



Review

# STEM/STEAM in Early Childhood Education for Sustainability (ECEfS): A Systematic Review

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**Abstract:** We sought to explore the intersection between interdisciplinary STEM/STEAM educational approaches and Early Childhood Education for Sustainability (ECEfS). For that, we conducted a systematic review of Web of Science, Scopus, ERIC, and Scielo databases from 2007 to 2022 following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) commandments. The systematic search led to a list of 12 articles, and we analysed them through theoretical orientations, educational perspectives, and pictures of children’s nature. We found that most studies focus on sustainability’s environmental pillar and address the discipline of science more frequently. Additionally, the authors tend to assume a theoretical orientation on the need for connecting children to a sustainable issue and picture the Apollonian child—assuming children are essentially good and emerge with virtuous traits from this contact, such as environmental care. Accordingly, researchers usually propose experiential learning in environments or settings related to sustainability, while there is a lack of teaching STEM/STEAM knowledge and skills on sustainability or engaging children to act for sustainability. We verified that they frequently lose opportunities to explicitly discern STEM/STEAM knowledge areas and their intersections in moments that could benefit children’s learning.

**Keywords:** STEAM education; STEM education; sustainability; environmental education; early childhood education



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## 1. Introduction

International organisations have published several reports on the necessity of environmental protection [1,2] and the urge for a sustainable society [3–5]. Accordingly, education has been summoned to participate in this global challenge that sustainability represents [5–7]: being sustainability conceived as a complex and entangled concept comprising a triad of social, environmental, and economic aspects [3]. In this context, education is portrayed as a critical motor and an outcome of sustainability. First, Education for Sustainability (EfS) is argued as necessary to develop students’ knowledge, values, agency, and actions that lead to a sustainable society [5]. Second, quality education for all is recognised as a Sustainable Development Goal (SDG) [5], since it is related to, for example, having access to good jobs and advancing social and gender equity [8].

On the one hand, considering education as a motor for sustainability, United Nations Educational, Scientific, and Cultural Organization (UNESCO) [7] argues for reorienting education to sustainability through interdisciplinarity pedagogy. Following this idea, in 2018, they mentioned the interdisciplinary approach of Science, Technology, Engineering, Arts/Humanities, and Mathematics (STEAM) education for achieving SDGs [9]. On the other hand, considering education an outcome of sustainability, interdisciplinarity is argued as a pedagogical strategy to enhance quality education. Jamali, Ale Ebrahim, and Jamali [10], for example, conducted a bibliometric study of the terms “STEM education”—an interdisciplinary educational approach between Science, Technology, Engineering, and Mathematics—and “quality education” reflected in publications from 1993 until 2000.

They concluded, through an analysis of keywords, that “STEM education” and “Early Childhood Education” were growing intensely [10]. At this point, we clarify that the STEM and STEAM approaches differ regarding the education scope. Respectively, they represent the concentration of efforts on technological knowledge areas or the inclusion of arts and humanities [9,10]. In this study, we mention them not as interchangeable approaches, but we focus on their accordance with interdisciplinarity’s role in enhancing education. For example, Varela-Losada et al. [11] pursued a bibliometric analysis in transformative learning for sustainable development. The authors detected the central cluster of closely-related terms to sustainability: critical reflection, social learning, and transdisciplinary/holistic education.

While EfS is defended throughout all educational levels [12], some reports highlight the contribution of Early Childhood Education (ECE) to sustainability [13,14]. The particular interest in early childhood—birth to eight—embraces the rationality that initial ages are foundational for environmental sensitivity, literacy, and behaviour later in life [15]. Furthermore, children are recognised as subjects owning the right to have an opinion about aspects that impact their lives, including sustainability issues [12,16].

Accordingly, literature reviews have focused on Early Childhood Education for Sustainability (ECEfS) [12,16,17]. For example, Davis [17] reviewed articles between 1996 and 2007. He evidenced that educators’ interest in sustainability was becoming apparent in this period. Somerville and Williams [16] reviewed studies published between 2003 and 2009, and Yıldız et al. [12] covered articles published between 2008 and 2021. Together, those studies help to draw a longitudinal understanding of ECEfS. They confirm an increasing interest in ECEfS and primarily positive outcomes observed in empirical studies. Notwithstanding, those reviews demonstrated that researchers’ attention to sustainability had been minimal in ECE, and the field lacks the necessary foundation and critique [12,16,17].

Despite the demands from society towards education to engage with sustainability, it is worth bearing in mind the intrinsic objectives of education [18,19]. Therefore, we propose inverting the logic from “Education for Sustainability” to “Sustainability for Education” and wonder about sustainability’s contribution to education, specially addressed through interdisciplinary approaches in ECE. Evidence shows, for example, that STEM and STEAM strengthen children’s agency and cognitive, attitudinal, and emotional abilities [20–22]. Moreover, researchers have stressed that students develop knowledge and abilities in STEM education while addressing ECEfS [23,24]. Reviews confirm the connection between EfS and interdisciplinarity [10,25]. However, no previous reviews have specifically addressed the intersection between ECEfS and interdisciplinarity.

Minding this research gap, we sought to conduct a review that explores the intersection between Early Childhood Education for Sustainability (ECEfS) and STEM/STEAM education.

## 2. Theoretical Framework

Following the research objective, we theoretically scaffold Early Childhood Education for Sustainability (ECEfS) and STEM/STEAM education. Next, we address the main discourses and theoretical orientations on those topics.

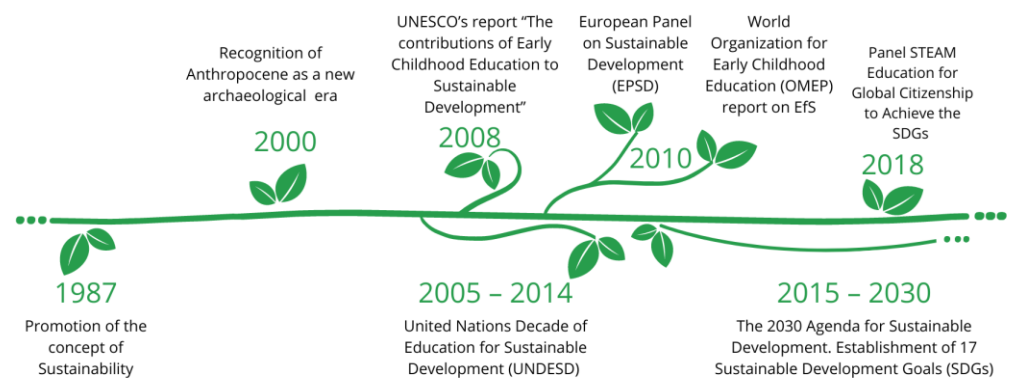
### 2.1. Early Childhood Education for Sustainability (ECEfS)

According to the Population Division from the Department of Economic and Social Affairs (DESA) of the United Nations [26], on 15 November 2022, the world’s population reached 8 billion people. Over the last century, the planet has experienced rapid population growth. For example, the move from 7 to 8 billion inhabitants took only 12 years to accomplish [27]. Even though the predictions indicate that this growth rate is slowing [27], human presence and activity have been so dramatic to the planet that researchers recognised the Anthropocene—a new geological era imprinted by humankind as the leading natural force with global implications [28–30].

In 1987, the World Commission on Environment and Development (WCRD) published the Report Brundtland, “Our Common Future”, framing sustainability in terms of human

temporality [3]. This document defined sustainable development as the ability to meet today's needs without compromising the ability of future generations to meet their needs. According to UNESCO [7] (p. 17), sustainable development "is not a fixed notion, but rather a process of change in the relationships between social, economic, and natural systems and processes". It is a complex concept where social, environmental, and economic pillars intertwine [6,7]. Consequently, sustainability requires many spheres of society to engage with it. Moreover, sustainability entails multiple and integrated knowledge areas to comprehend the world's complexity and provide creative solutions [7,31,32].

International reports have demanded education to engage with the endeavour of a sustainable future [12]. In brief, EfS is claimed to empower students to be subjects who make informed decisions to promote the well-being of current and future generations [25]. Accordingly, those discourses on the necessity of engaging education with sustainability have echoed at all educational levels [12], including the preschool period. Early childhood is critical for a sustainable life because values, attitudes, behaviours, and skills are cultivated in this phase [13]. In Figure 1, we present a timeline of international reports on fostering ECEfS and conducting STEAM education as an appropriate interdisciplinary educational approach for sustainable development.



**Figure 1.** Timeline of international reports related to fostering Early Childhood Education for Sustainability (ECEfS) and STEAM education.

As stated before, Brundtland's [3] report reinforced sustainability as a comprehensive concept encompassing environmental, sociocultural, and economic pillars. Next, according to environmental concerns [1,2], Anthropocene was recognised as a new geological era imprinted by humans as the main nature force that impacts the planet [28–30]. The need for change is reflected in many actions. For example, UNESCO [6] established 2005–2014 as the United Nations Decade of Education for Sustainable Development (UNDESD). Within this period, some arrangements focused on the preschool level, for instance, UNESCO's workshop named "The role of Early Childhood Education for a sustainable society", held in 2007 [13]. The European Panel on Sustainable Development (EPSD) was held in 2010 [16]. This same year, the World Organization for Early Childhood Education delivered a report indicating that sustainability includes children's right to have an opinion on sociocultural, economic, and environmental issues [12].

In 2015, United Nations set 17 Sustainable Development Goals (SDGs) in the Agenda 2030 [5]. Early Childhood Education (ECE) and Education for Sustainability (EfS) were articulated among those goals. Goal 4.2 stated that all girls and boys have access to quality early childhood development, care, and pre-primary education. Moreover, Goal 4.7 referred to the commitment to "ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyle." As a final point to the timeline, a panel focused on STEAM education as an interdisciplinary approach appropriate for achieving the SDGs [9].

## 2.2. STEM/STEAM Education

We further on STEM and STEAM education, initially, because those interdisciplinary approaches have been defended as relevant pedagogy to reorientate education for sustainability, but, then, we emphasise sustainable issues as authentic contexts that may contribute to developing children's STEM/STEAM literacy [22].

The acronym STEM was coined by the National Science Foundation (NSF) in the United States in the 1990s to refer to and justify many educational policies focused on the development of professionals in the areas of Science, Technology, Engineering, and Mathematics [32–34]. First, the central rationality behind STEM was qualifying professionals considered essential to national competitiveness, considering economic and warlike development [33]. Afterwards, educational practitioners and researchers resignified STEM into a pedagogy of interdisciplinarity between the knowledge areas that comprise the acronym. In 2007, STEAM emerged in the United States as there was discontent with the STEM focus on technical knowledge [34,35]. In this sense, STEAM represents a competitor research line. This new acronym differentiates by including the letter A—meaning arts and humanities—and, therefore, demanding a broader curriculum scope than STEM [32].

Despite the differences, STEM and STEAM are educational approaches centred on interdisciplinary teaching [36,37]. They are currently prominent educational practices and research approaches [38] that have been adopted in many countries, such as the United States [39], Korea [40], and Spain [41]. Both educational approaches are usually associated with meaningful (scaffolded in previous knowledge [42]), active (involving students' actions [43]), and authentic (contextualised in natural settings [44]) learning. In this sense, they are usually conducted through active teaching methodologies such as project/problem/inquiry-based learning and aligned with playful learning [45], such as in free or guided play [46,47], games [48], and gamification [35].

Incorporating Engineering and Technology is quite distinctive of STEM and STEAM education, since these knowledge areas were commonly absent in the pre-college curriculum [49–51]. One point that unifies STEM/STEAM and sustainability is the significant role of engineering and technology professionals in pursuing solutions towards an ecologically resilient, socially just, and economically viable society [11].

Furthermore, inverting the rationality from “Education for Sustainability” to “Sustainability for Education”, the authenticity of sustainable issues provides a rich context for meaningful learning in STEM/STEAM. Usually, those educational approaches integrate the knowledge areas that comprise each acronym through authentic contexts [52]—a sustainable issue, in this case. Hormazabal, Rodrigues-Silva, and Alsina [20], for example, reported an activity in primary education where children applied statistics to analyse conceptions about engineers from their drawings. They perceived and discussed the tendency to picture male engineers. Chen and Liu [25] reviewed studies on EfS and observed that the literature increasingly explores the relationship between interdisciplinarity and sustainability. They verified that between 1997 and 2010, only five articles promoted students' participation in sustainable action under interdisciplinary pedagogical frameworks. In contrast, from 2010 until 2007, 18 studies enrolled in interdisciplinary activities. According to them, students were empowered by working with interdisciplinarity while addressing authentic problems. After 2010, they specifically remarked on increased science and art studies. However, their study is somewhat limited regarding young children, because only 3 of the 34 documents reviewed concerned ECE.

At this point, we recall United Nations' [9] emphasis on STEAM to achieve SDGs. Accordingly, we clarify our perspective towards STEAM by stating that the complex triad of social, environmental, and economic pillars is better addressed if it encompasses knowledge and skills beyond the STEM technical areas.

## 2.3. Discourses in Early Childhood Education for Sustainability (ECEfS)

As presented above, sustainability enters educational practice and research remarkably as an external demand of society. As a following step, education may recognise teleolog-

ical rationalities [19], such as perceiving educational opportunities for interdisciplinary learning around sustainable issues [29]. Many discourses intertwine within education and sustainability regarding different theoretical orientations [16], educational perspectives [17], and pictures of children's nature [28].

Somerville and Williams [16] observed three theoretical orientations provided as critique in sustainability discourse: connection to nature, children's rights, and posthuman. The connection to nature orientation affirms that children should have experience in natural environments from early years to grow healthy and develop environmental care [16]. This idea is commonly encouraged by a "nature deficit disorder" concern [53] (p. 34). There is a complaint that children are immersed in technological and urbanised environments, as if they were detached from the natural world. Such disconnection would result in their disengagement from nature. The children's rights orientation states that very young children are capable of sophisticated thinking and should be recognised as subjects with the right to have an opinion about issues that impact their lives, such as sustainability [12,16]. In this vein, education should foster children's citizenship with recognised rights and responsibilities related to daily practices considered relevant to sustainable development. Consequently, children are recognised as active agents [12], and pedagogies supported by this rationality usually foster education through child-led practices. Finally, the third theoretical orientation, posthuman, criticises the centrality of humans regarding others as cohabitants on the Earth. Moreover, it suggests moving beyond the dilemma of nature and culture [54]. Frequently, researchers in this paradigm align with decolonising enterprises that value some indigenous traditions, such as ethnomathematics, which fuses nature and culture and humans and non-humans [55,56].

In terms of educational perspective, Davis [17] distinguishes between education in, about, and for the environment. Similarly, we translated those distinctions to sustainability. The educational perspective education in sustainability is centred on providing children with an experience in a sustainable aspect, education about sustainability is centred on developing knowledge about a sustainable aspect, and education for sustainability is centred on engaging action for a sustainable aspect. Those educational perspectives may be entangled and complement each other (as discussed later) in pursuing Education for Sustainability (EfS). We clarify that we distinguish the educational perspective of education for sustainability from the broader aim, capital letter Education for Sustainability.

Discourses around sustainability in ECE commonly draw pictures of children's nature. In this sense, Sjögren [28] used two images of children and childhood, the Dionysian child and the Apollonian child. The former image refers to the understanding of children as originally corrupted and inclined to harbour evil. The latter depiction considers children as born good and with a unique potential, which should be facilitated and encouraged. The author remarks that, although being just categorical depictions, they are robust theoretical frames for practices in ECE. Additionally, he points out that western discourse on children's nature, at first glance, tends towards the Apollonian image. However, the Dionysian image is constantly "somewhere lurking alongside" [28] (p. 04).

Additionally, we observe that the Anthropocene concept is well aligned with the posthumanist theoretical orientation. Anthropos reinforces the idea of referring to humans as one of many biological species on Earth—despite their significant impact on the current geological period [28,30]. Anthropocene has entered educational discussions [29], including early childhood [28]. Guyotte [29] (p. 07), for example, advocates for a philosophy of STEAM in the Anthropocene. This regard through the Anthropocene widens the scope of this educational approach in light of global issues, particularly the urge for sustainability. She posits that "sustainability issues and related power networks are non-linear, complex, and often irrational". Following, the author argues that STEAM education creates spaces where disciplines come together in dialogue; she says, "[i]n STEAM education at all levels, students should be exposed to the many complex and urgent issues of the Anthropocene—issues that are inter- and transdisciplinary in nature" [29](p. 07). Through a critical revision of studies addressing the Anthropocene in ECE, Sjögren [28] found the tendency in the



literature to romanticise children as essentially different from adults—since young children are less likely to have incorporated the humanist detachment of humans and nature, they could offer insights regarding illuminating wildlife that adults rarely could access.

### 3. Methods

Bearing in mind the ambition of exploring the intersection between ECEfS and STEM/STEAM education, we enrolled in a literature review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statements. Accordingly, the review process is structured and informed to guarantee reproducibility [57]. The review is organised into four phases: (1) search elements and Boolean logic, (2) eligibility criteria, (3) information sources, and (4) data collection and analysis.

#### 3.1. Search Elements and Boolean Logic

First, we identified the central terms of the research goal: “sustainability”, “STEM”, “STEAM”, and “Early Childhood Education”. Similarly to previous research in ECEfS, we encompassed “environmental education” [16,17] and early childhood settings such as nature, bush, or forest schools [15]. Eventually, while considering synonyms, we resulted in the string: (STEM OR STEAM) AND (“Early childhood” OR “early education” OR “early years” OR preschool OR kinder\* OR “Initial education” OR “nursery education”) AND (sustainab\* OR environmental OR bush OR forest).

#### 3.2. Eligibility Criteria

Table 1 presents the eligibility criteria applied to this review. We included documents available in English because this language is primarily used in educational research. Likewise, documents written in Spanish and Portuguese were considered to take advantage of the authors’ proficiency in those idioms and enlarge the study’s geographical coverage as much as possible.

**Table 1.** Eligibility criteria.

Criteria	Inclusion	Exclusion
Language	English, Spanish, and Portuguese	Other languages
Publication period	From 2007 to 2022	Before 2007
Type of document	Peer-reviewed article	Other formats
Research area	Education	Other areas
Level	Early Childhood Education (ECE)	Other levels

We considered documents published from 2007—because the acronym STEAM was coined this year [32,35]—until November 2022. Another reason is that this time, likewise, encompasses the period posterior to UNESCO’s [13] report “The contributions of Early Childhood Education to Sustainable Development”.

Next, we set the type of document criteria to include only peer-reviewed documents. Although we recognise that the peer-review process might sometimes be inconsistent, it suggests some research quality [15]. Finally, we included articles from educational research centred on ECE—from born to eight years [15]. The exclusion criteria were essentially antonyms of the inclusion ones.

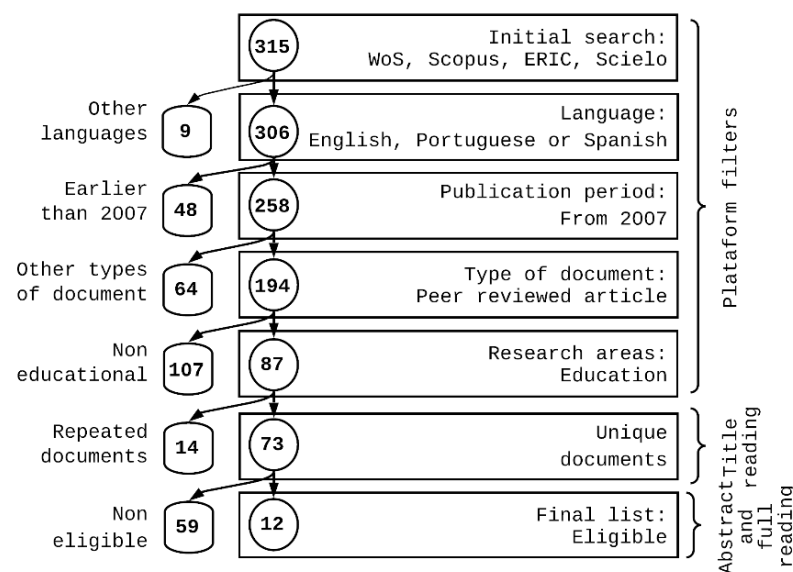
#### 3.3. Information Sources

In this third phase, we selected Web of Science (WoS), Scopus, Education Resources Information Center (ERIC), and Scielo databases because they are recognised for their rigour and importance in research, particularly in the educational field.

#### 3.4. Data Collection and Analysis

Once we established the Boolean logic, we used it to scan documents’ titles, abstracts, and keywords. Some adaptations were necessary, according to the coding from each

database. For instance, the string was simplified in ERIC because it is a specific index from the educational field and presents a filter on the educational level. It permitted restricting the search to documents registered in ECE. As shown in Figure 2, the initial search resulted in 315 records. We used the platform's filters to apply some eligibility criteria such as language, publication period, type of document, and research area. Next, data were exported from those index platforms and gathered into an Excel spreadsheet. Then, we excluded repeated documents by comparing articles' titles or Digital Object Identifier (DOI) numbers. Following, we read abstracts and full texts. At this point, we excluded articles that did not meet the eligibility criteria, such as those focused on other educational levels instead of ECE. Similarly, we excluded some articles that did not mention STEM or STEAM education, such as when the term "STEM" led to documents with the word "system" or when "STEAM" was scanned in studies meaning "vapour".



**Figure 2.** Data collection process flowchart.

The article "Mathematics learning in the early years through nature play" [58] seemed to accomplish the inclusion criteria, but it had to be excluded because we could not access the complete document. We contacted the authors, but they did not answer back. We highlight that other articles from the same authors are reflected in this review, so their visions are somehow already considered.

Eventually, the data collection process led to a final list of 12 eligible documents.

Afterwards, we proceeded with the analysis of the selected documents. First, we uploaded them into the Atlas-ti program for accounting word occurrence. Then, we plotted this information in a word cloud to provide an overview of the main terms in the articles as a group of documents. Then, we observed those terms regarding the Boolean logic, eligibility criteria, data collection process, and analyses a posteriori.

Following, the data analysis occurred through fluctuant readings to ascertain central topics. Then, we followed with in-depth readings and proceeded with multiple comparisons through categories deduced from the literature while permitting new categories to emerge from the data. First, we explored general research features such as publication year, region, sample, age, population, method, intervention, duration, design, and data collection instrument.

Subsequently, we explored the topics that directly involved ECEfS and STEM/STEAM education. Although sustainability is a complex concept that intertwines social, environmental, and economic aspects [6,7], we identified whether the study focused on one of them. In this case, the environmental dimension relates mainly to issues such as pollution, mitigation of climate change, and conservation of natural resources. The social dimension

includes respect for human rights, cultural diversity, health, social equity, and governance. Finally, the economic dimension recalls concern about issues such as poverty alleviation; fair access to human, natural, and financial resources; and corporate ethics, responsibility, and accountability [7].

Next, we classified which educational approach the authors positioned, STEM or STEAM, and the knowledge areas explicitly articulated in each study. As already defined in the theoretical framework of this study, we discussed the theoretical orientations: connection to nature, children's rights, and posthuman [16]; educational perspectives: education in sustainability, education about sustainability, and education for sustainability [17]; and children's pictures: Dionysian child and Apollonian child [28].

#### 4. Results

We start the result topic by presenting a word occurrence analysis of the manuscripts in a word cloud format, as shown in Figure 3. The words “children”, “education”, and “learning” appear in the spotlight of the image and indicate that the selected papers, as a group of documents, concern educational research. Additionally, the words “kindergarten”, “kinder”, “preschool”, “childhood”, “early”, and “young” assert that they are centred on young children. In addition, the word cloud highlights the educational approaches “STEM” and “STEAM”, with a more substantial occurrence of “STEM” than “STEAM”. Finally, the expressions “sustainable” and “sustainability” appeared as well.



**Figure 3.** Word cloud of articles on STEM/STEAM education in Early Childhood Education for Sustainability (ECEfS).

Still referring to the word cloud, we should note that “sustainable” and “sustainability” had a relatively low emphasis in comparison to other elements of the research. If we observe environmental, social, and economic pillars, the terms “environmental”, “nature”, and “bush” point to the environmental aspects. In this line, the words “social” and “girls”—we will see that specifying girls relates to gender equity concern—indicate addressing social aspects. Finally, the word cloud did not display economic-related terms such as “viability”, “economy”, and “cost”. This non-occurrence suggests that the economic pillar of sustainability might be absent in those studies.

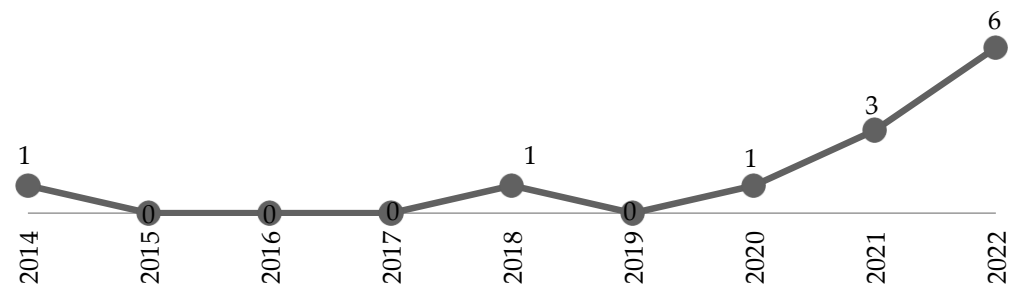
Table 2 lists the reviewed articles and presents research features. In advance, we remark that the low number of documents in this review—only twelve articles—already is a result that indicates the scarcity of studies on the intersection of ECEfS and STEM/STEAM education. Moreover, it confirms the tendency observed in other reviews on EfS that research in ECE is overlooked compared to other educational levels [16,17]. In the following paragraphs, we further explore information from this table.



**Table 2.** General research features.

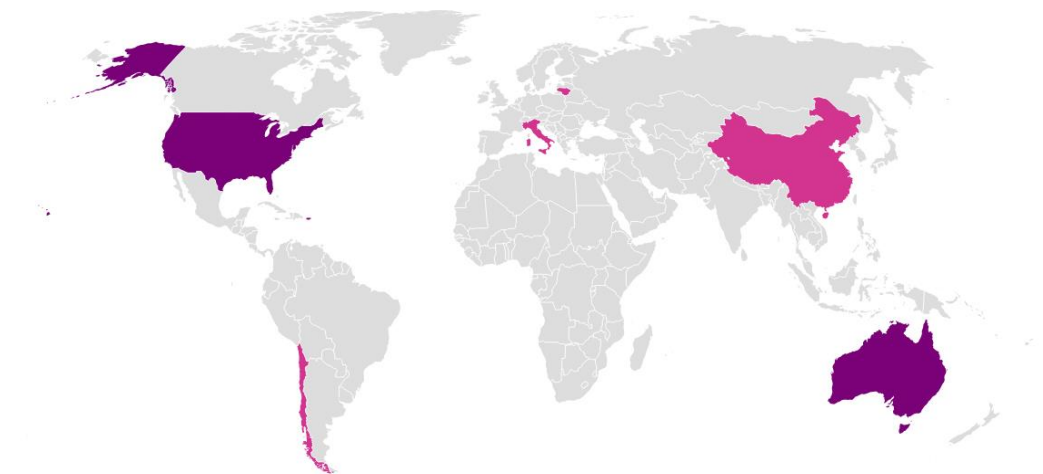
Author	Year	Region	Sample	Age (Year)	Population	Method	Intervention	Duration	Design	Instrument
Aladé et al. [59]	2022	USA	48	5 to 7	Children	Mixed	STEM-focused television series	Eight weeks	Pre-post with a control group	Interview and questionnaire
Bascope and Reiss [60]	2021	Chile	24	4 to 10	Teacher	Qualitative	Planning and implementing STEAM	One year	Ethnography	Interview
Borgerding and Kaya [61]	2018	USA	-	3 to 6	Children	Qualitative	Interactive yarn stories	One week	Case study	Field notes and image placement assessments
Campbell and Speldewinde [23]	2022	Australia	240–300	4 to 5	Children	Qualitative	Bush school	Three years	Ethnography (longitudinal)	Field notes, interview, video recording
Carr and Luken [62]	2014	USA	-	-	Children	Qualitative	Playscapes	-	Narrative review	-
Gurjar [63]	2021	Italy	-	-	Children	Qualitative	Maker space	No	Cross-sectional	No
Monkeviciene et al. [64]	2020	Lithuania	1232	-	Teachers	Quantitative	-	-	Cross-sectional	Questionnaire
Nong et al. [65]	2022	China	242	-	Teachers	Quantitative	-	-	Cross-sectional	Questionnaire
Speldewinde [66]	2022	Australia	80	4 to 5	Children	Qualitative	Bush school	One year	Ethnography (longitudinal)	Field notes and interview
Speldewinde and Campbell [67]	2021	Australia	80–100	4	Children	Qualitative	Bush school	Five years	Ethnography (longitudinal)	Field notes, interview, video recording
Speldewinde and Campbell [24]	2022	Australia	100	4 to 5	Children	Qualitative	Bush school	Five years	Ethnography (longitudinal)	Field notes, photo, interview
Spiteri et al. [68]	2022	Malta	9	3 to 7	Children	Qualitative	-	-	Multiple case studies	Interview and drawings

In Figure 4, we present the publication distribution time of the documents. Although we had set the timespan from 2007 to 2022, we only found articles published from 2014. Additionally, the graph shows a growth tendency from 2020, while the number of documents published doubled between 2021 and 2022. Accordingly, the time distribution shows that the intersection of ECEfS and STEM/STEAM education occurred very recently and is experiencing an uprising of interest. First, this result follows tendencies observed in general reviews on ECEfS, indicating a more significant number of studies published in the last years [12]. Second, it reflects the strengthening of STEM [10] and STEAM [38] as research lines. Moreover, United Nations [7–9] reports demanding a redirection of education towards sustainability and explicitly mentioning interdisciplinarity are expected to foster the intersection of ECEfS and STEM/STEAM education in the following years.



**Figure 4.** Publication distribution time of articles on STEM/STEAM education in Early Childhood Education for Sustainability.

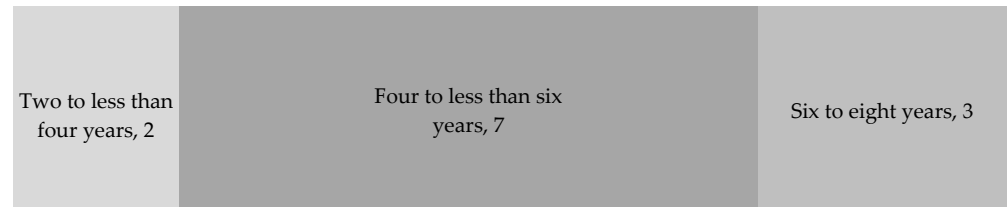
In terms of geographical distribution, as presented in Figure 5, the reviewed studies were enrolled in Chile [60], China [65], Italy [63], Lithuania [64], Malta [68], and the United States [59,61,62]. Moreover, Australia concentrates on four documents authored by Campbell and Speldewinde [23,24,66,67]. Those authors explored different aspects of STEM education in bush schools: an out-of-class setting fostered in this country wherein children experience the natural world mainly through playful activities [66] (we will discuss it later).



**Figure 5.** Geographical distribution of articles on STEM/STEAM education in Early Childhood Education for Sustainability (image created with Datawrapper).

Most studies (9) have children as their research population. Only three studies focused on teachers [60,64,65], while no research addressed other related groups, such as family members. Considering exclusively the reviewed articles that focused on children, we analysed children's age into four equal intervals of two years, embracing the whole childhood (0–8 years). Whenever research encompassed children from more intervals, they

were counted multiple times. Carr and Luken's [62] study was not accounted for because they addressed playscapes and did not specify age. Figure 6 shows that most studies investigated children aged between four and six (7). We remark that no study addressed children younger than two years old.



**Figure 6.** Children's age distribution.

The research method mostly followed a qualitative approach (9). Campbell and Speldewinde [23,24,66,67] pursued a similar methodology in their four studies. Those authors enrolled in ethnographies during repeated visits to bush schools for 1 to 5 years. Agreeing with ethnographies, which commonly use different sources of information, they used field notes, sometimes interviews, and image recording. Their research design can be understood as longitudinal regarding the evolution of the schools, but they did not accompany children's temporal changes. Aladé et al. [59] published the only mixed-method research. They enrolled a pre-post design with the control group using interviews and questionnaires to evaluate the effects of a counter-stereotypical STEM-focused series on children's mental schemes of STEM professionals.

Regarding the studies focused on teachers as a research population, Monkeviciene et al. [64] and Nong et al. [65] conducted quantitative research through the application of a questionnaire in a cross-sectional design, which means data were collected only one time [69]. Differently, Bascopé and Reiss [60] focused on teachers, but through qualitative research. They pursued an ethnographic study for a one-year programme of planning and executing STEAM activities on sustainability.

Henceforth, we explore topics specific to STEM/STEAM and ECEfS. In Table 3, we display the articles' theoretical orientations, children's pictures, educational perspectives on sustainability, and sustainability pillars. Additionally, we present which educational approach (STEM or STEAM) the authors adopted and the STEM/STEAM knowledge areas they explicitly addressed. We present each study's primary outcome or result in the table's last column.

**Table 3.** STEM/STEAM education and Early Childhood Education for Sustainability.

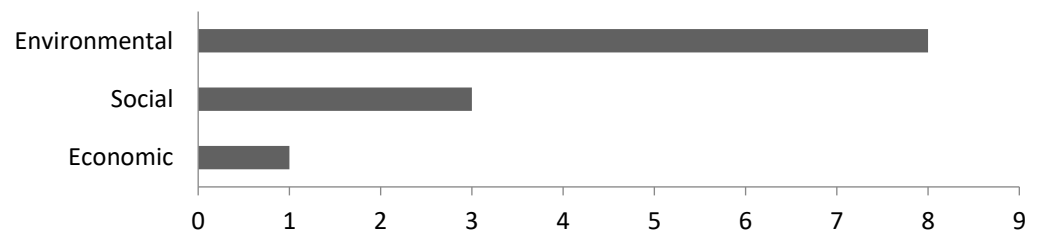
Author	Theoretical Orientation			Children's Picture		Educational Perspective on Sustainability			Sustainability Pillar			Educational Approach		Explicit Knowledge Area					Main Outcome/Result	
	Connection	Children's rights	Posthuman	Apollonian	Dionysian	In	About	For	Environmental	Social	Economic	STEM	STEAM	S	T	E	A	M		
Aladé et al. [59]	x			x		x				x		x		x	x	x			x	Children's occupational schemes had no quantifiable change before and after exposure to a counter-stereotypical STEM-focused series.
Bascope and Reiss [60]	x	x				x	x	x	x	x	x	x		x						STEM projects fostered collaborations of teachers with local actors and organisations usually sidelined from educational experiences. The authors summarised examples of meaningful learning experiences to tackle sustainability challenges.
Borgerding and Kaya [61]			x			x	x		x			x		x			x			Children used teleological reasoning to explain why particular organisms lived in particular environments. They succeeded at placing organisms' images corresponding to three different biomes.
Campbell and Speldewinde [23]	x	x		x		x			x			x		x						Children learned STEM abilities, such as problem-solving, scientific thinking, agency over the language of science, and environmental understanding in bush kinder.
Carr and Luken [62]	x											x								The study discusses the value of play and the environment to wonder about the natural world and precede teaching about the environment and STEM disciplines.
Gurjar [63]		x		x		x			x			x		x	x					Recognition of pedagogical potentialities of maker space with natural and recyclable material. E.g., learning STEM concepts and fostering children's self-efficacy in design.
Monkeviciene et al. [64]	x	x		x		x	x	x					x	x	x	x	x	x		ECE teachers developed STEAM activities targeting soft skills (problem-solving, creativity, communication) more frequently than concepts and abilities specific to the STEAM disciplines.
Nong et al. [65]													x	x	x	x				Short videos positively affected teachers' students STEAM learning performance and sustainable inquiry behaviour.

Table 3. Cont.

Author	Theoretical Orientation			Educational Perspective on Sustainability			Sustainability Pillar			Educational Approach		Explicit Knowledge Area					Main Outcome/Result	
	Connection	Children's rights	Posthuman	Apollonian	Dionysian	For	Environmental	Social	Economic	STEM	STEAM	S	T	E	A	M		
Speldewinde [66]	x			x			x			x		x	x	x			x	The study resulted in a five-phased cyclical conceptual model on STEM teaching and learning in Early Childhood Education (ECE).
Speldewinde and Campbell [67]	x			x			x	x		x		x	x	x			x	Bush kinder settings allowed young girls to develop STEM identities through social interactions and fostered STEM learning.
Speldewinde and Campbell [24]	x			x			x			x			x	x				Bush kinder could develop children's technological and engineering knowledge.
Spiteri et al. [68]				x				x			x	x					x	Children perceived the environment as nature, consisting of different elements of flora and fauna found in the Maltese Islands.

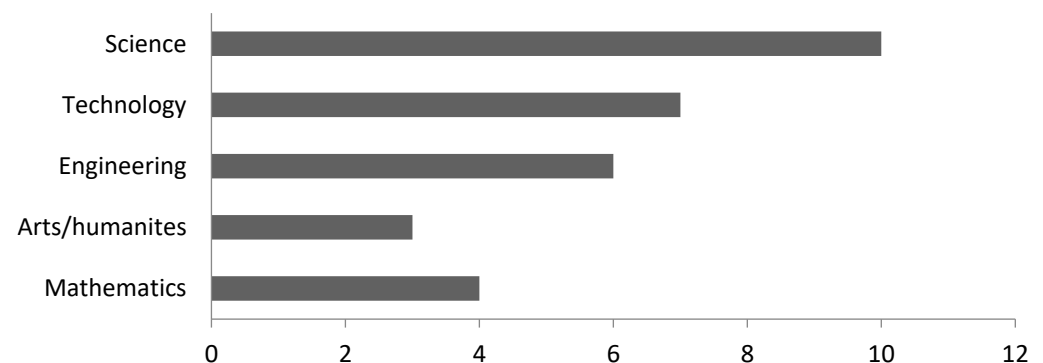


As shown in Figure 7, the environment is the primarily addressed pillar of sustainability (7), followed by social (3) and economic pillars (1). The social aspect concerned exploring the effects of a counter-stereotypical STEM-focused series [59] and gender equity [67]. Continuing to refer to the social pillar, Bascopé and Reiss [60] implemented a teacher training programme involving STEM projects interacting with local communities (Mapuche) and traditions from the south of Chile. Those authors observed that the STEM implemented by the teachers similarly tended to focus on environmental issues. One project from this teacher training programme exhibited an economic vein by connecting local food entrepreneurs and a food showcase. At this point, we mention that the low presence of the economic pillar confirms the previous suggestion in the word cloud by the non-occurrence of economic-related terms.



**Figure 7.** Sustainability pillars in articles on Early Childhood Education for Sustainability (ECEfS).

Regarding the educational approaches STEM or STEAM, as the word cloud suggested, STEM (8) was more frequently approached in the studies than STEAM (4). In this sense, we point out that, although STEAM is growing as a research line, it is newer and generally less noticeable than STEM education in the literature [38]. In Figure 8, we account for STEM/STEAM knowledge areas the authors explicitly addressed in the studies (not meaning that they were made explicit to children). We did not count areas called out only to refer to the ensemble of fields, such as while explaining the acronyms STEM and STEAM. As a result, science stands out as the discipline mainly addressed. Equally, Monkeviciene et al. [64] found that ECE teachers in Lithuania prioritised science over the other STEAM fields.

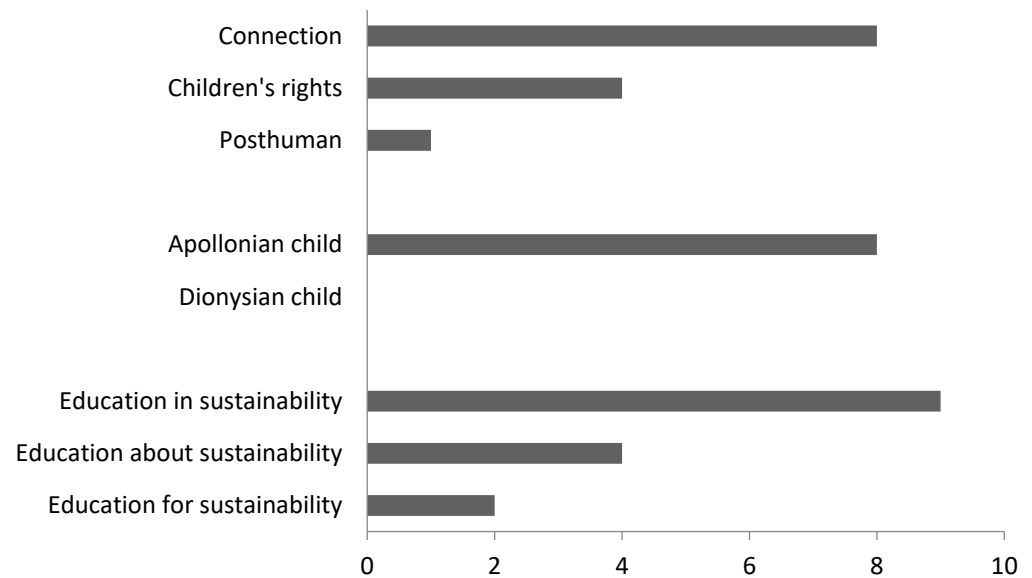


**Figure 8.** STEAM knowledge areas explicitly addressed in Early Childhood Education for Sustainability (ECEfS).

Following, we present in Figure 9 a horizontal chart bar with the prominent discourses regarding theoretical orientation, children's pictures, and educational perspectives on sustainability.

Most articles are theoretically oriented towards the necessity of connecting children to sustainability (8). This idea underlined experiential learning in sustainability and was applied by some authors as the rationality that justifies bush kinder [24,67] and playscapes [62]. Less frequently addressed, the children's rights orientation encompassed recognising children subjects with the right to construct an opinion and choose to act

for sustainability, but, altogether, emphasising that children would have a responsibility for it. For example, Bascopé and Reiss [60] (p. 2) say children should be “encouraged to become problem seekers and solvers in their localities”. Alternatively, Campbell and Speldewinde [23] assert that “[e]ven young children can act locally and responsibly in way to change their immediate environment”.



**Figure 9.** Theoretical orientation, children’s nature picture, educational perspectives.

The reviewed articles adopt a picture of children as the Apollonian child. For example, the authors report episodes when children encounter animals and “respectfully” investigate them in bush kinder. Children are not portrayed as a threat that might kill those animals. In this sense, no author centres on the Dionysian child image. However, some facets of this picture appear throughout the texts. For example, Carr and Luken [62] (p. 76) picture the children as Apollonian children. They argue that children’s inner desires (assumed as good) should be supported so that “they are more likely to be more sophisticated, diplomatic, and socially mature when adults”. Conversely, in another moment, they tilted (even though much less remarkably) to the Dionysian image, saying that “[p]lay leaders encouraged organised games to teach children about following rules and working with teammates. Children were often required to maintain good hygiene and use correct grammar”. According to this last view, children would not spontaneously emerge with, e.g., collaborative behaviour that should be supported.

Eventually, most studies remain in the educational perspective of education in sustainability. The authors seem to focus on children’s experiences with a sustainable aspect, principally through playful strategies. Spiteri et al. [68] focused on the educational perspective of education about sustainability because they explored children’s previous conceptions of nature. Bascopé and Reiss [60] touched on the three educational perspectives, but their study involved a teacher training programme wherein many STEM projects were implemented. Borgerding and Kaya [61] embraced education in sustainability and education about sustainability in the same pedagogical proposal.

In the following paragraphs, we will address some main contributions of the articles addressing their theoretical orientation, children’s pictures, and educational perspectives on sustainability.

Aladé et al. [59] explored the impact of eight-week exposure to a counter-stereotypical STEM television program called *Cyberchase*—the protagonists of this show comprise an African-American girl, a Latino-American girl, and an Irish-American boy. They argued that research has shown that children at very early ages already present stereotypical views of STEM professionals [70,71]. For example, boys and girls tend to picture engineers as

white men [72,73]. Interestingly, they found no quantifiable difference between interventional and control groups. They justified that the exposition time might not have been sufficient to change their conceptions. In terms of educational perspective, those authors enrolled in education in sustainability regarding the social aspect. In other words, they provided children with an environment where they could experience racial and gender representativeness in STEM. Their central discourse aligned with the idea of children's connection to nature since the authors, based on the cultivation theory, suggest that, through repeated exposure, the children could adopt attitudes consistent with the themes portrayed in the program (we considered nature the social environment). They pictured the pupils primarily as Apollonian children, following the idea that the stereotypes they likely stand for come from the external influence of society, such as the interaction with parents, teachers, books, and regular television shows.

Borgerding and Kaya [61] proposed lessons of a STEAM camp in ECE built around three yarn stories accompanied by visits to nature, play, artistic, and hands-on activities. Students could experience evolutionary and ecological concepts related to three biomes: desert, arctic, and deciduous forest. They assigned placards to each child to play with as if they were different organisms. As the story proceeded, a ball was tossed to connect children in a web representing ecosystems. In this sense, we remark that the lessons attended education about sustainability because they learned about ecosystems. For example, the researchers posed questions demanding children to raise their hands if their organism was from the desert/forest/arctic or if their organism's colour helped them hide in the show, forest, or sand. STEAM education was remarkably present in the lessons. For instance, they enrolled in a scientific inquiry about ways celery stalks (plants) could be protected from drying out in the summer sun. Children chose some materials such as water, petroleum jelly, and sunscreen. The following day, the children collected data and concluded that petroleum jelly was more effective in protecting them. This experiment approached the cactus characteristic of wax skin that helps them to live in dry and hot deserts. Arts, likewise, had a central role. Children created a large mural with natural features of each biome while discussing necessary evolutionary adaptations, such as lizards having the same colour as the sand.

Moreover, the activities included education in sustainability, showing that the educational perspectives can be combined. Children observed organisms from a walk outside the camp (deciduous forest) and during a visit to a greenhouse. Children's experiences with nature were enriched with a chart to colour and record the observed organisms and discussions related to their experiences and the yarn stories. Regarding this research, we highlight the authors' declared posthuman concerns. They adverted that children as young as two years old expect designed objects to have a function. Eventually, they explain that the "texts were written without reference to intentional teleology and are free of anthropological language". Accordingly, the yarn stories did not present plants and animals through their utilities, as objects to humans, nor from anthropological relationships, such as birds "love" trees. Borgerding and Kaya [61] (p. 86) stated that "children did not want to be assigned plant roles", and the authors had to emphasise how vital plants were to each environment. Finally, we remark that they did not enrol in education for sustainability, such as the need for taking action and changing behaviours to protect the environment and endangered species.

Campbell and Speldewinde explored bush kinder regarding STEM education in ECEfS [23,66] and specific topics such as enabling girls' STEM identities [67] and developing technology and engineering understandings [24]. Since bush kinder aims to connect children with nature through playful activities, those authors repeatedly declare the theoretical orientation of children's connection to nature. They concluded that the bush kinder facilitate STEM because of its rich materials, such as loose parts, that can be moved around, designed, and redesigned. Their studies found evidence of playfulness, problem-solving, design thinking, testing [24], and agency over the scientific language [23]. Additionally, they point out that the natural environment enables girls' STEM identities

because it allows playing in an environment with less stereotypical elements, such as toys that retain social gender expectations, compared to traditional and human-altered school ambience.

They prominently picture children as the Apollonian child. They conceive a child as having good intentions and behaviour while exploring the natural world. They highlighted, for example, episodes of environmental care, observing that children would “gently prod” found animals to understand how the animal moves [66] (p. 453). In the vein of children’s centrality and the spontaneity of bush kinder, they report that teachers have minimal planning given. In this case, teachers would apply their previous knowledge of STEM and occasionally do some research to support children’s learning. The authors say, “[r]ather than spending time in preparing, often there is a need for educators to adopt a place-based approach to their teaching” [66] (p. 447). They stated that at least two disciplines of STEM have to be intentionally emphasised in an activity to be considered STEM. Additionally, they present a cyclical process of STEM in bush kinder, defending that in the “assessment and evaluation” phase, “children evaluate what type of STEM learning has occurred in bush kinder” [66] (p. 452). Notwithstanding, learning skills and knowledge of STEM remained an analysis a posteriori instead of an outcome explicit to students. The authors affirm that “children’s learning would be taken from bush kinder into the indoor kindergarten program”, but they do not explore this transposition.

Eventually, their proposal lies in the sustainability education category because boys and girls experience activities in nature. However, they do not focus on children reflecting on sustainable issues or taking actions, such as changing behaviour and regarding environmental and gender inequality issues. Those authors claim STEM education would be built as a basis for understanding sustainability issues, such as in the fragment, “[t]he obvious links for EfS with the key disciplines that underpin our understanding of the world (science, technology, engineering, and mathematics) allow students and young children to draw on their understandings in STEM as a basis for acting for sustainability” [66] (p. 3). However, their studies show STEM as an outcome of bush kinder and do not follow the subsequent stage where those understandings could be directly intertwined with sustainability problems. Finally, although they focus the research on STEM education, they demonstrate openness to other knowledge of areas that would comprise STEAM in bush kinder. They stated, “there is the potential for other discipline-based learning domains such as Art, Literacy or Humanities, and their connection to bush kinder STEM teaching and learning, to be explored in future” [66] (p. 459).

## 5. Discussion and Conclusions

Several international reports warn about the need to change toward a sustainable society [1,3] and summoned education to participate in this endeavour [6,9,13]. We remind that, on the one hand, society has essential and somewhat legitimate demands towards education, such as the eagerness for sustainability [19]. However, on the other hand, we call attention to the fact that education is a teleological practice and, thus, pursues intrinsic objectives [74,75]. From that standpoint, we propose the move from “Education for Sustainability” to “Sustainability for Education”, while emphasising the contribution of sustainability to education. In this sense, we particularly remark on sustainable issues providing authentic contexts for developing interdisciplinary educational approaches such as STEM and STEAM education. Accordingly, we enrolled in a systematic review to explore the intersection between ECEfS and STEM/STEAM education.

As a result, on the one hand, we highlight the dearth of research regarding the intersection between EfS and STEM/STEAM in early childhood. We found few studies on the topic (12) that were enrolled in a few countries (7). It reflects that ECE is traditionally overlooked in educational research compared to other levels [16]. The ECE period is usually non-obligatory and has a complex and diverse organisational structure, making it hard to coordinate, such as assuming sustainability is a core topic of interest. ECE is usually voluntary and has limited resources compared to compulsory schooling [17]. Addition-

ally, research practices may encounter particular ethical concerns while involving young children [16]. On the other hand, we point to an augment of interest in the intersection of ECEfS and STEM/STEAM in recent years; 2021 exhibited three studies, which doubled in the following year.

Additionally, we mention that no research addressed the youngest age group, 0 to 2 years old, neither involved their family. Other reviews in EfS arrived at similar results and defended that more researchers should conduct interventional studies encompassing parents [12].

One reviewed study reported null results about exposing children to a counter-stereotypical STEM television series [59]. The remaining authors usually reported good outcomes on the relationship between STEM/STEAM education and ECEfS. We acknowledge the possibility of a bias on the overrepresentation of studies reporting positive impacts, since some researchers and papers are hesitant to publish negative and null findings [15]. At the same time, even though gains for sustainability are legitimate, we suggest stressing educational goals such as learning related to STEM or STEAM education.

The investigation on STEM/STEAM education and ECEfS is centred on the environmental pillar, while social and economic aspects were barely addressed. Previous reviews on EfS have concluded that research on the three pillars of sustainability began in 2016, but environmental studies remain prominent, while the economic aspect is somewhat limited [12]. In this vein, we assert that the lack of theory and practice on sustainability's social and economic pillars implies missing critical educational opportunities. Interventional research on ECEfS should integrate elements from the three pillars of sustainability because they intertwine with each other [3]. Economic aspects, for example, encompass discussions about the environment, such as reducing consumption, reusing, recycling materials, and avoiding waste of resources such as water, energy, and food.

Economic concerns similarly relate to ideas of social inequality and the pursuit of social justice, which is one sustainable challenge of our society [5]. To mention some insights, Borg [76] interviewed preschool children and observed that almost all (94.3%) had some knowledge about poverty. They know about economic inequalities among individuals and countries and may have ideas about addressing those problems. In another study, Borg [77] explained that children's understanding of economics does not necessarily relate to the cash economy. This author operationalised sustainable economic issues with young children using candies. She observed that children mainly demonstrated consumerist behaviour when hypothetically receiving money—they would go shopping or save it for buying something more expensive on a long-term basis. Differently, children exhibited care for others while sharing resources—most of them would share candies because it is kind, just, and so their friends are not sad.

As sustainability encompasses the social pillar, it seems reasonable to incorporate knowledge closely related to understanding societies, such as arts and humanities. Accordingly, STEAM (instead of STEM) would be appropriate because this educational approach considers the fields of arts and humanities in the acronym. However, STEM has a more substantial presence in the literature on ECEfS, and this may reflect on overseeing social issues. This difference implies rethinking EfS, from setting the foundation to developing scientific and technological professionals who could solely provide sustainable solutions. The absence of social and economic pillars signals that EfS is not embracing the complexity of sustainability. Future research on ECEfS should investigate how young children conceive, at an appropriate age level, tensions involved in sustainability, especially from situations related to their daily life at home and school. Accordingly, there is a need for pedagogical strategies that apply STEAM knowledge and skills to foster children's action competence [78]. Accordingly, children investigate sustainable issues (understand them) and develop visions (imagine alternatives, ponder their preferences) to take action and change (engage with them, mind trade-offs, individual and collective sacrifices and the outcomes of actions).



We share with Varela-Losada et al. [11] the judgment that sustainability demands are urgent and that adults are responsible for making today's decisions. At the same time, newcomers should become involved so that future adults may continue the initiatives. However, we shift from "Education for Sustainability" to "Sustainability to Education", highlighting the pedagogical opportunity of authentic context on sustainable issues.

This review indicated that the intersection between STEM/STEAM and ECEfS is currently focused on sustainability's environmental pillar. The literature on this topic usually follows the theoretical orientation connection to nature, adopts the educational perspective of education in sustainability, and pictures children as Apollonian—assuming children are essentially good and emerge with virtuous traits from this contact, such as environmental care. While remaining in education in sustainability, STEM/STEAM knowledge areas were not deepened and explicitly explored with the children. Frequently, the disciplines served as categories of analysis in a posteriori investigation. Conversely, Borgerding and Kaya [61] provided children with experiences of education in sustainability by visiting a forest around the STEAM camp and a greenhouse, combined with an intense phase of education about sustainability where children learned about scientific concepts of ecology and biomes.

Worryingly, the educational perspective of education for sustainability could be identified only in research about teacher training programmes. We claim that more studies should focus on children's awareness and engagement with actions on sustainable issues. Future research should focus on children taking (age-appropriate) action on sustainability, such as reducing consumption and reutilising and recycling products. Accordingly, we evoke the concept of action competence proposed by Jensen [78]. This concept criticises health and environmental education from a moralistic pedagogy, suggesting that just knowledge is not enough. People must undergo deep reflection to make effective transformation occur. In this sense, simply demanding children to have sustainable behaviour is not enough. They must feel connected to it somehow and understand the rationalities behind assuming and engaging with different behaviours [78].

STEAM in ECEfS requires intentionality—the child-led transdisciplinary (no distinction between knowledge areas) experience has to be balanced with interdisciplinary interventions (explicit knowledge areas and their intersections) representing educational contribution. Similarly, we suggest future research addressing particular STEAM disciplines, such as science or engineering education, in the context of ECEfS. There might be exciting studies that enrol interdisciplinary teaching with those knowledge areas but are not framed on STEM/STEAM education.

Explicating knowledge areas and their intersections require teachers' preparedness to be more than just "supporters" since they have something to add to the transdisciplinary experience. This review found only three articles on teacher training in STEM/STEAM and ECEfS. Researchers have warned that teachers are not sufficiently trained to teach sustainability [79]. Currently, there are some efforts intending to reorient teacher training for sustainability [80]. Additionally, teacher training in STEAM education has concluded that this educational approach is complex to enrol in and requires appropriate planning [51].

This study enlightens essential theoretical orientations, educational perspectives, and pictures of children's nature that might help future practice and research in ECEfS. We suggest more research on the intersection of STEAM and EfS, such as thematic reviews, regarding specific settings of ECE, such as the strong connection with playful learning [45,62]. Subsequent investigations should distend from the Apollonian child picture and the belief that children can emerge long-term sustainable concerns just by education in sustainability. The theoretical orientation of connection to nature could instead reinforce the idea that education for sustainability purely might be insufficient if children are disconnected and disengaged from sustainable issues. In sum, we claim that children should undergo education in, about, and for sustainability to achieve the capital letter Education for Sustainability. Consequently, future research should expand educational practices to incorporate

experience, knowledge, skills, awareness, and action involving sustainable issues while considering integrated environmental, social, and economic pillars.

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