that cover the curricular demands of all learners are needed (Rieser, 2012). Changes that reinforce the principles of justice, equity, care and diversity, which Göransson and Nilholm (2014) identified in the definition of inclusion coined by Naraian (2011).

Some of the most common approaches towards inclusive pedagogy and the specific school settings of students, as we have seen in this systematic review, were undertaken through learner-centered approaches (Al-Azawei *et al*., 2016). Specifically, scientific inquiry is highlighted (Abels, 2015) as long as the teacher uses structured and guided instruction that reduces the strong cognitive load usually associated with learning science; so that not only learning objectives, but also intrinsic motivation and epistemic beliefs were achieved (Aditomo & Klieme, 2020). These proposals were not exclusively defended for SSEN, but for all students. However, the impact of these implementations has not been analyzed in depth from a perspective of diversity. In other words, the analysis is focused, almost exclusively, on either SSEN, a common characteristic of the studies included in this review, or students not identified as SSEN, as with the vast majority of publications in Science Education journals. Likewise, the specific support that SSEN receive to learn science can in many cases have a positive impact on non-SSEN, as Santana and Sofiato (2019) highlighted. This lack of connection in Science Education research seems to limit progress towards the universalization of science learning.

Conclusions

This systematic review, the objective of which has been to identify the current characteristics that define SSEN science-learning proposals, will require more specific and complementary studies that focus attention on ascertaining the effectiveness of the different didactic and methodological strategies in use. Studies through which the objectives and the lines of action to be followed may be closely specified and explained, without for one minute losing sight of the diversity of students.

The approaches to the teaching-learning processes proposed in the literature and identified in this review have shown a firm commitment towards the active involvement of students in the construction of their own learning, offering support so that they gain greater autonomy and responsibility. Likewise, it is worth highlighting those proposals that seek to use variable methods and learning experiences, as well as, those which stress the relevance of teacher training and collaboration.

In addition, this line of research should have greater relevance in specialized journals on science education and should not be limited to those on special education. In this way, effort and knowledge will be added to contribute to a solid development of inclusive pedagogies through which the universalization of science learning may be pursued.

Unlike other reviews of a similar nature, broader results on the opportunities that the SSEN have to learn science in different educational contexts have been obtained in this literature review, as its focus has not been on specific groups. Its broader global vision has led to the identification of points of convergence in which, regardless of the characteristics of the students and the educational context, common strategies and methodologies have been implemented.

The results in this review are subject to a series of limitations that should be identified. As is the case with the search process for the configuration of the study sample for which only two databases were used. A fact that may have excluded studies that, even meeting the initially established inclusion and exclusion criteria, have not been included because they were published in journals not indexed in the selected databases. In this regard, it should be noted that the choice of keywords to search for articles may also have limited the identification of articles that could have been incorporated into the corpus of the study. Both limitations could to some extent have been mitigated through the use of the snowball technique, with which the most relevant articles could have been included among those selected after completion of the database searches.

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