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Conditions for promoting inclusive science education among children and youth (0–16 years) living in communities in vulnerability risk situation: a scoping review

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ABSTRACT

This paper presents findings from a transdisciplinary study exploring conditions for Inclusive Science Education (ISE) for children aged 0–16 from communities in vulnerability risk situation. A two-step literature review was conducted to identify inclusive teaching and learning interventions. The first phase applied a Scoping Review, followed by an Integrative Literature Review focusing on community-oriented ISE, examining: (1) the main pedagogical approaches and interventions supporting inclusive, community-based science education; and (2) the conditions necessary to promote science education involving children and youth in contexts of vulnerability. A qualitative Constant Comparative Method was used to guide the data analysis. Three core themes emerged as pivotal for fostering community-oriented ISE: Contextual Factors, Pedagogical Approaches, and Critical Approaches. Findings highlight the importance of creating safe, supportive environments within local communities, enriched by creative, nature-based learning spaces. Exploratory and playful science activities were shown to enhance social inclusion. Moreover, participatory teaching and learning methods are essential for fostering inclusive settings that value diversity through an intersectional lens. Finally, applying intersectionality within science education encourages reflection on social and power relations in both classrooms and communities, making science education more equitable, responsive, and socially just.

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Science education; education; intersectionality; gender equity; literature review; children and youth

Introduction

This paper aims to present the results of a scoping literature review (SLR) followed by an integrative literature review (ILR) aimed at identifying the educational conditions and

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pedagogical strategies to promote Science Education inclusively for all children and youth, regardless of their physical condition, gender, cultural or socioeconomic background. The results and the ensuing discussion will be presented starting from the framework of Inclusive Science Education (ISE), which will be defined in both formal and non-formal education settings. This systematization may prove to be useful to implement strategies for science education activities, especially for children and youth belonging to communities in vulnerability risk situation, i.e. those children and youth who are at risk of experiencing marginalisation and exclusion due to overlapping identities, such as gender, migration background, ethnicity or disability shaped by structural power imbalances (Jackson, Colson-Fearon, and Versey 2022). These are individuals, in fact, whose needs and rights often go unrecognised. Examples of communities in vulnerability risk situation include migrants or refugees, individuals with physical or mental disabilities, or members of the Roma community, among others. A core definition of 'community' is conceptualised 'as a group of people with diverse characteristics who are linked by social ties, share common perspectives, and engage in joint action in geographic locations or settings', even though they may be of diverse backgrounds' (MacQueen et al. 2001, 1929).

This study departs from the research and the SLR conducted during the 3-year Horizon 2020 SwafS project 'Communities for Sciences (C4S) – Towards Promoting an Inclusive Approach in Science Education' (grant agreement No 872104). This project aimed to engage children and youth aged 0–16 years in inclusive science education (ISE) activities, focusing especially upon certain social and cultural groups facing issues of exclusion (children from the Roma community and/or migrant background and/or with a disability). In particular, the project examined the systemic conditions (micro, meso, and macro) that enable an inclusive approach to science education for children and youth between the ages of 0 and 16 (regardless of context or condition), with a view to improving access and participation for all (the reference framework for these concepts is the Universal Design for Learning: Meyer, Rose, and Gordon, 2013). The project actions implemented this inclusive approach through pedagogical strategies and educational practices that have sought to remove barriers to accessibility and enjoyment of science education for all children and youth (Cotza 2024). In order to deploy the project, an initial SLR was conducted, with the aim of both defining the framework to better understand ISE issues and organising, summarising and synthesising the results regarding the impact of educational interventions and pedagogical strategies in the field of science teaching, particularly when groups include children or youth in vulnerable risk situations. This previous SLR overview has also made it possible to identify certain gaps in ISE.

This Integrative Literature Review (ILR) therefore supplements the previous SLR, focusing more on community-oriented pedagogical approaches.

The conceptual framework: Inclusive Science Education (ISE)

Science education plays an important role in the different pedagogical settings of formal, informal and non-formal education (Kuhn 2010; Harlen 2010; Dawson 2014; Furman 2016; Pedreira and Márquez 2019), since children, from early childhood, have a spontaneous interest in exploring their daily environment and discovering causal relations

in their surrounding world (Dewey 2004; Gopnick, Meltzoff, and Kuhl 1999; Furman 2016). Several studies establish how children's natural curiosity and capacities set up the basis for offering them interest in scientific enquiries (Harlen 2010; Eshach and Fried 2005). Science education, however, is not only about offering scientific content, but it is also about engaging students in scientific procedures and habits (Harlen 2010) that take into account the economic and socio-cultural context in which these proposals are situated (Wertsch 1991; Eshach and Fried 2005; Fitzgerald, Danaia, and McKinnon 2019), with particular regard to communicative interactions in social contexts (Lemke 1990) and spatial settings (Brauns and Abels 2021; Frabboni 2005). In this framework, the ways in which micro-systems (such as the play environment, the professional team, and the family) interact with each other at the meso-systemic level and how this network responds to the exo- and macro-systemic levels, i.e. for example, to the training of operators, educational policies, and the underlying culture of services, play a central role (Bronfenbrenner 1979, 2005).

Nevertheless, recent studies show that barriers persist in the success of involving all children in science education, especially those from underrepresented backgrounds (Lynch et al. 2017; Stinken-Rösner et al. 2020) and girls (Katz et al. 2017; Stephenson, Fleer, and Fragkiadaki 2022). Such barriers occur as a result of social inequities and lack of cultural awareness by educators (Reiser et al. 2007), due to issues regarding hidden or null curriculum in the pedagogical settings (Essex 2020), lack of teachers' awareness of inclusive strategies for students with specific learning disabilities or other needs or unintentional biased teaching by educators (Hodges et al. 2020; Duchaine et al. 2018), or even due to societal gender bias (United Nations 1995; Bian, Leslie, and Cimpian 2017; Stephenson, Fleer, and Fragkiadaki 2022), amongst other potential factors.

Hence, science education for all children and youth becomes essential not only to comply with the curricular contents or to boost scientific competences related to meta-cognitive capacities (Furman 2016), executive functions development (Miller 2005), or to increase the workforce potential in science and the soft skills of students (Lynch et al. 2017). It is also essential, as stressed by Harlen (2010), to allow them to take part in future decisions as informed citizens confronting issues of technological development, negative outcomes of scientific advances (Garcia 2020) or even future developments in science. Thus, it is essential for educators and teachers to learn how to detect and dismantle existing barriers and bias in science education, especially those affecting girls (Stephenson, Fleer, and Fragkiadaki 2022), cultural or ethnic minorities (Bianchini and Solomon 2003) and children/youth with disabilities. It also becomes essential to find new pedagogical strategies that could be more successful in promoting children's and youth's interest in science learning, regardless of their background or condition.

Finally, in recent years, the specific field of science education (in which this contribution fits in terms of the inclusion of all children and youth) has been conceptualised within the broader field of STEM (Nasri et al. 2021; Lynch et al. 2017) or even STEAM (Jamil, Linder, and Stegelin 2018; Stephenson, Fleer, and Fragkiadaki 2022), which are acronyms that respectively refer to the intersecting areas of Science, Technology, Engineering, Mathematics (and Art, for the 'A' of STEAM), leading to a more globalised approach to the field of science education in intersection with the other aforementioned fields. In this sense, the research undertaken is

thus valid as well for those STEAM/STEM approaches that focus on issues of inclusion.

Integrative literature review (ILR): research questions

From what has been illustrated so far, there is a clear need to better correlate the framework of ISE with the teaching and learning interventions that are actually put into practice in formal, informal, and non-formal education, with regard to communities in vulnerability risk situation. To promote science education from an inclusive approach presented above, and to have a better understanding of the issues, barriers and pedagogical strategies involved, it is necessary to have a better understanding of the contexts and needs of the participant vulnerable communities (that are key targets of ISE approaches) and also the potential pedagogical approaches and didactic interventions required. Here, by pedagogical approach, the authors mean the vision, principles, and educational values that guide teaching, while by didactic intervention they mean the set of concrete actions, strategies, and activities implemented to put that approach into practice in learning. As a result, the following research questions were developed to guide this Integrative Literature Review (ILR), which focuses specifically on community-oriented ISE, i.e. the interconnection between science education contexts and educational practices:

1. What are the main pedagogical approaches and teaching and learning interventions on inclusive, community-oriented science education?
2. What are the main conditions for promoting science education when involving children and youth in vulnerability risk situation?

Methods

Research design

An Integrative Literature Review (ILR) was conducted in two steps to identify literature describing current challenges for promoting ISE. Firstly, the literature search was conducted by the C4S Consortium (hereinafter referred to as the first step) through a Scoping Literature Review (SLR). A second step of the review was conducted using an Integrative Literature Review (ILR) approach (Whittemore and Knafl 2005), which enables inclusion of empirical and theoretical literature and supports synthesis across diverse methodologies. Data were analysed using the Constant Comparative Method, allowing for inductive identification and comparison of key themes.

To ensure transparency and comprehensiveness in the literature search and selection process, the PRISMA Extension for Scoping Reviews (PRISMA-ScR) (Tricco et al. 2018) was applied as a reporting framework, visualised in a flow diagram (Figure 2).

Target groups

This scoping review identifies conditions for inclusive community-oriented science education for children aged 0–16 on a micro-, meso- and macrolevel based on Bronfenbrenner's socioecological theories (Bronfenbrenner 1979).

The concept of communities in vulnerability risk situation is defined as particular social groups who may be more susceptible to certain risks, such as social exclusion or segregation (Jackson, Colson-Fearon, and Versey 2022). Their demands and needs often go unrecognised. Communities at risk of vulnerability may include migrants or refugees, people with physical or mental disabilities, or members of the Roma community, among others. The concept of 'community' is understood as a group of people who are linked by social ties to a habitat or geographic setting, even though they may be of diverse backgrounds (MacQueen et al. 2001).

Literature search

The first step of the SLR primarily provided a broad mapping of Inclusive Science Education. This comprehensive search across relevant databases and grey literature was time bound and conducted during the initial phase of a three-year Horizon 2020 project (2020–2023). This first step identified 214 relevant bibliographic sources, including 63% academic books and peer-reviewed articles, 14% non-academic literature, 12% reports from EU-funded projects, and 11% didactic materials and educational tools illustrating best practice. The methodological design and topics that emerged in the results of the first step (SLR) is presented in Figure 1 (C4S 2022). Based on the results of this first step (SLR), a second step (ILR) was performed, focusing more upon community-oriented approaches and challenges. We evaluated and re-analysed the results from the first step (SLR) in the literature search to synthesise and integrate important findings that answered the new ILR research questions developed to guide the integrative literature review. In this two-step review process combining a SLR and an ILR, we followed the Preferred Reporting Items tailored for reviews PRISMA-ScR guidelines (Tricco et al. 2018) to keep a record, ensure transparency and replicability.

Sources and search strategy

The following electronic bibliographic search engines were used in the SLR literature search: Embase, Eric, Cochrane Library, Cordis, Dialnet, PubMed, GoPressAcademic, Google Scholar, peDOCS, ResearchGate, Scopus, and Web of Science. Additionally, personal article archives and libraries were screened for relevant literature.

Search terms were structured using three Boolean operators ('AND', 'OR', and 'NOT') to combine the search terms, and the truncation '*' was used to include grammatical declinations (for example, the keywords 'scien*' stand for 'science', 'scientific', etc.).

The following four sets of topics were searched: (1) Inclusive education; (2) Science Education/Science Teaching and Learning; (3) Teacher Training/Education; (4) Education and Public Engagement. Examples of keywords: STEM /STEAM; inclusive science education; early childhood education; intersectionality; multicultural education; intercultural education; childhood educa*; intercultural science education; vulnerable communities; didactic material AND refugee children; inclusive citizen science; special educational needs; Roma children; participation AND communities; and scientific learning.

Finally, additional relevant academic books and published results of other HORIZON 2020 projects related to C4S topics were also identified.

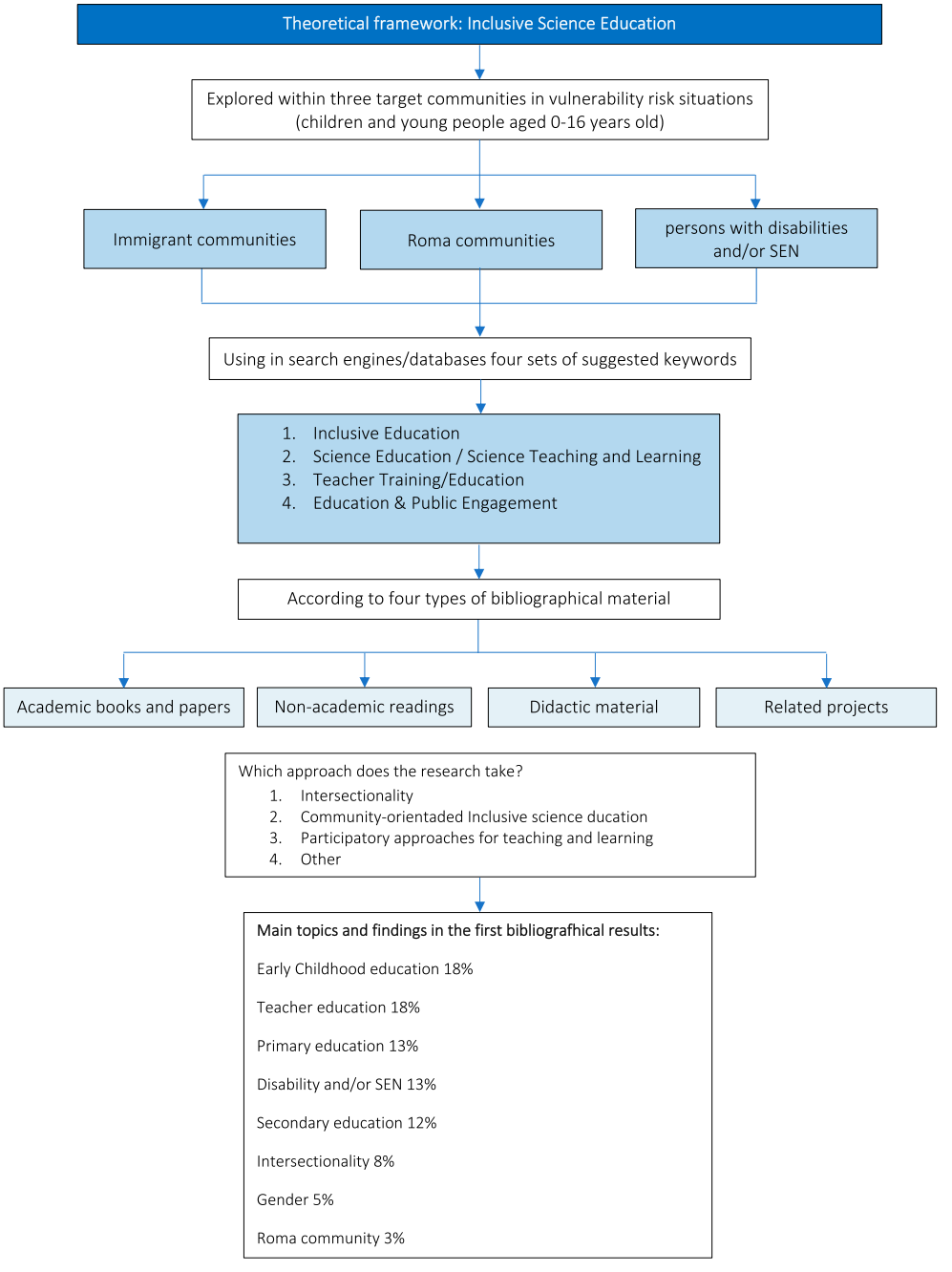
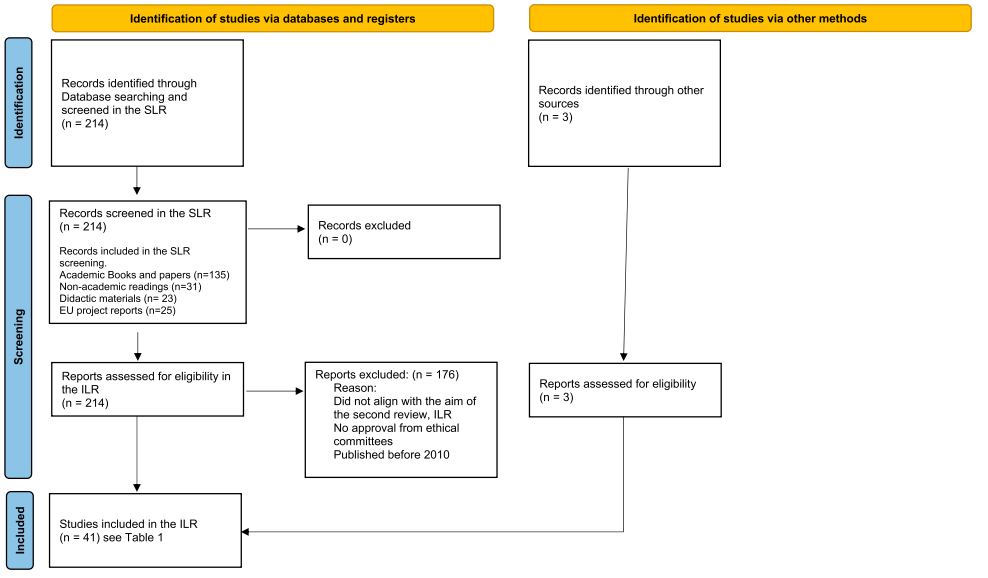


Figure 1. An overview of the design and topics in the bibliographical search from the first and second step in the review (i.e. respectively, SLR and ILR reviews).

Eligibility criteria in the second step of analysis

We re-analysed and integrated the first step (SLR) in the new second step (ILR) by reviewing papers with a focus on ISE and community-oriented approaches, engagement,



PRISMA ScR flow diagram data extraction in the Scoping literature review (SLR) and the Integrative literature review (ILR)

PRISMA *statement for reporting scoping reviews.* (Tricco et al. 2018)

Figure 2. PRISMA-ScR flowchart of data extraction

infrastructures, pedagogical and didactic strategies in teaching and learning published in peer-reviewed journals, national reports, and guidelines. Academic books were included if written or translated in English. Considering the extent of scientific literature on certain main topics, we limited the ILR to include only papers and books published from 2010 onwards. Three additional papers were retrieved from the reference list of selected literature in the SLR.

Exclusion criteria: Studies not aligned with the aim of the ILR, studies not including community/public engagement in ISE or published before 2010. Studies with no ethical approval for research involving potentially vulnerable groups. Scientific papers and books not published in English.

Data extraction

Data was extracted using a qualitative constant comparative method described by Whittemore and Knafl (2005). In detail, four phases were performed in the ILR. During the first phase, the 214 bibliographic references collected in the SLR were reviewed together with three references retrieved from reference lists and published in peer-reviewed journals (in total 217 references, see Figure 2). The extraction was conducted manually by reading the title, abstract and full text when assessing the eligibility aligned with the aim of this ILR. Eligibility and exclusion criteria in the second step of the analysis are presented below. Data display matrices were developed to display all the reports assessed for eligibility. Meaningful references and codes were developed from the literature and were iteratively compared before inclusion or exclusion. Furthermore, ethical considerations were made ensuring that only records with approval from ethical committees were accepted for inclusion.

Data analysis

The qualitative Constant Comparative Method (CCM) was initiated when the final 41 references were determined for analysis in the ILR. A manually spreadsheet approach was used for data analysis according to CCM principles in an Integrative Review (Whittemore and Knafl 2005). Mind-maps and figures were created to document and understand the information in the 41 references. Tables with samples displaying primary sources started the data reduction with meaningful units and open codes that captured descriptive information close to the data. This data-reduction phase allowed selecting detailed texts relevant for the research question and aim of this study.

In this second phase, the sampled literature was visually displayed in matrices to facilitate and visualise relationships and patterns emerging. The review matrix was designed as a table that outlined the key information from each published source (see Table 1). This process allowed the authors to synthesise a large amount of information from the sample of abstracted data.

The third phase involved examining the data displays for patterns, themes, commonalities, and differences across the review sample. The authors performed this phase independently from each other.

In the final fourth phase, conclusions and verifications were discussed thoroughly among the authors. This verification process implied re-reading some of the literature before the results were conceptualised by comparing codes, then grouped into themes and subcategories (see Figure 3). Conclusion drawing and verification were performed by all authors to ensure that findings matched the aim of this paper.

Results

This section summarises key educational conditions and pedagogical strategies identified in our ILR that promote community-oriented Inclusive Science Education. It also examines the main challenges and potential pedagogical opportunities for advancing this educational approach.

Drawing from these compelling findings (see Table 1), we have devised a dynamic and interactive wheel (see Figure 3) based on analytical discussions that led the research team to the metaphor of a gearwheel. Each wheel stands for an overarching theme that needs another wheel to work. This visualisation elucidates the intricate interplay among infrastructures, didactics, and critical approaches, providing a comprehensive comprehension of community-oriented ISE. The interactive wheel illustrates how these elements intersect and synergize, ultimately advancing the inclusion of children and youth facing vulnerable risk situations. Three main themes with three to four subcategories respectively emerged as pivotal components for fostering community-oriented ISE: Contextual Factors, Pedagogical Approaches and Critical Approaches (see Figure 3).

Main theme 1: *Contextual Factors* include subcategories: Community-oriented policies and regulatory frameworks, safe learning environment, and local neighbourhood.

Main theme 2: *Pedagogical Approaches* with subcategories: Participatory learning teaching and approaches, Natural science activities, Community science projects, Explorative and playful science.

Table 1. Sources included in the integrative literature review.

Year	Author/s	Title	Country	Core message	Category
2022	ACTION Project	ACTION project – Recommendations to mainstream citizen science.	European Commission, Luxembourg	Recommendations to mainstream citizen science in policy	Community-oriented policies and regulatory frameworks
2021	Brogna et al.	Springboard to action. Recommendations for improving equity, inclusion, and diversity in Astronomy.	Headquarters in France	Policy recommendation to ensure inclusion, equity and diversity in the field of astronomy.	Community-oriented policies and regulatory frameworks Equity
2020	Brown E.D.	The Art of Early Childhood Education.	USA	Explored first-generation immigrant families' and classroom teachers' expectations. One of the results has been that the expectations of the families were higher than the teachers' expectations because parents want that the children develop a close relationship to the hosting country.	Intersectionality, Equity
2018	Campbell et al.	STEM Practice in the Early Years	Australia	Observed STEM Education as a play-based pedagogical approach in early year education. Findings show self-beliefs of children to learn STEM. Integrated STEM in early education promotes children's interest and curiosity towards science.	STEM, Explorative and playful science
2019	Cantó et al.	Science in early childhood education: the perception of Spanish teachers during initial training.	Ireland	Study on teachers' perception towards content, didactics and learning outcomes of science education in second cycle education (3–5 years). The results show a lack of attention to including science activities as content and therefore less attention to didactics.	Participatory learning and teaching approaches
2020	Chan A.	Superdiversity and critical multicultural pedagogies: Working with migrant families.	New Zealand	Address the issue of super diversity in education and therefore consider frameworks of superdiversity and critical multiculturalism to address transforming policy and pedagogical processes.	Intersectionality, Equity
2016	Counsell S.	STEM Learning with Young Children: Inquiry Teaching with Ramps and Pathways.	USA	Trough ramps and pathways (R&*P*) early physical science activities educators and young children (3–8 years) explore and investigate what happens as marbles and rolling objects are released on constructed ramp structures and pathways using wooden cove molding. Purpose is to examine the potential impact of R&*P* investigations for children with and without disabilities.	STEM, Explorative and playful science

(*Continued*)

Table 1. Continued.

Year	Author/s	Title	Country	Core message	Category
2019	Davies et al.	*Teaching Science and Technology in the Early Years*	UK	Book for early year's educators and students to plan science education based on research-based pedagogical approaches.	STEM
2018	DeJarnette, N. K.	Implementing STEAM in the Early Childhood Classroom	USA	Need for STEAM education in early childhood education is explored through ethnographic research activities, including interviews, observations, etc. The results show limited implementation of STEAM education.	STEAM
2018	Djonko-Moore et al.	Using Culturally Relevant Experiential Education to Enhance Urban Children's Knowledge and Engagement in Science.	USA	Explored how experiential science education supports urban children's science knowledge and engagement through cultural relevance and an eco-justice approach during a 1-week summer camp. Authors emphasise the establishment of culturally relevant experiential learning opportunities to engage children in science.	STEM, Natural science activities
2018	Education International	Promoting integration of migrants and refugees in and through education: Toolkit	Headquarters in Belgium	Guidelines in promoting integration of refugee children in and through education – Toolkit	Community-oriented policies and regulatory frameworks
2025	European Union	Sustainable Development in the European Union – Monitoring report on progress towards the SDGs in an EU context.	European Commission, Luxembourg	Monitoring report about the achievement of the UN-formulated global goals. With a specific focus on goal no. 4 'education' an underachievement regarding reading, mathematics and science is described	Equity
2018	Florian, L. & Beaton, M.	Inclusive pedagogy in action: getting it right for every child.	UK	In this study, participant observation and video footage from three classrooms were used to capture 'learning moments' identified by teachers and pupils. The findings show how teachers learn from the pupils' self-assessments of their learning to reflect on inclusive pedagogy.	Participatory learning and teaching approaches, ISE
2010	Florian et al.	Preparing teachers for inclusive and diverse educational environments: studying curricular reform in an initial teacher education course.	UK	Reform in teacher education is needed to improve inclusive education for children and young people regardless of social, emotional, intellectual, or other differences. The need for a reform to promote inclusive education is not yet represented in the teacher's everyday work. Teachers should be prepared by being aware of differences in the classroom and to reflect on strategies to include them.	Participatory learning and teaching approaches

2019	Husband T.	Using Multicultural Picture Books to Promote Racial Justice in Urban Early Childhood Literacy Classrooms	USA	To promote racial awareness in U.S. classrooms, the use of multicultural picture books is recommended. Practical consideration of using these books is addressed in this publication.	Intersectionality, Equity
2020	Khalfaoui et al.	Bridging the gap: engaging Roma and migrant families in early childhood education through trust-based relationships	Spain	The authors present a case study that shows the positive impact of involving Roma and migrant families in the education process. An intensive collaboration between the families and the schools is characterised by trust and confidence-based relationships and a high-quality education for all children as a common value.	Intersectionality, Equity
2021	Khalfaoui et al.	A Systematic Review of the Literature on Aspects Affecting Positive Classroom Climate in Multicultural Early Childhood Education.	Spain	To ensure the inclusion of children from minority background in education, positive classrooms are relevant. Eight aspects that are relevant for positive classrooms include, e.g. teacher-student supportive interactions, peer interactions and friendship, child engagement.	Safe learning environment
2017	King Miller B. A.	Navigating STEM: Afro Caribbean Women Overcoming Barriers of Gender and Race.	Australia	Focus is on Panamanian Afro-Caribbean women's experiences in STEM education and how they were able to overcome race and gender barriers to receive education and employment in STEM. Further, socio-cultural values and strategies influence a positive self-identity.	STEM
2018	Koomen et al.	Towards Inclusion of All Learners through Science Teacher Education	USA	Book to promote inclusion in education through Science Teacher Education. Experts with a disability share their classroom experiences and describe, together with educational experts, how inclusion in education can be achieved.	Participatory learning and teaching approaches
2019	La Force et al.	Revisiting Race and Gender Differences in STEM: Can Inclusive STEM High Schools Reduce Gaps?	USA	The authors examined 20 inclusive STEM projects focusing on supportive relationships, problem solving and teamwork relating to race and gender.	STEM
2020	Larimore R.A.	Preschool Science Education: A Vision for the Future.	USA	This essay highlights the strengths of early childhood and science education in promoting the understanding of natural phenomena and the living environment of children. The meaningfulness of early childhood and science education includes a holistic teaching approach (i.e. physical, social-emotional, and cognitive development).	Natural science activities

(*Continued*)

Table 1. Continued.

Year	Author/s	Title	Country	Core message	Category
2021	MacIsaak et al.	Learning Physics with refugee children in Germany.	Germany	Physical and playful experimentations with refugee children in Germany aimed to distract them from everyday life and make them feel welcomed. The experiments were offered by volunteers and had informal learning goals: maker culture, language, and having fun – motivating science.	Natural science activities, Explorative and playful science
2020 (2023 in English)	Magrin F.	Eco Heroes, vidas en defensa del planeta.	Spain	Teacher training plays a key role in Inclusive Education. A book addressing issues of environmental justice for children, Eco-heroes from different communities and countries worldwide.	Ethical considerations, Equity
2018	Maina Okori et al.	Reimagining intersectionality in environmental and sustainability education: A critical literature review	Canada	Critical review that stresses the need to consider intersectional and feminist approaches in environmental perspectives towards sustainable education.	Intersectionality
2016	Markic & Abels	Science Education towards Inclusion.	Austria	International perspectives in inclusive science education. A broader view on inclusion and diversity, including second language learning or intercultural pedagogy that is combined with science education and science education research.	Participatory learning and teaching approaches
2020	Monkeviciene et al.	Impact of innovative STEAM education practices on teacher professional development and 3–6-year-old children's competence Development.	Lithuania	The findings of this study show an increase of soft skills (problem-solving, creativity, ability to learn, communication) through STEAM education for children at an early stage. In comparison, hard skills (mathematical, technological, and engineering) are less frequently developed. This means that making decisions and critical thinking can be achieved through STEAM, but the development of STEAM abilities is learned less sustainably.	STEAM
2021	Nilholm C	Research about inclusive education in 2020 – How can we improve our theories in order to change practice?	Sweden	Two examples about education in Sweden show the benefit of using case studies to develop inclusive education theories. Inclusive education theories that are empirically discussed support the creation of tools to promote inclusive school systems.	Participatory learning and teaching approaches
2016	Pettibone et al.	Citizen Science for All – A guide for Citizen Science practitioners. German Centre for Integrative Biodiversity Research (iDiv)	Germany	A guide to implementing citizen science activities in research as a participatory approach to involve citizens actively in science.	Community-oriented policies and regulatory frameworks
2016	Poon-McBrayer	Complexities of Shared Ethnicity, Immigrant Education, and Disabilities: Reconceptualizing Multicultural Special Education	Hong Kong	This research illustrates narratives that show the complexity of immigrant children's education regarding language, culture, and disability in the classroom.	Intersectionality

2018	Reynaga-Peña et al.	Creating a dialogic environment for transformative science teaching practices: towards an inclusive education for science.	Mexico	Principles of dialogic learning are used in teacher training to be prepared to work with students with disabilities in the science classroom. Self-awareness and critical reflection are part of the teacher training that allows the creation of a spirit of solidarity and social action. It is suggested to consider these issues at the curricular and practical level for teacher training schools.	Participatory learning and teaching approaches
2020	Rosenberg A.R.	Social studies in early childhood education and care: A scoping review focusing on diversity.	Norway	The use of social studies to address cultural diversity and educational challenges in the classroom has been identified through a scoping literature review. The analysis of the review led to discussions about the critical educational challenge to familiarise children with diversity on the one hand and to be aware of the risk of using biased information and stereotypical views.	Intersectionality
2020	Sáinz et al.	Parent and Teacher Depictions of Gender Gaps in Secondary Student Appraisals of Their Academic Competences.	Spain	Gender gaps in STEM and non-STEM domains were identified through focus groups with parents and secondary teachers. Teachers reflected on the question of how gender disparities in STEM can be overcome. Parents reflect less on their role in relation to gender stereotypes.	Intersectionality
2018	Straßer, T.	Ampel-Pilot: Citizens Create Knowledge	Germany	he Ampel-Pilot app, a smartphone application designed to recognize red and green phases at pedestrian traffic lights. Citizens participation to improve technology for the blind and visually impaired.	Community science project
2017	Sotiriou et al.	Creativity, Arts and Science in Primary Education. Training Material. Learning Science Through Theatre.	Greece	Training material for teachers to connect Science and Theatre through Inquiry Based Science Education (IBSE). The idea behind this is to support students in understanding science through IBSE. Through their own experiences, perceptions, and reflective processes.	Explorative and playful science.
2021	United Nations Children's Fund, UNICEF	Global Annual Results Report 2021: *Every child learns.*	Headquarters USA	Recognize children who experience marginalisation in education during the COVID-19 pandemic, early-age marriage, or being pushed out to labour. Further, the report shares achievements in education for children, e.g. gender-responsive teaching and learning systems.	Ethical considerations, Equity

(*Continued*)

Table 1. Continued.

Year	Author/s	Title	Country	Core message	Category
2019	Universität Osnabrück	"Sei dabei" –- Nitrate Measurements at Your Own Doorstep.	Germany	This community science project involved citizens and students in collaborative research with scientists to monitor nitrogen pollution in water. Alongside technical measurements, the project emphasizes participant education and awareness of broader water pollution issues.	Community science projects, explorative Science
2022	United Nations Children's Fund, UNICEF	Seen, Counted, included: Using data to shed light on the well-being of children with disabilities	Headquarter USA	The publication covers more than 60 indicators of child well-being – from nutrition and health to access to water and sanitation, protection from violence and exploitation, and education. The report also includes the first-ever global and regional estimates of children with disabilities.	Community-oriented policies and regulatory frameworks, Safe Learning Environment
2019	Vandekerckhove et al.	The role and place of ECEC integrated working, benefitting vulnerable groups such as Roma	Luxembourg	In this report, the role of Early Childhood Education and Care in Integrated working is reflected to address complex educational needs of children in vulnerable situations, with a focus on Roma children. A literature review and six case studies illustrate different ways of integrated working in a variety of contexts. ECEC integrates childcare with education, health, and social services, etc., that improve health and wellbeing for children.	Intersectionality, Equity
2018	Varis et al.	Promoting participation in society through science education	Finland	Description of a lower secondary school teacher who connected active citizen responsibilities with physics studies. The students learned physics through participation in their living environment, acting as citizens, e.g. painting pedestrian crossings	Community science project, Local neighbourhood
2017	Zeynep et al.	Multidisciplinary Perspectives towards the Education of Young Low-Income Immigrant Children.	USA	This study shows the effect of educational experiences of immigrant children in the U.S. through a multidisciplinary perspective (sociology, family studies, education, and mental health). Therefore, best practice examples from politics and practice to promote cultural understanding, bilingual competencies, etc. were collected. A positive inclusive classroom environment, building integrated support for families and understanding of cultural strengths is relevant.	Community-oriented policies and regulatory frameworks, Safe learning environment

2019	Zinga & Styres	Decolonising curriculum: Student resistances to anti-oppressive pedagogy.	Canada	Reflections and discussions about decolonising and anti-oppressive pedagogies, including the view on curricula, classroom practices and power relations between teachers and students. This article contains perspectives from indigenous and non-indigenous instructors who share practical examples in higher education.	Intersectionality, Ethical considerations, Equity

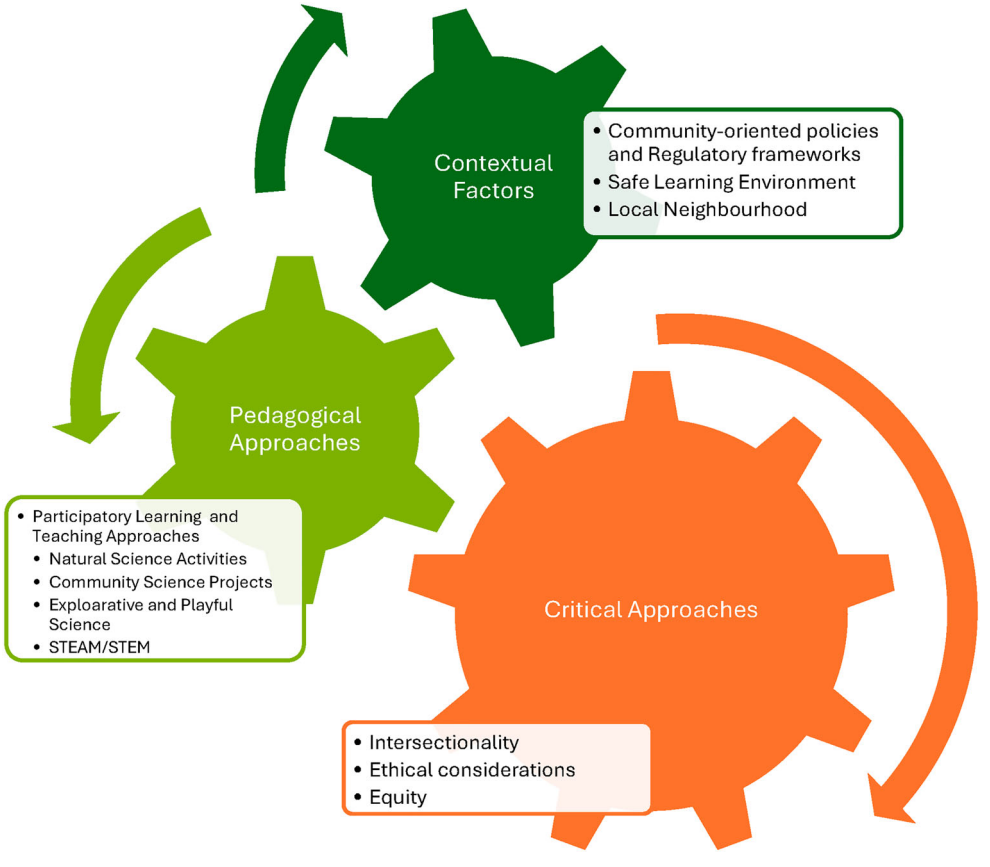


Figure 3. The dynamic interactive wheel of Contextual Factors, Pedagogical and Critical Approaches in Community-oriented ISE.

Main theme 3: *Critical Approaches* includes the subcategories: Intersectionality and Ethical Considerations

To highlight the main findings of the review, we summarise below the main themes and topics that emerged, as presented in the dynamic interactive wheel (Figure 3).

Main theme 1: contextual factors. The local neighbourhood and safe learning spaces indoors and outdoors, enriched through community-based policies

To ensure ISE with and for communities in vulnerable risk situations, contextual factors are key to understanding existing resources and implementing pedagogical approaches for all, as well as reflecting on power dynamics within society, the neighbourhood, and within pedagogical institutions.

Playful science activities in non-formal settings emerged as an important/relevant means of bringing diverse community members together. Families in vulnerable situations, engaging with people from the neighbourhood, experienced a sense of belonging and togetherness, both of which are integral to promoting social participation (ACTION

2022; UNICEF 2021; Universität 2019). These findings highlight the importance of adopting a community perspective as a foundation for developing community-oriented policies. Furthermore, such a perspective is essential to consider in educational frameworks, as emphasised by Brauns and Abels (2021).

Trust-based relationships and a safe learning environment are vital for ISE (Khalfaoui, García-Carrión, and Villardón-Gallego 2020, 2021). These factors promote inclusive and playful interactions, ensuring that no one feels excluded based on gender, ethnicity, or other factors (LaForce et al. 2019). The safe learning environment described by LaForce and colleagues (2019) and trust-based relationships (Pedreira and Márquez 2018) are crucial to support a child-centred inclusive learning environment.

Main theme 2: pedagogical approaches. Natural environment and teacher training opportunities to boost inclusion

Pedagogical approaches provide structured opportunities to advance the concept of ISE during specific teaching and learning activities. The selection of these approaches depends on contextual factors and requires critical reflection.

Involving participatory approaches through Citizen Science projects, which we named community science projects[1] (Figure 3), or collaboration with children and their families in vulnerable risk situations seems to be beneficial for inclusive science education. The need to involve participatory approaches in education has been highlighted regarding policies, learning, teaching methods, and pedagogical approaches (Cantó, de Pro, and Solbes 2019; Nilholm 2021). Frameworks are needed that are aware of inclusion and diversity in educational settings. Several projects emphasise the impact of inclusive science approaches for children in vulnerable risk situations. Findings highlight how natural science activities facilitate the development of physical, cognitive, and emotional skills (Larimore 2020).

The importance of stress-free, informal learning environments through natural science activities is further emphasised by Pedreira and Márquez (2018). Implementing an eco-justice pedagogical approach in community science activities presents a valuable opportunity for promoting ISE (Djonko-Moore et al. 2018). For example, science activities that connect children living in urban areas to nature and the ecosystem can empower marginalised or underrepresented children (Djonko-Moore et al. 2018).

Inclusive Science Education aims to empower and reduce inequalities within communities (Campbell et al. 2018; Cantó, de Pro, and Solbes 2019). Thus, to implement ISE, teacher training is crucial. Educators need to be equipped with pedagogical tools and aware of the negative impact of environmental inequities and injustices on children in the community (Magrin 2023).

Principles of dialogue-based learning, with an emphasis on self-awareness and critical reflection, should be incorporated into the training (Florian, Young, and Rouse 2010; Florian and Beaton 2018; Reynaga-Peña et al. 2018). Diverse teaching approaches and frameworks should prepare educators to successfully implement ISE in the classroom (Brown 2020; DeJarnette 2018; Education 2018; Monkevičienė et al. 2020).

Another example of innovative didactic approaches is shown by (MacIsaac, Genz, and Resvoll 2021), who established physical and playful experiments with refugee children with the idea of giving positive experiences in their everyday life and of giving a sense

of being welcomed. Furthermore, examples of science education activities have been described to overcome language and cultural barriers in very diverse learning groups (Davies et al. 2019; LaForce et al. 2019; Poon-McBrayer 2016).

Main theme 3: critical approaches. Awareness of exclusionary practices, equity and ethical aspects

Critical approaches are foundational to ensuring ISE for communities in vulnerable risk situations within the context. They also help find creative pedagogical ways to implement ISE at all levels. Critical approaches are not a separate layer of analysis. Instead, they serve as a transversal lens that intersects with contextual factors and pedagogical approaches in the dynamic, interactive wheel.

Intersectionality as a critical approach is urgent to consider, ensuring equality in education in terms of gender equality and the inclusion of minorities, e.g. Roma communities and/or immigrants and children with disabilities. Understanding the intersection of factors like gender, race and disability is essential in addressing inequalities (King Miller 2017; Sáinz, Fàbregues, and Solé 2020). Educational equity is further in line with the 2030 Agenda for Sustainable Development, SDG 4 (UN 1995).

Including gender perspectives and multidisciplinary approaches for immigrant children is crucial for a comprehensive and inclusive education (Brogna et al. 2021; Sáinz, Fàbregues, and Solé 2020; Zeynep et al. 2017). The latter is essential to include cultural strength and lingual competencies in the learning environment. A study by Poon-McBrayer (2016) clarifies the complexity of education when migration, language, culture, and disability collide in the classroom.

Awareness of social and race justice based on socio-cultural and economic conditions promotes equal opportunities (Chan 2019; Husband 2018; Khalfaoui, García-Carrión, and Villardón-Gallego 2021; Zinga and Styres 2019; Rosenberg 2020). Specifically, a report on Early Childhood Education and Care (ECEC) addresses the complex needs of Roma Children. The authors published six cases in different European cities and illustrate possible ways of integration in various contexts. They gave emphasis on work integration, showing an impact on the children's health and wellbeing. Finally, this report calls for action to change policies and practices regarding education (Vandekerckhove et al. 2019).

Ethical considerations in education are essential for guiding children and youth toward becoming ethically responsible adults who care for people and the natural environment (Magrin 2023). For pedagogues and policymakers, an awareness of the need to decolonise curricula and embrace anti-oppressive pedagogies is equally important. Such approaches encourage critical reflection on one's own position of power within educational contexts (Zinga and Styres 2019).

The culmination of insights from our ILR, and reflections generated from the interactive wheel, solidifies our findings. These themes and subcategories presented in the interactive wheel are instrumental in fostering inclusive science education for all. Particularly, the integration of critical approaches and participatory methodologies, such as intersectionality, playful learning, and community science initiatives, has highlighted its importance in enhancing engagement and learning outcomes in ISE.

Discussion

The aim of this Literature Review (ILR) was to identify the educational conditions and pedagogical strategies to promote ISE with communities in vulnerable risk situations, regardless of their physical condition, gender, cultural or socioeconomic background.

To show how the findings support participatory and community-oriented inclusive science education in vulnerable groups and their communities, we created a dynamic and interactive wheel (Figure 3). The wheel incorporates intersectionality, ethical considerations, and equity. It highlights how participatory approaches and supportive contextual factors can offer equal learning opportunities. With the wheel as reference and informed by our investigation, we have identified several conditions and learning-teaching methods that are key to addressing the research questions in the discussion to promote community-oriented ISE initiatives. (1) What are the main pedagogical approaches and teaching and learning interventions on inclusive, community-oriented science education? (2) What are (or should be) the main conditions for promoting science education when involving children and youth in vulnerability risk situation?

We emphasise considering the interaction of contextual factors, pedagogical and critical approaches as the main conditions for promoting ISE. Therefore, the dynamic interactive wheel was developed to display the results as interconnected in a dynamic way.

The main pedagogical approaches and teaching–learning interventions on inclusive, community-oriented science education contain community science activities (ACTION 2022; Pettibone et al. 2016; Universität 2019; Straßer 2018). Activities that offer play- and inquiry-based learning experiences (Campbell et al. 2018; Larimore 2020) are relevant conditions for long-term oriented learning outcomes. Further, good practice examples show that creative activities like theatre (Sotiriou, Koukovinis, and Triantafyllou 2017), natural science activities, and physical experimentations through play, impact the inclusivity of children in vulnerable situations.

ISE includes formal, non-formal, and informal educational strategies and methodologies. Reflections about existing policies to ensure equal learning opportunities are also urgent to understand possibilities to act in formal, non-formal, and informal learning activities with diverse groups of children. We conclude that the Socio-ecological systems' theory (Bronfenbrenner 1979) brings together ISE and community issues to a quadruple helix approach that empowers to become active and inquisitive members of societies.

Intersectional approach is the basic condition to identify and overcome inequalities in education.

Critical Approaches were identified in our dynamic, interactive wheel as foundational to ensuring inclusiveness in science education and reducing power imbalances in the learning setting. Therefore, critical approaches provide the basic condition for reflecting on pedagogical approaches and how they are used within existing contextual factors.

The concept of intersectionality (Crenshaw 1989; Morris 1993; Carbin and Edenheim 2013), which encompasses principles of equity, and ethics emerged as a guiding theoretical framework of ISE (Maina-Okori, Koushik, and Wilson 2018). It highlights the need to consider the unique and overlapping identities and experiences of individuals to tailor

educational approaches that are sensitive to the diverse needs of children and youth (Bianchini, Cavazos, and Helms 2000).

On a political level, education should be promoted for the sustainable development and redesign of public areas, creating participatory opportunities for people from diverse backgrounds (e.g. immigrants) (Djonko-Moore et al. 2018) and to meet and feel responsible for the renaturation of the urban space (Burke 2020; Chalufour and Worth 2003). Moreover, intersectionality is essential in curricula to address gender, disability, and immigrant perspectives and consider cultural strengths and linguistic competences in the learning environment.

Local initiatives through socio-cultural pedagogical initiatives – opportunities for social participation in and beyond the classroom

The engagement of educators with the community is another crucial condition to understand the ecosystem that surrounds children (Burke 2020; Djonko-Moore et al. 2018). Community engagement encompasses both individual and societal levels when addressing all members of the community. Existing challenges within the community can be addressed through ISE. Therefore, educational strategies aimed at improving inclusiveness in science are relevant in curricula and policies. Teachers need to be trained to ensure a safe learning environment and to be aware of the diversity (Florian, Young, and Rouse 2010) that should be considered through the lens of intersectionality (Carbin and Edenheim 2013; Crenshaw 1989; LaForce et al. 2019; Lemkow–Tovías et al. 2023; Morris 1993; Maina-Okori, Koushik, and Wilson 2018).

The challenge of strengthening the importance of a diverse working force

The findings of the Integrative literature review led to further reflection on existing challenges and gaps toward the implementation of ISE with and for communities in vulnerable risk situations. In a context of social and cultural diversity, with children belonging to a diversity of backgrounds or having a number of physical conditions that may affect the educator's pedagogical intervention and/or be a challenge for the children's own learning processes, it becomes relevant to offer children accessibility and awareness of plural referents in science education. In this sense, it becomes important to promote the access of teachers and educators who are members of communities in vulnerability risk situation to formal, informal and non-formal spaces of science education (Murray et al. 2015; 'UK Science Workforce' 2014) to enhance inclusion and equity in these pedagogical settings and break with bias and stereotypes about who can become a science expert and educator. This confirms the importance of having a plural/diverse, context-based workforce to boost inclusion in science education. Intersectionality and ethical considerations help address existing challenges and facilitate a dynamic, interactive flow to promote ISE.

Methodological considerations

Considering our experiences of performing a scoping review followed by an integrative literature review approach, we would like to discuss this methodological approach. As

described in the methods section, a comprehensive literature search was performed by the partners of an EU-funded project (C4S). In the ILR, data was extracted and reviewed using a qualitative constant comparative method as described in Whittemore and Knafl (2005). The results from the SLR and the ILR are a synthesis of methodological learnings from both reviews.

Limitations of this scoping review (SLR) followed by an integrative review (ILR) approach need to be acknowledged and addressed

Although a comprehensive search strategy was implemented in the first step, it is important to acknowledge that the literature search was based on search engines chosen by each C4S partner representing their target community. This approach may have caused potential selection bias, as relevant studies could have been missed. Even if efforts were made to evaluate the methodological rigour of the primary findings, the quality assessment of included publications could have introduced bias. Given the integrative nature of the second step, the included publications may vary in terms of methodologies and settings. This could limit the ability to make conclusions or generalise the findings across different contexts. Efforts were made to address and enhance the validity and reliability of the review. Qualitative constant comparative analysis was conducted, and the constant comparison within-paper and between-papers were incorporated to strengthen the review's findings. Iterative memos describing why codes were altered or merged clustered together and/or conceptually formed higher level categories. Comparative analytic questions were discussed when authors judged saturation. A thematic conceptual map was built with sub-categories forming 'The dynamic interactive wheel of Contextual factors, pedagogical approaches and Critical approaches in Community-oriented ISE'.

Despite the limitations, our results allowed us to create the dynamic interactive wheel (Figure 3) including the target group, the community and inclusive science education as interacting determinants that are related to contextual factors and infrastructures. This model allows us to reflect on children's and families' interactions and interrelations with their surrounding environments (home, school, community, region, national policies, etc.).

This scoping review provided additional information on the potential impact of ISE for sustainable communities, although such an idea is still a working hypothesis, and this causal connection still needs to be proven through further and more detailed research and analyses. We also explored resources and risk factors that ensure sustainable ISE in different communities. Finally, this integrative review method identified general useful empirical information for the development of sustainable inclusive science activities that may have an impact on community engagement and inclusivity in science education.

Challenges and future prospects

ISE plays a key role in enhancing the capabilities of children and youth to participate in science and societal development processes. To be aware of inequalities in the educational setting, educators should thus be trained to implement inclusive teaching approaches (Brauns and Abels 2021; Florian, Young, and Rouse 2010; Florian and

Beaton 2018) and reflect on intersectional determinants that might cause inequality and exclusion of children in vulnerable situations. Our findings suggest including community-oriented approaches (Haywood and Besley 2014; LaForce et al. 2019; Avery and Hains 2017; Reynaga-Peña et al. 2018) and knowledge about participatory pedagogical approaches (Frejd 2021; Harlen et al. 2010; Pedreira and Márquez 2018; Waller and Davis 2014) in the educator's training and using participatory strategies to reflect communities' strengths and barriers through the lens of intersectionality.

Concluding comments

ISE plays a key role in enhancing the capabilities of children and youth to participate in science and societal development processes. Based on the scoping review (SLR) and an integrative review (ILR), we developed a dynamic and integrative wheel that illustrates the interconnections among pedagogical approaches, critical approaches, and contextual factors. The wheel helped identify the main pedagogical approaches and teaching and learning strategies for inclusive, community-oriented science education. Participatory approaches such as nature-based activities or community-science projects exemplify how ISE can address educational needs of communities in vulnerable risk situations. Successful implementation depends on creating safe learning spaces and the involvement of the local context. Critical approaches, including intersectionality, are essential for addressing power dynamics and inequalities that influence participation in Science Education. Future research should further explore the dynamic interactions among pedagogical, critical, and contextual conditions, and examine how this influences ISE practices with communities in vulnerable risk situations. This integrative perspective provides a foundation for advancing equitable and community-oriented approaches to ISE.

Notes

1. We chose to use the term community science projects in Figure 3, instead of citizen science projects, to be more inclusive of individuals in our communities who may not hold citizenship status.
2. http://www.communities-for-sciences.eu/.

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Authors' contributions

Dr. Kristina Orban and Sarah Scheer were responsible for the administration of the Integrative review approach. They dealt with the Constant Comparative methodology and set up the analysis and presentation of results, discussion and concluding comments. They edited the original draft of the manuscript. Dr. Valeria Cotza and Gabriel Lemkow, with their respective Hubs (Milano and Manresa), were responsible for the administration of the first Scoping Literature Review (SLR). They dealt with the methodology and set up

the analysis and presentation of results of this first review. The University of Milano-Bicocca was the lead partner of the Work Package (WP4 – Research Management & Pilots) within which the C4S Literature Review Report was produced (Deliverable 4.1 – Report on literature review). All authors contributed to defining the framework and to developing and discussing the findings. Everyone also worked on writing, revising the paper and approving the final version.

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Data availability statement

Upon request, please contact the corresponding author.

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