WP3.1. REVIEW TRENDS IN STEAM APPROACH IN STANDARD EDUCATION IN EU AND ASSOCIATED

Due date of deliverable: 30/04/2024
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Technical References

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Project duration	**36 Months**

Deliverable No.	**D3.1 Description of STE(A)M trends in education systems in Europe**
Dissemination level[1]	**CO - Confidential**
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Task	**Task 3.1. Review trends in STE(A)M approach in standard education in EU and associated**
Lead beneficiary	**UPV/EHU**
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1 PU = Public
PP = Restricted to other programme participants (including the Commission Services)
RE = Restricted to a group specified by the consortium (including the Commission Services)
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Document history

V	Date	Modifications	Author
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Abstract of Deliverable

The European Union identifies STEM education as a key pillar for competitiveness and innovation in member countries (European Commission, 2019). Thus, the promotion of STEM competence in European education systems is seen as crucial to prepare young people for the challenges of the current and future labour market. From that perspective, in recent years, the inclusion of the arts in STEM, STE(A)M, is postulated as a new approach that, in addition to preparing students for careers in scientific and technological fields, aims to enhance creativity and innovation (Smith et al., 2019).

This new approach poses challenges for interdisciplinary implementation in education, not only because of the disparate basic knowledge of each discipline, but also because they are disciplines with traditionally different pedagogical approaches to teaching. This leads us to pose some questions to investigate what the trends in STEAM education in Europe are, in partner countries, and internationally, what has proven to be effective pedagogical practice in the area, and what are the characteristics of practices that foster inclusion.

To this end, a review of the literature on four specific topics has been carried out, both at European and international level, in order to gather the maximum number of contrasted scientific contributions. The research includes the development of a review protocol and the selection of information sources to interpret and present the results, which involves a bibliometric analysis and a systematic review.

The results include:

a) Evolution of the STEAM concept. There is evidence of the consolidation of the STEAM concept at international level, with a greater inclusion of the Arts in the STEM approach and with creativity, interdisciplinarity and learning methods as emerging research topics. Although there are proposals and strategies at European level to promote STEAM education, research in this field is more predominant in the Spanish context.

b) STEAM education. Problem-based learning, with group work, interdisciplinary approach and formative assessment, are the pedagogical characteristics that receive most scientific support.

c) The inclusive perspective in STEAM studies. The results of the scientific literature on the impact of STEAM/STEM education on aspects such as the social, gender or learning gap are analysed.

d) Benefits of STEAM integration in the curriculum. The STEAM approach has the potential to make these fields more accessible, relevant and attractive, favouring inclusion. Strategies such as peer mentoring, female role models and social support exist to increase women's interest and confidence in STEAM disciplines.

e) STEAM/STEM Research Methods. Questionnaires used to assess STEAM experiences and to assess STEAM competence in learners are listed.

Therefore, the systematic review of European and international education systems and their indicators provides valuable guidance for the design, implementation and assessment of STEAM activities in the STEAMbrace project, as well as for addressing gender inclusion and gender mainstreaming.

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1 Objective of the task 3.1.

The main objective of the task was to carry out a systematic review of European education systems and associated, led by EHU and supported by EDE and EFZG, to obtain the latest indicators and scales related to STE(A)M education focusing on in STE(A)M approach in standard education.

In order to define what could be the most relevant topics to be researched in response to the objective of task 3.1, several research questions were identified among the participating partners:

A. Current situation of STEAM Education in EU and associated; it would describe the analysis of the reality that should be taken into account for the design of the activities.

a. What are the **current trends** in the implementation of the STE(A)M approach in standard education in the European Union? Presence of (A)?
b. Which **teaching strategies and pedagogical methods** are most frequently used in STE(A)M education in EU countries?
c. What is the **impact of integrating STE(A)M** into the standard education curriculum in the EU in terms of academic outcomes and skill development?
d. Are there significant **differences** in the adoption and application of the STE(A)M approach among different **countries** in the European Union?
e. How are **challenges and barriers** in the effective implementation of STE(A)M in standard education in the EU being addressed?
f. Are there **gender disparities** in student participation, access, and achievements in STE(A)M education programs in the European Union, and how are these disparities evolving over time?
g. What is the impact of gender gaps on student participation and achievements in STE(A)M programs in relation to the educational strategies employed in the EU?
h. What **measures** are being taken to address gender disparities and improve equity in STE(A)M education, considering both the public and private sectors in different urban and rural contexts in the European Union?

B. Analysis of current STEAM practices, to analyse their specific approach, and to learn something/try to avoid bad approaches/ or to improve the situation.

a. **Art thinking approach** in the practice/community.
b. Where does **STEAM stand** in the educational system/specific school?
c. What about in the **job market** and STEM fields?
d. How balanced are the **STEAM approaches** in the area of research or in the practice?
e. **Gender balance** and resource balance.
f. What can this specific example teach us? Why this practice?
g. Which **teaching strategies and pedagogical methods** are most frequently used in STE(A)M education in EU countries?
h. How are **challenges and barriers** in the effective implementation of STE(A)M in standard education in the EU being addressed?
i. How do **educational strategies** implemented in STE(A)M programs vary based on current legislation in EU countries?

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j. Is there a **significant difference** in the quality and accessibility of STE(A)M education between public and private systems in urban and rural settings in the European Union?

It must be clarified that such a diversity of topics would have required differentiated literature analyses for each of them. From a scientific point of view, the literature review or state of the art corresponds to the detailed description of a certain topic or technology (Gómez-Luna et al., 2014). Thus, and with the intention of delimiting the systematic review, the above research questions have been generalised to **three main topics**:

1. Trends in the implementation of STEAM in education, where trends are understood as developments in STEM/STEAM education contexts (systematic reviews).
2. Characteristics of effective educational proposals (experiences), examples of experiences and pedagogical methodologies.
3. Benefits of integrating STEAM into the curriculum with respect to performance, gender and inclusion.

Therefore, taking into account the purpose of the project and the tasks following the literature review, a systematic review of the three topics described was considered. Thus, as a **specific objective** of the literature review it is highlighted: "to review the evolution that STEM/STEAM education has had at European level, analysing the characteristics of the educational proposals with the most scientific evidence, in order to use the benefits identified in the literature in the proposals to be designed, as well as in the methodological procedure for their implementation and assessment".

2 Methology

2.1 Search and select information sources

For the study of the first topic, it was decided to carry out a bibliometric analysis, in addition to the systematic review carried out in all the topics. This decision was based on the fact that bibliometrics as a scientific method is based on the investigation of statistically regular behaviour of the different factors related to scientific production (Moreno-Fernandez and Fuentes-Lara, 2019), making it an appropriate method when we want to assess trends. *Voswiever* software was used for data analysis.

The article selection process was conducted according to The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) (Moher et al., 2009) in its PRISMA2020 version. The PRISMA 2020 statement replaces the 2009 statement and includes a new publication submission guideline that reflects advances in methods for identifying, selecting, assessing and synthesising studies (Page et al., 2021).

A systematic search of the international literature was conducted in *Web of Science* and *Scopus* electronic databases by selecting articles published in peer-reviewed journals.

The last research was conducted on 23rd March 2024. Restrictions were made limiting the research to peer-reviewed academic journal or conference publications, in English and Spanish, in the area of social sciences or education, published from 2014 onwards. The search strategy used Boolean combinations of the following keywords:

- Web of Science, WOS: ("STEAM*" OR "STE(A)M*") AND ("education*" OR "curriculum*" OR "school*")

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- Scopus: TITLE-ABS-KEY TS=("education*" OR "curriculum*" OR "school*") AND ("literature review" OR "trends" OR "meta-analysis")

2.2 Develop a review protocol

After the first filtered search, manual searches were conducted to identify target articles. Articles were selected for review based on five main inclusion criteria:

- The research work is related to the evolution of STEM/STEAM education.
- The article collects practical and empirically assessed experiences on the pedagogical implementation of STEAM/STEM in education.
- The article reflects results on the impact of STEAM/STEM education on aspects such as the social, gender and learning gaps.
- The study describes the methodology followed and the instruments/materials used.

Studies were excluded where:

- The target audience was not 'students in non-university education'.
- Country-specific systematic reviews.
- Experiences where STEAM resources or projects used were not displayed or linked.
- Experiences that were not empirically assessed.

The reference management software *Refwork* was used to group the papers and eliminate duplicates.

2.3 Conduct search and study selection

The articles selected in the 1st and 2nd screening were differentiated according to the target topic to extract the information according to whether it responded to an evolution of STEAM/STEM education, an experience, or evidence regarding the improvement of inclusion and equity.

In a first screening, the selection criteria were searched for in the title, keywords and abstract of the article. In the second screening, the full text was read.

The flow chart (Figure 1) shows the number of studies identified from databases and other sources, the number of studies screened by authors and assessed for eligibility.

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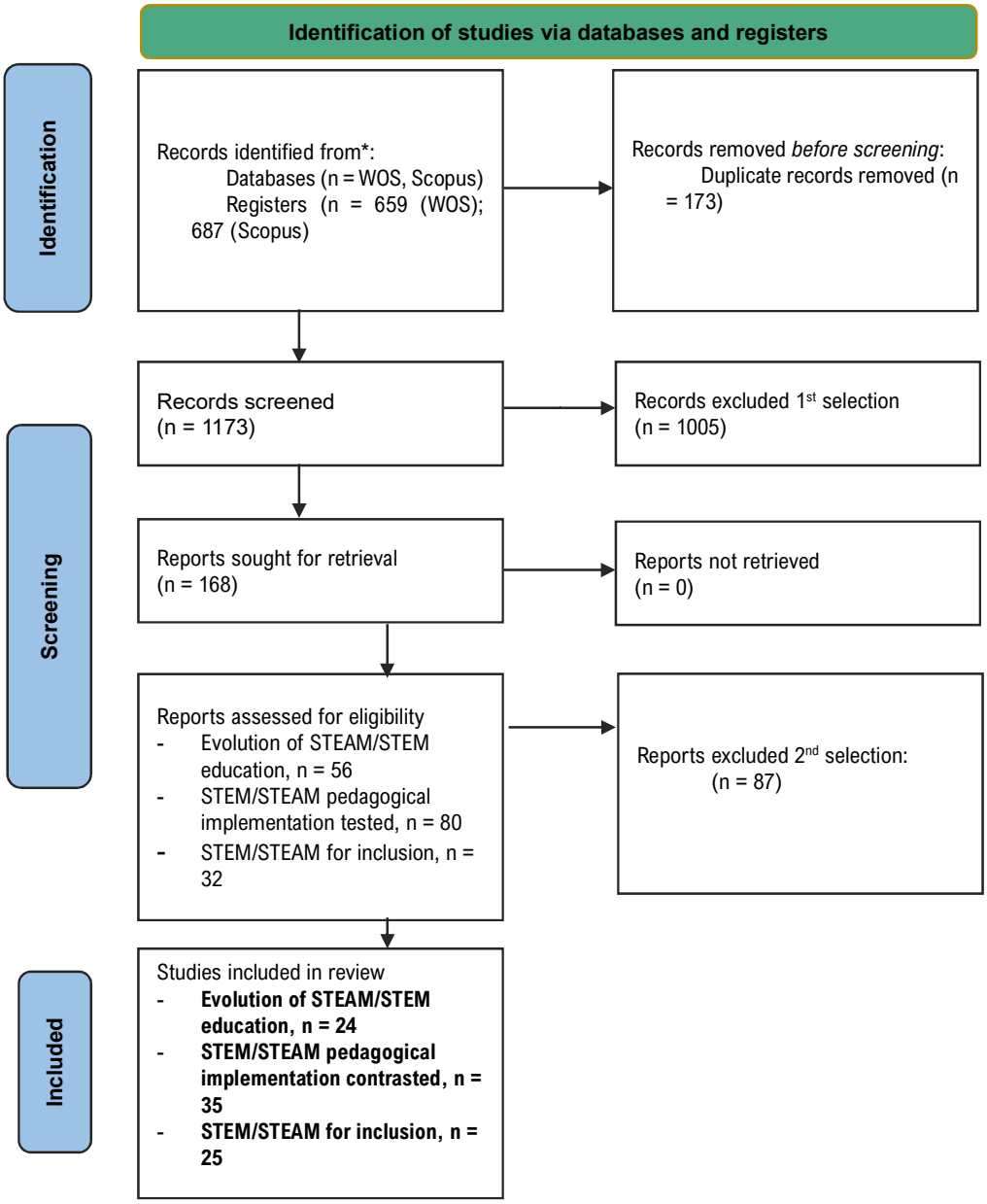

Figure 1. Flow chart describing the process followed for sample selection according to PRISMA.

The literature review has been extensive in order to cover different aspects that could serve as a guide for the various actions of the project. The selected articles have been grouped according to the information they can contribute to each of the 3 topics in order to identify the current situation of STEAM education, as well as the characteristics and research methodologies that have scientific support and that we should consider in our project. Number of articles gathered in each topic:

1. Trends in the implementation of STEAM in education. 24 articles have been included in the review. Annex 1 lists the references of the articles.

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2. Characteristics of effective educational proposals (experiences), examples of experiences and pedagogical methodologies. 35 articles have been included in the review. Annex 2 contains the references of the articles.
3. Benefits of integrating STEAM into the curriculum with respect to achievement, gender and inclusion. 25 articles have been included in the review. Annex 3 lists the references of the articles.

2.4 Extract and synthesize data

Once the articles to be studied had been selected, the relevant information from the selected studies was extracted and systematically organised. Summary tables were used to compare, interact and analyse the data.

In each table, the following information was collected:

- Identifying data: Authors, Title, Journal and Publish date, Country of experience/ research
- Summarized Abstract
- Methods Used
- Results
- Conclusions
- Contributions

The summary table for the topic 'Trends in STEAM implementation in education' can be found in Annex 4.

Annex 5 contains the summary table of the topic 'Characteristics of effective educational proposals (experiences), examples of experiences and pedagogical methodologies'. Finally, the summary table corresponding to the topic 'Benefits of STEAM integration in the curriculum with respect to performance, gender and inclusion' can be found in Annex 6.

3 Interpret and present results

The results were grouped into four dimensions. Three responded to the topics of interest described in the objectives section:

A) Evolution of the STEAM concept. It explores the evolution and development of the STEAM concept, the proven contributions of its implementation, the barriers studied and the directions for the future.
B) STEAM education. It describes the pedagogical characteristics studied in the literature whose results could be considered for the design of STEAM projects. In this section, the pedagogical process (methodologies, types of activities, strategies, technologies), curriculum and assessment are differentiated.
C) The inclusive perspective in STEAM studies. The results of the scientific literature on the impact of STEAM/STEM education on aspects such as the social, gender and learning gaps are analysed.

However, in addition to the three topics mentioned above, when extracting and presenting the results of the publications, it was decided to add a fourth research topic:

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D) STEAM/STEM Research Methods. Mainly the questionnaires used for the assessment of STEAM experiences and for the assessment of STEAM competence in students have been studied.

3.1 Evolution of the STEM/STEAM concept in recent years

As described in the methodology section, in order to study the evolution and trends of the STEAM/STEM concept in recent years, a bibliometric analysis and a systematic review of the literature has been carried out using the Web of Science (WOS from now on) and Scopus sample.

3.1.1 Results of the bibliometric analysis

The bibliometric analysis has been carried out using *WOS* data and the *Vosviewer* software.

Firstly, an attempt was made to identify the evolution of the STEAM/STEM concept over the years. The results show that the largest publication is concentrated in the last 5 years (see Figure 2), with a huge increase in the study of STEAM in education.

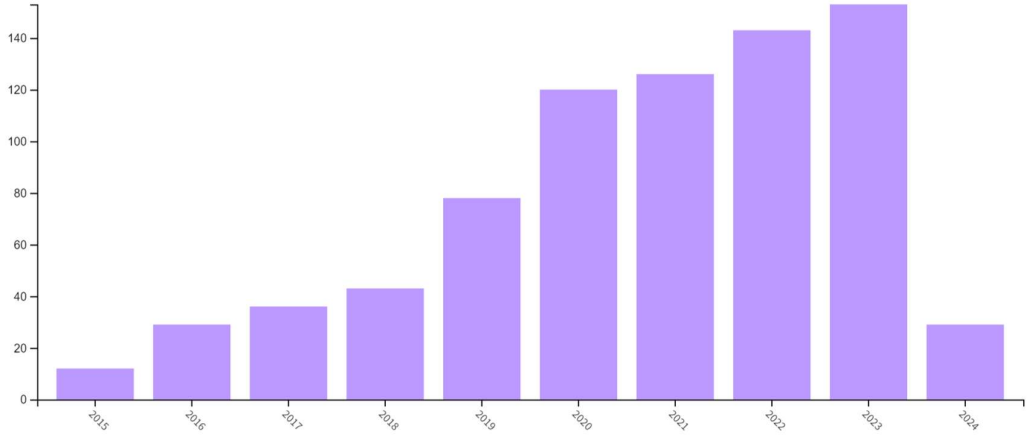

Figure 2. Number of articles related to STEAM/STEM studies in education on the WOS database over the last 10 years

The COVID'19 factor as a driver of this increase need to be considered, as cited in some articles. What is certain is that it was already on the rise before the pandemic, but the effects of emergency education led to measures being taken both in educational policies and in educational practices and research that have undoubtedly had an effect on all areas related to educational technology.

The countries with the highest scientific publication impact on STEAM/ STEM in education are the USA and Spain (see Figure 3), according to the WOS database (n = 659).

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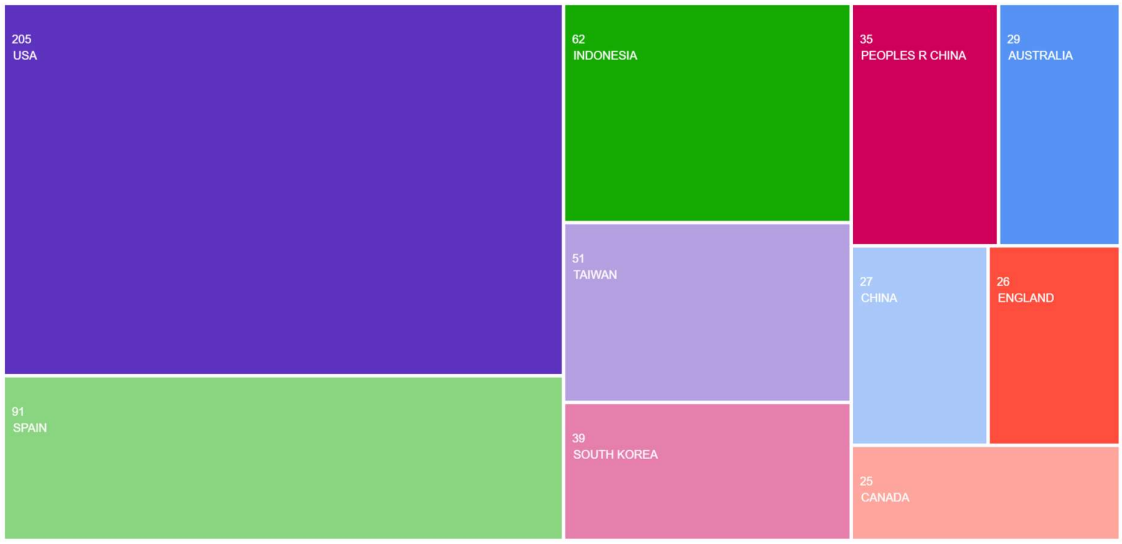

Figure 3. Number of publications by country, according to the selected WOS sample (n = 659).

Note: Only 15 of the selected articles were due to being written in Spanish, so this criterion does not interfere with the results shown.

From the full WOS sample, it was decided to analyse what percentage were published in EU and associated. The analysis was conducted on 30th March 2024, so the WOS sample had slightly expanded to 692 articles at the international level. Specifically, 34% of the publication (n=234) in relation to the analysis of STEAM/ STEM in education were from EU and associated. As can be seen in the Figure, 41% of the impact publications came from Spanish contexts.

Figure 4. Number of publications by EU and associated, according to the selected WOS sample (n = 692).

During the analysis of the most studied topics in recent years, which could give us a vision of the impact of the Arts in STEM education, it was decided to use the complete sample of the WOS and Scopus databases at the international level. The reason was to broaden the search for the elements studied in the experiences and projects on STEAM/ STEM+Art, given the high presence of American and Southeast Asian studies, it was decided not to exclude these countries in case in a subsequent study there might

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be educational projects or validated instruments that could serve as a guide for their subsequent adaptation to our context.

Thus, in order to illustrate research hotspots in the area of STEM/ STEAM and education, the co-occurrence of keywords was analysed with *VOSviewer* and a minimum of 10 occurrences per keyword was established. A keyword study was conducted on the full sample of publications, n = 1173. The bibliometric data from the study found 2633 keywords, of which 64 met the selected threshold.

Table 1 below lists the keywords from highest to lowest incidence and their Total link strength, i.e. the number of publications in which two keywords occur together. As can be seen, the current research hotspots (highest occurrence), in order, are mainly concentrated in the areas of *STEAM, STEM education, art education, foreign countries, creativity, interdisciplinary approach and teaching methods*.

Keyword	Occurrences	Total link strength
stem education	171	800
art education	148	728
foreign countries	79	437
interdisciplinary approach	53	284
steam	183	278
teaching methods	35	207
creativity	57	192
active learning	21	149
design	29	147
student attitudes	22	129
elementary school students	26	128
student projects	16	124
teacher attitudes	19	122
engineering education	31	104
students	34	104
teaching	31	104
elementary school teachers	15	103
instructional effectiveness	16	102
skill development	14	100

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Keyword	Occurrences	Total link strength
curriculum development	16	98
stem	46	98
faculty development	15	96
steam education	98	96
elementary secondary education	18	95
educational technology	14	91
problem solving	16	85
thinking skills	14	85
cooperative learning	13	83
technology uses in education	14	80
program effectiveness	12	79
education	28	75
barriers	11	74
learning activities	13	73
science education	25	72
high school students	12	71
curriculum	23	68
middle school students	14	68
educational change	11	67
creative thinking	13	66
learning	20	65
higher education	16	63
robotics	16	63
21st century skills	11	62
inquiry	11	60
integrated curriculum	14	60
curriculum implementation	11	59
early childhood education	18	59
self efficacy	11	59
preservice teachers	10	54
student	13	54
project-based learning	14	52
covid-19	14	48
innovation	12	47
art	12	41
mathematics education	12	37
curricula	10	35
sustainability	10	33
design thinking	10	31
computational thinking	20	30
mathematics	10	26
primary education	13	25
technology	11	24
teacher training	11	23
artificial intelligence	10	20

Table 1. Results of the co-occurrence analysis of the keywords

Figure 5 reflects the study hotspots and their relationship to other study areas.

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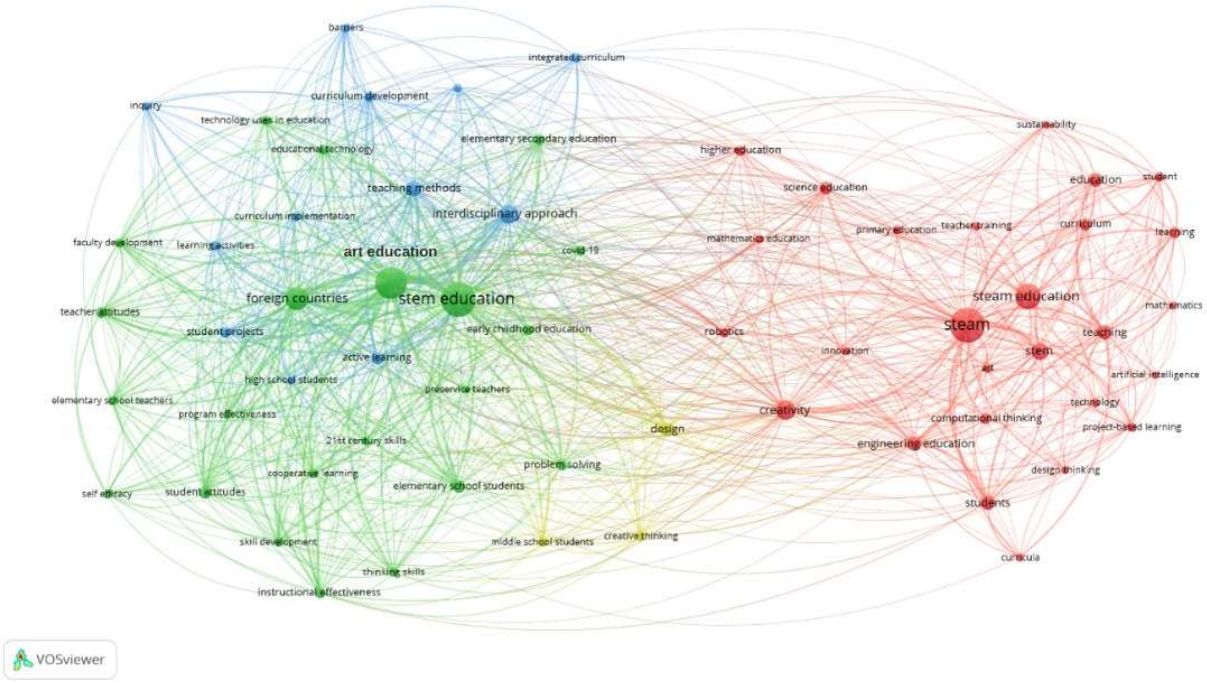

Figure 5. Visualisation of the keyword network in STEM/STEAM and education research. Note: This figure is shown in a larger size in Annex 7.

The size of the circles represents the occurrences of the keywords. The larger a circle is, the more a keyword was co-selected in the STEM/ STEAM and education publications. The keywords "STEM education" and "STEAM" were the strongest. The distance between the two keywords shows the relative strength and thematic disparity. The circles of the same colour suggest a similar theme between these publications. In other words, the higher the node's size, the more it is studied, and the closer the concepts are to each other, the more they are studied together.

The keyword network in Figure 5 clearly illustrates four distinct clusters (see Table 2). Each represents a subfield of the field of study in STEM/STEAM in education.

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The appropriate labels for the four main clusters are shown in Table 2:

Cluster 1 (27 items)	Cluster 2 (22 items)	Cluster 3 (12 items)	Cluster 4 (3 items)
art	21st century skills	active learning	creative thinking
artificial intelligence	art education	barriers	design
computational thinking	cooperative learning	curriculum developme	middle school students
creativity	covid-19	curriculum implementa	
curricula	early childhood educati	educational change	
curriculum	educational technology	high school students	
design thinking	elementary school stud	inquiry	
education	elementary school teacl	integrated curriculum	
engineering education	elementary secondary e	interdisciplinary approa	
higher education	faculty development	learning activities	
innovation	foreign countries	student projects	
learning	instructional effectivene	teaching methods	
mathematics	preservice teachers		
mathematics education	problem solving		
primary education	program effectiveness		
project-based learning	self efficacy		
robotics	skill development		
science education	stem education		
steam	student attitudes		
steam education	teacher attitudes		
stem	technology uses in educ		
student	thinking skills		
students			
sustainability			
teacher training			
teaching			
technology			

Table 2. Interrelated subfields of study in STEAM/STEM in education research

3.1.2 Results of the systematic review

The systematic review of the trends and evolution of the STEAM concept in education explored the evolution and development of the STEAM concept, as well as the demonstrated contributions of its implementation, the barriers studied and the directions for the future. A total of 24 articles have been selected for review. Annex 1 contains the bibliographical citations of the articles studied, and Annex 4 the comparative table with the data extracted.

3.1.2.1 Evolution of the STEAM concept

Regarding the evolution of STEAM research in education, like the mapping done in the literature review, the study by Lan Phuong (2021) or Silva-Díaz et al. (2022) show a significant increase in research, especially in the last five years, with a growth rate of 30.47% per year. The expansion from STEM to STEAM in these years includes the arts, recognising that creativity and innovation are crucial to solve complex problems and make learning more complete and engaging.

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3.1.2.2 Contributions of STEAM/STEM education

There are several contributions that receive scientific evidence on the implementation of STEAM in education. On the one hand, it is shown that STEAM education from early childhood has a positive influence on children's social and cognitive skills, Su et al. (2024).

From that point of view, studies over the last 20 years (Marin et al., 2021) conclude that - STEAM-EDU contributes to critical thinking, problem solving and gender equality.

Creativity is another contribution of STEAM that has been studied in recent years (Aguilera, 2021; Smaniego, 2024). In fact, in Aguilera's study (2021), in both the STEM and STEAM approaches, positive effects on students' creativity are observed.

In the case of educational robotics, the review of the last 15 years by González et al. (2021) points out that educational robotics improves communication, teamwork, creativity and problem-solving skills. It also benefits STEAM learning, interdisciplinary skills and critical thinking.

On the other hand, Krüger et al., 2021, in their systematic review, study the relationship between 21st century competences and STEAM learning environments. They conclude that ICT development and digital literacy are associated with the use of technology in STEAM.

From the point of view of the contribution that STEAM/ STEM education can make to boosting science careers, Caspi et al. (2023), through the development of informal STEM development programmes in primary education, showed that informal STEM programmes for primary school students increase STEM career aspirations and 1/3 of participants aspire to STEM careers, with gender variations.

3.1.2.3 Barriers

The Pearson 2021 article highlights three main barriers to the development of STEAM education:

A) **Political barriers** as the main difficulty for the development of STEAM education. Schools face difficulties in implementing high-quality STEAM programmes due to lack of funding (also highlighted in the study by Carter et al., 2022) and restrictive local and state policies, which hinder the adoption of innovative, student-centred learning approaches.
B) **Curriculum and time constraints**. Schools often must follow strict guidelines and tests, leaving little room for lecturers to explore STEAM education, which requires time for students to engage in creative and interdisciplinary learning.
C) **Lack of teachers' preparation in STEAM**. Many lecturers are not familiar with STEAM or how to integrate it into their teaching, especially in primary schools, because their training programmes may not include arts and interdisciplinary practices. In this regard, Silva-Hormazábal's (2023) study shows that the familiarity of lecturers with STEAM is low, and although their attitude is positive, their confidence to implement it is moderate, so they conclude that training is key for better implementation in the classroom. This is also highlighted in articles such as Marín et al. (2021), Peppler (2018) and Belbase et al. (2021). The study by Quigley et al. (2020) emphasises the need for design thinking training for lecturers and strategies to help students make connections between their lives and the problems they are solving. Finally, the study by Montés et al., (2023) underlines that the specialisation or profile of the lecturers not only influences the design of STEAM projects, but also how they are explained.
D) Curriculum integration in STEAM education means adding arts and design to the usual mix of science, technology, engineering and mathematics, which requires changing the school curriculum to include these new elements (Belbase et al., 2021).

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To overcome these barriers, it is essential to advocate for policies that provide more funding and flexibility, allowing schools to adopt STEAM programmes that are interdisciplinary and address the diverse needs of students, fostering creativity and equity.

3.1.2.4 Lines for the future

Future research should explore the long-term effects of STEAM education (Su et al., 2024). Marin et al. (2021) agree that STEAM studies lack a solid line of research over time.

Also, more research is needed to identify effective pedagogical approaches in STEAM (Su et al., 2024). Leavy (2022) adds the need for sound methodologies to study emerging technologies in STEAM.

González et al., 2021, in their study on educational robotics conclude that more systematic studies are needed on computational thinking and STEAM education, and to assess the impact on educational policies.

3.2 STEAM Education

In the systematic review on STEAM education, we describe the pedagogical characteristics studied in the literature whose results could be considered for designing the educational activities of the STEAMbrace project. In this section, the pedagogical process (methodologies, types of activities, strategies, technologies), curriculum and assessment are differentiated. A total of 36 articles have been selected for study. Annex 2 contains the bibliographical citations of the articles studied, and Annex 5 the comparative table with the data extracted.

It is worth mentioning that this study has been conducted under the approach that considers STEAM education as one that focuses on how teaching and learning takes place, with the aim of transforming education by making it more connected to real-world problems and fostering creativity and innovation through a blend of science, technology, engineering, arts and mathematics (Belbase et al., 2021).

From this perspective STEAM education includes two main parts (Belbase et al., 2021): the way lecturers teach (pedagogical process) and the way students' learning is tested (assessment), both designed to make learning more engaging and relevant to students' future careers and lives.

3.2.1 Pedagogical process

In terms of educational methodologies, emphasis is placed on hands-on learning, project-based learning, STEAM and interdisciplinary approaches (Rodriguez-Silva, 2023). Thus, Su et al. (2024), in their systematic review, find that most of the studies used technology-mediated learning and inquiry-based learning. This is echoed in the systematic review by Conde et al. (2020), Chistyakov et al. (2023) and Belbase et al. (2021). In fact, the latter point out that this approach helps students develop important skills, such as problem solving, critical thinking and teamwork, by working on projects that require them to use knowledge from different subjects together, which makes learning more interesting and useful.

The article by Dasuki et al. (2020) describes the phases and activities that could be included in a PjBL (Project Based Learning) design. It describes three phases for the development of this methodology in STEAM:

1) Planning: This phase involves identifying a problem or question, crafting the problem, and planning the learning process, including what will be learned and how it will be assessed. It is about setting the

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stage for the project by deciding on the topic, questions, and the thinking process needed to explore the topic.

2) Testing: In this phase, students put their plans into action. They test their ideas or products and engage in self-directed learning. This means they learn by doing, exploring specific topics, and adapting their plans based on what they find.

3) Reflecting: The final phase focuses on reflecting on the project's outcomes. Students assess what they have learned and how they have learned it. This reflection helps them understand the project's impact and their growth through the process.

Krüger (2021), adds Research Based Learning as a methodology in STEAM. Lg, 2021, also emphasise inquiry-based learning as it allows lecturers to adapt the curriculum based on children's interests, strengths and readiness, fostering a hands-on learning environment in which children can explore and share their discoveries. All of these methods foster a dynamic, participatory environment that encourages creative thinking through constant practice and collaboration.

Ng (2022), in his review on the integration of STEAM in Education, underlines that when integrating STEAM subjects, we can consider four levels of integration: disciplinary, multidisciplinary, interdisciplinary, and transdisciplinary. In this regard, Montes et al. (2023) differentiate and describe the approaches in the literature when working with STEAM in education:

- The multidisciplinary approach involves learning content separately in each discipline, but within a common theme.
- The interdisciplinary approach combines content from at least two disciplines, making explicit connections.
- In the transdisciplinary approach, "the curriculum transcends individual disciplines" and knowledge and skills are applied in real-world situations.

But regardless of their level of integration, it should be ensured that all STEAM subjects receive sufficient attention and are taught in a way that makes sense together, rather than separately. As highlighted by Rodríguez-Silva (2023), interdisciplinary projects allow students to approach problems from various perspectives, integrating knowledge from different disciplines and skills. This approach not only stimulates creativity by connecting seemingly incongruent ideas, but also reflects the interconnected nature of real life. Thus, it is important that lessons connect with children's interests and help them see how STEAM topics are part of everyday life. This is also echoed in the study by Zarei (2021).

Research by Montés et al. (2023) shows that STEAM projects are hardly contextualised in real life, and that the design of these real contexts depends on the lecturer's training. In that line, Samaniego (2024) emphasises experiential learning, STEAM, and interdisciplinary approaches to creative thinking.

In short, all these methodologies not only challenge students to apply knowledge in tangible ways, but also cultivate essential 21st century skills such as critical thinking and problem solving (Rodriguez-Silva, 2023). In the same vein, Krüger, 2021, emphasises the use of gamification, games and social environments in STEAM activities for the development of 21st century skills. Indeed, Caspi et al. (2023), note that interest and enjoyment drive participation in programmes; concern for utility is less frequent.

There are also studies that have developed their own pedagogies for STEAM development. Lin (2021), proposes the STEAM (Scaffolding, Tutoring, Engaging, Argumentation, and Modelling) pedagogical model for implementing interdisciplinary STEAM curricula: 1) Scaffolding: lecturers help students by providing pathways for projects, including conducting field research and learning about green product design; 2) Tutoring: Each project group has a teacher who guides them through the project, making sure they understand and follow the necessary steps; 3) Engaging: students participate in activities that make them think and ask questions, helping them to go deeper into their projects; 4) Argumentation: students

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discuss and debate issues, which helps them to understand different points of view and strengthen their arguments; Modelling: students create models or representations of their scientific ideas or concepts, which helps them to understand and explain them better.

Lin's (2021) study suggests that the STEAM model can be a useful guide for teaching secondary school students in an interdisciplinary curriculum. The model seems to be particularly effective in maintaining and even increasing students' motivation to learn over time.

In terms of **strategies** that can be used, Delgado (2022) highlights the use of pedagogical games, problem-based learning, the integration of educational robotics, the application of brainstorming, the use of mind maps, the implementation of creative dramatization and the adoption of interactive teaching platforms.

Regarding the type of **technology** to be used, virtual reality and educational robotics predominate (Silva-Díez et al., 2022; Chappell, 2022). The bibliometric study by Silva-Díez et al. (2022) on emerging technologies in STEM education shows that, in the last four years, virtual reality was the most widely used technology, accounting for 51.7% of all the documents analysed. It was followed by educational robotics, which accounted for 38.1 % of the technologies used in the sample. Maker spaces, the Internet of Things (IoT) and analytics technologies, although less prevalent, appeared mainly in the most recent period from 2017, indicating their emerging status in the field.

Conde et al. (2020), in their review of educational robotics in the STEAM approach, conclude that the integration of robotics and mechatronics enhances engagement with STEAM education. In addition, technological advances make educational robotics more accessible in schools. In this regard, González et al., 2021, in their review on educational robotics, urge the use of active teaching methodologies such as gamification and collaborative work, as well as constructivist and constructionist pedagogies such as ProblemBL or ProjectBL.

3.2.2 Curriculum

Few articles talk about the curriculum followed for STEAM development, understanding curriculum by the competences, contents or description of developed projects that can be found in the selected articles.

In terms of content description, it is interesting to note the curriculum proposed by Lin (2021), in which the curriculum consisted of interdisciplinary projects involving science (biology, chemistry and earth science), technology (biotechnology, information technology and green technology), engineering (living technology, disaster prevention technology, electromechanical applications), art (scientific argumentation, scientific drawing, cultural creativity and scientific writing) and mathematics (logical reasoning).

For their part, the Hsiao team (2022) describe the design of a 10-week course in which, through the design and creation of an electric boat, students develop different STEAM contents under the PjBL and cognitive-affective interaction model (CAIM) methodology. Specifically, the course begins with an introduction to basic scientific principles (buoyancy, Newton's laws of motion and electricity), continues with the teaching of Arduino electronic components and programming, and ends with the design and construction of electric boats, facing and solving real-world problems.

Considering the variety of projects that can be designed in a STEAM curriculum, Chappell (2023), proposes cross-disciplinary projects to work on Ocean Literacy in Primary and Secondary Education. His study describes the following 6 projects developed in Denmark, Spain and England: (a) Students explore biodiversity through creative approaches and virtual reality (VR); (b) Students create and deploy fish nursery areas, where they design, build and track these habitats using 360 cameras and VR to

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understand fish behaviours and support biodiversity; (c) Students learn about ocean adaptations by asking their own questions and using interdisciplinary methods, connecting with ocean experts through VR to understand how organisms survive in the ocean; d) In order to work on the issue of ocean plastics, students use creative pedagogies and digital technologies to learn about pollution and develop potential activism skills; e) Students learn key ideas about the oceans by visiting an aquarium and use virtual reality and augmented reality (AR) spaces to express their knowledge creatively; f) The last project helps students learn about the ocean and fish behaviour through AR games, encouraging them to ask questions and engage in thoughtful conversations.

In the same vein, the article by Quigley et al. (2020), describes relevant units for Kindergarten to Grade 5 problem-based work that connect to the lives of primary school students to improve engagement and learning outcomes. Among the projects described, the following are highlighted: (a) The importance of bees in food systems, the environment or causes of declining bee populations were explored, with a focus on the impact humans have on the environment and its relationship to climate change; (b) School cafeteria redesign and water quality issues related to population growth were addressed, with students investigating real-world problems such as improving the cafeteria experience and understanding the impact of population growth on water quality; (c) Life cycles and food webs, building a bee model for engineering, introducing hexagons in mathematics, creating a bee dance and a school mural project were part of a unit plan outlining interdisciplinary connections; d) Activities around life in the lake, such as creating murals, designing fishing devices, developing digital activity books, designing video games and programming robots to mimic fish life cycles, were used to engage students in STEAM learning.

3.2.3 Assessment

The interdisciplinary and competence-based nature of STEAM projects requires forms of assessment that allow us to know what, how, when and how much students are learning, in order to regulate the strategies, resources and activities that will allow us to obtain better results.

In this regard, Belbase et al. (2021) analyse the importance of developing new ways of assessing students in STEAM, going beyond traditional tests to include assessments that reflect the interdisciplinary and creative nature of education. Studies by Krüger (2021) and Zarei (2021) highlight the importance of formative assessment, collaboration and gamification in education.

However, it should be highlighted that few articles point out what assessment process has been used to assess students' competence development. And on too many occasions, the assessment of performance has been limited to a final questionnaire, moving away from process and formative assessment.

3.3 Study of inclusive aspects in relation to STEAM education.

The systematic review of the inclusive perspective in STEAM studies has been carried out by analysing the results of the scientific literature on the impact of STEAM/ STEM education on aspects such as the social, gender and learning gaps. A total of 25 articles have been selected for study. Annex 3 contains the bibliographic citations of the articles studied, and Annex 6 contains the comparative table with the data extracted.

The review of articles on the inclusive aspects of STEAM education in the scientific literature has shown that it promotes gender equality and diversity in fields such as technology and engineering. But, in addition, the inclusion of people at risk of social exclusion or with educational needs through STEAM programmes has also been shown to promote equal opportunities by providing accessible and personalised learning opportunities.

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To this end, fostering curriculum flexibility and interdisciplinarity, along with providing multiple opportunities for students to cultivate their creativity, are key steps towards implementing STEAM programmes that are accessible to all, especially marginalised populations (Pearson, 2021). Along these lines, Aguilera (2021) concludes that more STEAM programmes are needed in contexts such as Latin America or countries where there is a gap in the scientific literature and that their development should begin in early childhood. In this regard, Belbase et al. (2021) point out that diverse and creative teaching methods can improve learning outcomes in populations considered at risk.

Lu et al., (2021) also design a PBL-oriented STEAM curriculum for students with learning difficulties and their results show that students with Learning Difficulties improve creative competence and their learning outcomes.

Special mention should be made of the gender perspective and the study of gender in STEAM scientific literature. The gender landscape in STEAM education has undergone significant changes, but the literature review shows that disparities remain, particularly in representation, equal pay and recognition of women (Ampartzaki, et al. 2022). Research indicates that women are significantly underrepresented in STEM careers, with UNESCO reporting that less than 30% of all STEM positions are held by women (UNESCO, 2019). Indeed, research indicates that women face numerous barriers in STEM, including stereotypes, lack of resources, role models and discrimination (Blackburn et al., 2019; Kenneth, 2022).

However, the integration of STEAM education can challenge and overcome entrenched gender stereotypes in society. Thus, STEAM/ STEM education plays a crucial role in contributing to women's engagement, confidence and representation in traditionally male-dominated fields (Sevilla et al., 2023). But, the inclusion of women in STEM/STEAM is not only a gender equity issue, but also essential to foster innovation, creativity and diverse perspectives in solving global challenges (Adams et al., 2022).

Specific educational interventions that have been shown to improve the inclusion of women in STEAM areas can be found in the literature. This is the case of design thinking workshops in Japan (Kijima et al., 2021), which have shown promise in changing young women's perceptions towards STEM, increasing their interest, confidence and their perceptions of STEM fields. Similarly, the STEAMpunk Girls programme in Australia has demonstrated the potential of STEAM education to increase girls' engagement with STEM through learning project and design thinking strategies, significantly increasing their confidence and motivation (Ng et al., 2020). Programmes that provide mentoring, parental support and participation in STEM learning environments from an early age have also been proposed to increase the number of women entering STEM careers (Areljung et al., 2021). These interventions are important as they address motivational patterns and expectancy-value theory beliefs (Atkinson, 1964) that enable women to overcome the challenges posed by gender stereotypes in STEM fields (Barkatsas et al., 2019).

The Hughes et al. study (2020) stresses that overcoming persistent gender disparities requires addressing social stereotypes, improving educational practices and providing favourable learning environments.

3.4 STEAM/STEM research methods

Finally, it was decided to include a section in the data collection of the literature review that responded to the STEAM/ STEM research methods used in the articles reviewed. Although no comparative analysis has been carried out in this section, the research designs and especially the questionnaires used to assess STEAM experiences, as well as the instruments for assessing STEAM competence in students, have been collected.

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It is emphasised that mixed (quantitative-qualitative) research designs are commonly used to investigate the effectiveness of STEAM education (Su et al., 2024), with pre-post test designs, and sometimes with a control group.

Tests used to assess the effectiveness of STEAM programmes

- Knowledge Integration, Project Skills, and Self-Efficacy (KIPSSE) instrument (Lin 2018) to assess the competencies of students engaged in project-based learning: https://link.springer.com/article/10.1007/s10956-017-9708-y/tables/4
- Students' Motivation Toward Science Learning (SMTSL) questionnaire (Tuan et al. 2005)
- Ad-hoc tests designed for the assessment of knowledge
- Interviews

Tests used for the assessment of STEAM projects

- Although Quigley et al (2020) design assessment rubrics aimed at observing lecturers and their materials, their indicators could be included in the assessment of activities in terms of:
    - Integration of STEAM areas
    - The manner in which the PjBL is presented
    - The way in which project activities promote skills for PjBL

- Pérez-Torres' team (2024) assesses 46 STEAM projects developed in secondary education in Spain. For this purpose, they design a **STEM PBL rubric** that serves as a tool for the assessment and categorisation of instructional designs within the STE(A)M PBL framework. Within this structure, 21 criteria were organised into 6 dimensions.

- Bati, K., Yetişir, M. I., Çalişkan, I., Güneş, G., & Gül Saçan, E. (2018). Teaching the concept of time: A steam-based program on computational thinking in science education. *Cogent Education*, *5*(1), 1507306.

    - *They implement concurrent-triangulation design (Creswell, 2009) as mixed methodology. Instruments: Observation notes, Semi-structured interviews, Computational thinking test by Weintrop et al. (2014), students diaries.*

- Hsiao, H.-S.; Chen, J.-C.; Chen, J.-H.; Zeng, Y.-T.; Chung, G.-H (2022). An Assessment of Junior High School Students' Knowledge, Creativity, and Hands-On Performance Using PBL via Cognitive-Affective Interaction Model to Achieve STEAM. *Sustainability, 14,* 5582.

    - *STEAM Knowledge Examination Paper, STEAM-KEP, Creativity Assessment Packet (CAP) by Williams (1972), CPAM to evaluate hand on performance (Besemer, 1981).*

    - *Besemer, S.P.; Treffinger, D.J. Analysis of creative products: Review and synthesis. J. Creat. Behav.* ***1981****, 15, 158-178.*

    - *Williams, F.E. Identifying and Measuring Creative Potential; Educational Technology Publications: Englewood Cliffs, NJ, USA, 1972.*

- Huang, X., & Qiao, C. (2022). Enhancing computational thinking skills through artificial intelligence education at a STEAM high school. *Science & Education*, 1-21.

    - *Korkmaz et al. (2017) developed a scale to determine the levels of Computational Thinking skills.*

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- *Students' Motivation Toward Science Learning (SMTSL) proposed by Tuan et al. (2005).*
- *Knowledge integration, project skills, and self-efficacy (KIPSSE) instrument put forward by Lin (2018) to measure the self-efficacy.*

- Quigley, C. F., Herro, D., King, E., & Plank, H. (2020). STEAM designed and enacted: Understanding the process of design and implementation of STEAM curriculum in an elementary school. *Journal of Science Education and Technology, 29*(4), 499-518.
  - *STEAM observational rubric to understand how teachers design and implement STEAM learning environments, and teacher reflections.*
- Lu, S. Y., Lo, C. C., & Syu, J. Y. (2022). Project-based learning-oriented STEAM: The case of micro-bit paper-cutting lamp. *International Journal of Technology and Design Education*, *32*(5), 2553-2575.
  - *Revised version of Creativity Assessment Packet done by Lin and Wang (1994)*
- Greca Dufranc, I. M., Ortiz Revilla, J., & Arriassecq, I. (2021). Design and assessment of a STEAM teaching-learning sequence for Primary Education. *Eureka Journal of Science Education and Popularization*, *18*(1), 1-20.
  - *Participant observation through the recording of field notes (Spradley 2016) by the researcher and teachers immersed in the teaching-learning context and the material developed by the students (Massot Lafon, Dorio Alcaraz and Sabariego Puig 2004).*
- Lage-Gómez, C., & Ros, G. (2023). How transdisciplinary integration, creativity and student motivation interact in three STEAM projects for gifted education? *Gifted Education International, 39*(2), 247-262.
  - *A questionnaire (Supplementary Appendix 2) to assessment student's perception about transdisciplinary integration, motivation, and creativity of the projects.*
  - *Participant observation carried out by the five teachers and researchers and collected in their class diary through the established categories.*
  - *Observation of the lessons video recordings by the researchers*
  - *Semi structured group interviews*
- Cabello, V. M., Martínez, M. L., Armijo, S., & Maldonado, L. (2021). Promoting STEAM learning in the early years: "Pequeños Científicos" Program. *LUMAT: International Journal on Math, Science and Technology Education, 9*(2), 33-62.
  - *Gómez-Motilla & Ruiz-Gallardo's (2016) attitude survey to assess attitudes towards science in early childhood education for the Spanish speaking population.*
  - *Class observation protocol of developed by the PentaUC program*
  - *Narratives, anecdotal records*.
- Chang, C. Y., Du, Z., Kuo, H. C., & Chang, C. C. (2023). Investigating the Impact of Design Thinking-Based STEAM PBL on Students' Creativity and Computational Thinking. *IEEE Transactions on Education*.
  - *Torrance Test of Creative Thinking*

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- *International Challenge on Informatics and Computational Thinking*

- Casado Fernández, R., & Checa Romero, M. (2020). Robotics and STEAM Projects: Developing creativity in Primary Education classrooms. *Pixel-Bit*.
  - *CREA Creative Intelligence Test (Corbalán et al., 2003).*
- Szabó, T., Babály, B., Pataiová, H., & Kárpáti, A. (2023). Development of spatial abilities of preadolescents: What works?. *Education Sciences*, *13*(3), 312.
  - *Test for Creative Thinking/Drawing Production (TCT/DP), an instrument developed by Klaus Urban and Hans Jellen, standardised and regularly used in 19 countries.*
- DeJarnette, N. K. (2018). Implementing STEAM in the Early Childhood Classroom. *European Journal of STEM Education, 3*(3), 18. https://doi.org/10.20897/ejsteme/3878
  - *Teachers' Comfort with STEM Instruction*
- Suryanti, Nursalim, M., Choirunnisa, N. L., & Yuliana, I. (2024). STEAM-project-based learning: A catalyst for elementary school students' scientific literacy skills. *European Journal of Educational Research, 13*(1), 1-14. https://doi.org/10.12973/eu-jer.13.1.1
  - *Scientific Literacy Test (SLT) Questions focus on a) defining scientific phenomena, (b) evaluating and designing scientific studies, and (c) analysing data and scientific evidence.*
- Anwari I. et al. (2016) Implementation of learning & assessment via -12 STEM education, 1.
- Lin Z. et al. (2022) Evaluating student's creative thinking in STEAM education: model construction and validation. ICEDS'22, ACM, NY, USA, 96 103.
- Hsu T.C., et al. (2022) A validity and reliability study of the formative model for the indicators of STEAM education creations. Educ. Inf. Technol.
- Herro, D., Quigley, C., Andrews, J., & Delacruz, G. (2017). Co-Measure: developing an assessment for student collaboration in STEAM activities. *International journal of STEM education*, *4*, 1-12.

Tests used for the assessment of STEAM/STEM competence

- Chen, S., & Ding, Y. (2023). Assessing the Psychometric Properties of STEAM Competence in Primary School Students: A Construct Measurement Study. *Journal of Psychoeducational Assessment*, *41*(7), 796-810.
- Arikan S., Erktin E., Pesen M. (2022) Development and Validation of a STEM Competencies Assessment Framework. *Int. J. Sci. Math., 20*, 1-24.

Other

- Silva-Hormazábal (2023): Questionnaire to assess lecturers' self-perception of their knowledge, attitudes and confidence in implementing integrated STEAM education.

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4 Conclusions

The main objective of this task has been to carry out a systematic review of European education systems and associated, led by EHU and supported by EDE and EFZG, to obtain the latest indicators and scales related to STE(A)M education focusing on STE(A)M approach in standard education.

Given the breadth of the topics to be studied that the partners considered important in this review, it was decided to broaden the study and carry out different systematic reviews. Specifically, three research topics were delimited whose results would be beneficial for reviewing the evolution that STEM/ STEAM education has had at European and international level, analysing the characteristics of the educational proposals with the most scientific evidence, and identifying the benefits that could serve as a basis for the educational proposals to be designed, as well as the methodological procedure for their implementation and assessment.

In the systematic review and bibliometric analysis carried out on the ***trends and evolution of STEAM Education***, the consolidation of the STEAM concept at the international level seems clear, as the data indicate that in recent years the inclusion of the Arts within the STEM approach has been reinforced worldwide. However, the inclusion of the Arts is not clear in the articles studied and is approached from two perspectives in the literature: from the inclusion of the Arts discipline and its contents; or from the inclusion of creativity, as a necessary skill for flexibility in solving complex problems. On the other hand, the bibliometric data show that, although the studies on STEAM/ STEM in Education at European level reach 34% of the international ones, most of them are in the Spanish context. This contrasts with all the proposals that the EU has put in place to promote STEAM Education in member countries; the policies and strategies of the European Union for the development of STEM education, the investment and economic support to promote STEM education or the implementation of programmes such as Horizon, Erasmus+, Science Education Partnerships, STEM School Label, EU Code Week, Girls in STEM... are clear examples of these efforts. Although these data can be interpreted in different ways, it could be interesting to strengthen the research aspects in European programmes and projects developed within the STEAM education framework, as well as to reinforce the methodological design that makes it possible to publish the results of the projects with high quality, increasing their visibility at an international level.

Finally, we highlight that most studies already associate the Arts with the STEM field, and that the development of creativity, interdisciplinarity and learning methods are emerging hotspots of study in the literature.

From the systematic review of the ***characteristics of effective educational approaches*** (experiences), it is concluded that, in most research, the study of STEAM competence is associated with the development of other 21st century skills and/or key competences (such as computational thinking, creative thinking, group work, problem solving, critical thinking, positive attitude). This is one of the reasons why most studies measure how the development of STEAM/ STEM learning influences the development of other types of skills. This leads us to suggest that in the educational activities that are designed, as well as in the scientific methodology that is defined to assess the effectiveness of educational interventions, other skills, competences and attitudes should be taken into account as intentions and as study variables.

In terms of methodology, Problem-Based Learning receives the most scientific support, including group work activities for problem solving, focusing on topics close to the learner and from an interdisciplinary or transdisciplinary perspective.

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With regard to assessment, process and formative assessment are considered appropriate and comprehensive in the current methodology. However, few articles describe the process of learning assessment, and most of them are reduced to the application of knowledge questionnaires that have little to do with process and formative assessment.

Finally, and taking into account the barriers and future lines of action identified in this research, the projects and educational proposals that are designed must be easily implemented by the teachers in their curricula. There are few articles describing the areas and contents developed in each discipline of STEAM; however, considering that some official curricula (such as the Spanish one) define minimum basic knowledge, it would be advisable to make sure that the contents that will be developed in an interdisciplinary way will be transferable in the participating countries, facilitating their integration and implementation in classroom planning. We should also address interdisciplinarity in STEAM projects, as this is a feature that has been presented time and again as a determining factor in tackling problems from a real and holistic viewpoint. Furthermore, we should also take into account that one of the barriers in the implementation of STEAM projects is the lack of training of the lecturers, so our proposals should have resources to facilitate their implementation.

Considering the two previous points, it would be interesting to standardise the pedagogical design of the activities to be designed, which would facilitate the validation of the activities, as well as the definition of a precise research methodology for the assessment of their effectiveness. This would enable replicability and visibility in the educational and scientific context.

Finally, the literature review on the ***Benefits of STEAM integration in the curriculum with respect to achievement, gender and inclusion*** concludes that the STEAM approach has the potential to make STEAM fields more accessible, relevant and attractive to a diversity of students, which may contribute to greater inclusion of students at risk of exclusion, students with diverse educational needs or girls in these disciplines.

Although in the STEAMbrace project there are other spaces where the gender perspective will be explored in greater depth, the review carried out in this first task concludes that STEAM/ STEM education offers substantial benefits to women by fostering engagement, confidence and representation. It underlines that overcoming gender disparities requires addressing social stereotypes and improving educational practices. The studies reviewed include strategies such as peer mentoring, inclusion of female role models, participation in STEAM learning environments, and social and family support, to increase women's interest, confidence and positive attitudes towards STEAM.

We would like to stress again that this is not a single systematic review. This review has been very broad, giving a greater focus to what could guide us in the STEAMbrace project. The study allows us to visualise the STEAM evolution in Europe in relation to the world, giving us the route to follow in order to make visible from a scientific point of view the efforts that are being made in Europe regarding STEM/STEAM education. It also describes the pedagogical characteristics with the most scientific evidence that we should consider when designing and implementing STEAM activities. Finally, it provides us with strategies to consider in order to promote the presence and interest of women in these disciplines, as well as to favour the inclusion of all students.

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6 Annex 1. References selected in the research topic Evolution of STEAM in Education

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9 Annex 5. Summary table of the articles selected for the study of the topic STEAM in Education.

Authors	Title	Journal	Country	Publish date	Summarized Abstract	Methods Used	Results	Conclusions	Contributions
- Avner Caspi - Paul Gorsky - Rakefet Nitzani-Hendel - Bruria Shildhouse	STEM-oriented primary school children: participation in informal STEM programmes and career aspirations	International Journal of Science Education.	Israel	2023	- Informal STEM programs for primary school children boost STEM career aspirations. - Demographic data of 3rd-6th graders in STEM programs analyzed. - Boys more involved than girls; younger students participate more.	- Chi square test for statistical differences, Cramer's V for effect size.	- More boys than girls participated; younger students were more involved. - Interest and enjoyment were key reasons for participation in STEM programs. - Informal STEM programs lead to early entry into STEM career pathways.	- Participation in STEM programs leads to early STEM career aspirations. - Informal STEM studies enhance STEM knowledge and sustain student interest.	- Participation in STEM programs at a young age influences career aspirations. - Girls breaking gender stereotypes by aspiring to STEM careers early.
- Jiahong Su, Iris Heung, Yue Yim, Rupert Wegerif, Samuel Kai, Wah Chu	STEAM in early childhood education: a scoping review	Research in Science & Technological Education	International	2024	- Scoping review on STEAM in early childhood education. - Analyzed 26 articles, identified frameworks, learning activities, outcomes, and challenges.	- Mixed-research design, qualitative design, quantitative method were utilized. - Data collection methods included surveys, tests, interviews, field notes, observations. - Arksey and O'Malley's	- Most studies used technologically enhanced learning and inquiry project-based learning. - Mixed-research designs were commonly used to investigate STEAM education	- STEAM in ECE improves skills and inspires positive contributions. - Mixed-research designs are common for investigating STEAM effectiveness in ECE. - Qualitative and quantitative	- Characteristics of STEAM in early childhood education. - Learning activities, assessment methods, outcomes, and challenges in ECE settings. - Recommendations for educators

						scoping review framework was followed.	effectiveness. - STEAM education positively impacts children's social and cognitive skills. - Future research should explore long-term effects of STEAM education.	methods are essential for understanding STEAM impact. - More research is needed to identify effective pedagogical approaches in STEAM.	and future research directions.
- José-Antonio Marín-Marín, Antonio-José Moreno-Guerrero, Pablo Dúo-Terrón, Jesús López-Belmonte	STEAM in education: a bibliometric analysis of performance and co-words	International Journal of Stem Education	International	2021	- Analyzed STEAM education studies from 2006 to present. - Identified themes and trends in STEAM-EDU research. - Utilized WoS database for academic performance and co-word analysis.	- Bibliometric analysis, academic performance analysis, and co-word analysis. - Use of WoS programs like Analyze Results, Creation Citation Report, and SciMAT. - Data analysis with programs like Analyze Results, Creation Citation Report, and SciMAT. - Thorough procedure following considerations from other studies.	- STEAM studies began in 2006, with irregular scientific community interest. - Topics include gender differences, skills developed by students, and teacher training.	- STEAM studies lack a robust line of research over time. - Trends focus on gender differences, skills developed by students, and teacher training.	- STEAM studies focus on gender, race, student skills, and teacher training. - Research areas include education, engineering, and computer science. - Themes like science, computational thinking, and broadening participation are highlighted.

- María González Fernández **- Yadira Flores González** **- Claudia Muñoz López**	Overview of educational robotics for STEAM learning	Eureka Journal on Science Education and Outreach	International	2021	- Overview of educational robotics and STEAM learning. - Analysis of 105 documents from 2005 to 2019. - Emphasis on primary and secondary educational levels.	- Qualitative interpretative research - Document analysis of 105 documents from 2005 to 2019 - Matrix bibliographic and content analysis proposed by Gomez et al.	- Analysis of 105 documents from 2005 to 2019. - Benefits include communication skills, teamwork, creativity, and problem-solving competencies. - Educational experiences mainly in primary and secondary levels.	- Educational robotics enhances communication, teamwork, creativity, and problem-solving skills. - Robotics education benefits STEAM learning, interdisciplinary skills, and critical thinking. - More systematic studies needed on computational thinking and STEAM education. - Implement active teaching methodologies like gamification and collaborative work.	- Development of competencies in communication, teamwork, creativity, and problem-solving. - Integration of educational robotics in science and environmental areas. - Emphasis on constructivism and constructionism in pedagogical approaches.

- Wilson Krüger, Andrés Chiappe	- 21st-century skills and their relationship to STEAM learning environments.	Distance Education Network-Magazine	International	2021	- Focus on 21st-century skills and STEAM learning environments relationship. - Review based on 153 scientific articles from Scopus and Scielo. - Emphasizes formative assessment, collaborative environments, research-based learning in STEAM.	- Systematic literature review based on 153 scientific articles. - Defined keywords applied in Scopus and Scielo databases.	- Consider formative assessment, collaborative environments, research-based learning, and gamification. - Identify relationships between 21st-century skills and STEAM learning environments.	- Emphasizes the importance of considering various factors in STEAM environments. - Highlights the need for formative assessment, collaboration, research-based learning in STEAM.	- Identifying 21st-century skills and their relationship to STEAM learning environments. - Reviewing the consistency of conceptualizations about 21st-century skills. - Emphasizing the importance of science, engineering, and technology components in STEAM. - Associating ICT and digital literacy development with technology in STEAM.
- Daniel White, Seamus Delaney	- Full STEAM ahead, but who has the map for integration?	LUMAT	International	2021	- PRISMA review on STEM/STEAM interdisciplinary learning in high schools. - Identified 99 articles, only 11 met selection criteria for synthesis. - Emphasized real-world project-based or problem-based learning	- Identification of need for interdisciplinary learning evidence. - Inclusion of exclusion criteria for research focus. - Preliminary screening through examination of title, abstract, and keywords.	- Only eleven studies met the selection criteria for the final synthesis. - Improved outcomes were best achieved through real-world or problem-based learning.	- STEM/STEAM enhances learning outcomes through project-based learning. - Further research is needed to provide more empirical evidence. - Implementation relies on project-based learning	- Emphasized real-world project-based learning for improved outcomes in high schools. - Highlighted the importance of community and industry support in interdisciplinary learning. - Identified the need for further research to

					for improved outcomes.			and community collaboration.	support empirical evidence. - Advocated for integrated STEM education to enhance student learning outcomes. - Urged the development of evidence-based practices for interdisciplinary STEAM education.
- Andrea Ng - Sarika Kewalramani - Gillian Kidman	- Integrating and navigating STEAM (inSTEAM) in early childhood education.	Eurasia Journal of Mathematics, Science and Technology Education	International	2022	- Integrative review on STEAM integration in early childhood education. - Development of inSTEAM conceptual framework from 17 reviewed articles.	- Integrative review methodology to conceptualize integrating STEAM into ECE. - Developed a precise search strategy for collecting data. - Used Rayyan for screening titles and abstracts to exclude articles.	- No clear definition of STEAM integration in early childhood education. - Four levels of integration: disciplinary, multidisciplinary, interdisciplinary, and transdisciplinary. - Ten articles defined STEAM integration, seven did not. - Provides a conceptual framework for integrating and navigating	- Synthesizes existing STEAM understanding, quality, and literature gaps in ECE. - Provides certainty to integrating STEAM through the inSTEAM conceptual framework. - Reveals STEAM integration perceptions, current approaches, and challenges in ECE.	- Consolidation of STEM integration approaches in early childhood education. - Development of a conceptual framework for integrating STEM in early childhood. - Factors to consider when integrating STEM in early childhood classrooms.

							STEAM in ECE. - Synthesizes existing state of integrating STEAM, quality, gaps in literature.		
Nguyen Lan Phuong , Le Thi Thu Hien , Nguyen Quang Linh, Trinh Thi Phuong Thao, Hong-Hanh Thi Pham, Nguyen Truong Giang , Vu Thi Thuy	- Implementation of STEM education: A bibliometrics analysis from case study research	- Education Sciences is the only Q2 journal in Scopus. - Top journals in STEM education are ranked Q1 in Scopus.	International	2021	- Analyzed 750 publications on STEM education case studies from 2006-2022. - Identified key research directions: higher education, STEAM, K12 education.	- Utilized bibliometric analysis for examining STEM education research trends. - Data collection and analysis methodology established by Ha et al.	- 750 publications analysed, including articles, conference papers, book chapters, and reviews. - First case study on STEM education dates back to 2006. - Rapid increase in the number of articles published in the last five years. - Annual growth rate recorded from 2006 to 2022 is 30.47%.	- STEM education research has grown significantly from 2006 to 2022. - Main research directions include STEM in higher education and K12. - Most influential articles provide background insights for readers.	- Identified significant countries, authors, and publications impacting STEM education research. - Highlighted three main research directions in STEM education.

- Morteza Zarei - Hossein Zeinalipour - Seyed Abdul Wahab Samawi	- Identify the components of the STEAM curriculum in elementary school.	International Journal of Pediatrics-Mashhad	Iran	2021	- STEAM curriculum model designed for elementary schools in Iran. - Qualitative thematic analysis used to identify curriculum components. - Integration of art essential for children's creativity and real-world connection.	- Qualitative thematic analysis method used for research. - Sampling done purposefully from various databases. - Content analysis and theme network system utilized for data analysis.	- Results include identifying components of STEAM curriculum based on Drake model. - Results show organizing themes for teaching methodology and goals of STEAM. - Study limitations due to lack of Persian sources and STEAM specialists.	- Elements of the STEAM curriculum benefit from unique characteristics. - Final evaluation in STEAM should focus on understanding and problem-solving.	- Identifying components of STEAM curriculum for elementary schools in Iran. - Emphasizing context-based approach in teaching methodology for holistic learning. - Fostering creativity, interdisciplinary research, and project-based learning in students.
- Rachael Pearson	- Title: STEAM STEAM Education and the Whole Child: Examining Policy and Barriers	International Journal of the Whole Child	USA	2021	- Whole Child education nurtures students in critical skills for the future. - STEAM programs align with Whole Child approach, fostering inquiry and skills. - Research highlights barriers to implementing high-quality STEAM	- Policy lens analysis to discuss barriers and suggestions for implementation. - Exploration of Whole Child STEAM programs through a policy lens. - Practical strategies provided for promoting high-quality STEAM education.	- Discusses barriers to implementing high-quality Whole Child STEAM programs. - Highlights the importance of STEAM education for student development. - Emphasizes the need for further research on STEAM education. - Provides	- Emphasizes the need for high-quality STEAM programs in schools. - Discusses barriers and funding issues hindering the implementation of STEAM programs. - Advocates for flexible, interdisciplinary curriculum to nurture student creativity.	- Emphasizes high-quality STEAM programs for diverse student needs. - Discusses barriers and funding issues in implementing Whole Child STEAM programs. - Advocates for policy changes to enhance curriculum flexibility and interdisciplinary learning.

		programs in schools.	strategies for promoting high-quality STEAM education in schools.

- **Mariela Samaniego, Nancy Usca, José Salguero, William Quevedo**	- Creative Thinking in Art and Design Education: A Systematic Review	Education Sciences	International	2024	- Identifies characteristics of creative thinking in arts and design education. - Emphasizes experiential learning, STEAM, and interdisciplinary approaches for creativity. - Highlights core skills like originality, fluency, flexibility, and elaboration. - Urges research promotion in specific regions like Latin America. - Stresses fostering creativity from an early age for effective education.	- Hands-on learning, project-based learning, STEAM learning, challenge-based learning. - Interdisciplinary and collaborative approaches prioritising practical experience in learning. - Techniques include nature-based activities, artistic practices, and digital tools.	- Emphasizes experiential learning, STEAM, and interdisciplinary approaches for creative thinking - Techniques include interdisciplinary projects, artistic practices, nature-based activities, and digital tools - Core skills identified: originality, fluency, flexibility, and elaboration - Urgency to promote research in specific regions like Latin America	- Emphasizes experiential learning, STEAM, and interdisciplinary approaches for creative thinking. - Urges research promotion in specific regions like Latin America. - Highlights the importance of fostering creativity from an early age.	- Specific methods, techniques, and tools for fostering creative thinking in students. - Enhancing educational processes by providing practical and applicable resources for educators.

- David Aguilera **- Jairo Ortiz-Revilla**	- STEM vs. STEAM Education and Student Creativity: A Systematic Literature Review	Education Sciences	International	2021	- STEM and STEAM education impact student creativity positively. - Review of 14 educational interventions from 2010-2020. - No clear definitions of STEM and STEAM in some studies.	- Systematic literature review based on defined criteria and PRISMA Declaration. - Search conducted on Web of Science and Scopus databases for data.	- STEM and STEAM education lack clear definitions in studies. - Positive effects on student creativity were observed in both approaches.	- STEAM education doesn't surpass STEM in promoting student creativity. - Lack of clear definitions in STEM and STEAM approaches.	- Review of STEM and STEAM interventions on student creativity. - Evaluation of creativity through process, environment, and person. - Data extraction on STEM and STEAM education impact on creativity. - Systematic literature review on STEM and STEAM interventions.
- Jefferson Rodrigues-Silva **- Thaís Coutinho** **- Ángel Alsina**	Conceptualising and framing STEAM education: what is (and what is not) this educational approach?	Journal "Linguagem e Tecnologia."	International	2023	- STEAM is an interdisciplinary educational approach involving science, technology, and more. - The paper clarifies misconceptions about STEAM and proposes a framework. - It differentiates STEAM disciplines, activities, and education in detail.	- Narrative review of articles indexed in Web of Science. - Snowball process to analyse references of selected documents.	- Defined STEAM as not an evolution of STEM or a methodology. - Proposed a framework emphasizing interdisciplinarity and the five knowledge areas.	- STEAM is not an evolution of STEM, teaching methodology, or transdisciplinarity. - Defined STEAM disciplines, activities, and education approach clearly. - Emphasized interdisciplinarity and the five knowledge areas in STEAM framework.	- Clarifies STEAM as distinct from STEM, teaching methodology, or interdisciplinarity. - Proposes a framework for STEAM emphasizing interdisciplinarity and five knowledge areas.

Aisling Leavy, Lara Dick, Maria Meletiou-Mavrotheris, Efi Paparistodemou	The prevalence and use of emerging technologies in STEAM education: A systematic review of the literature	Journal of computer assisted learning	International	2022	- STEAM Education literature review on emerging technologies for innovative teaching approaches. - Focus on developing 21st-century skills with a lack of emphasis on arts - Need for intervention studies with multidisciplinary collaboration for learning outcomes.	- Mixed-methods approaches for richer insights and broader conclusions. - Questionnaire, survey, interview, focus group, observation, field notes.	- Fast-growing use of emerging technologies in STEAM education worldwide. - Emphasis on developing STEAM-related disciplinary knowledge and 21st-century skills. - Lack of targeted emphasis on developing understandings in the arts.	- Fast-growing use of emerging technologies in STEAM education worldwide. - Emphasis on developing STEAM-related disciplinary knowledge and 21st-century skills. - Need for carefully designed intervention studies involving multidisciplinary collaboration.	- Identifies the prevalence of emerging technologies in STEAM education. - Highlights the need for carefully designed intervention studies in STEAM.

Miguel Á. Conde 1 | Francisco J. Rodríguez-Sedano1 | Camino Fernández-Llamas 1 | José Gonçalves 2 | José Lima2 | Francisco J. García-Peñalvo	Fostering STEAM through challenge-based learning, robotics, and physical devices: A systematic mapping literature review	Comp Applic In Engineering	International	2020	- Focus on integrating robotics and mechatronics in STEAM Education. - Highlights the success of robotics and physical devices in education. - Emphasizes the importance of active methodologies in engaging students.	- PrBL is the most popular methodology in the paper. - Systematic mapping review methodology is employed for analysis.	- Robotics and physical devices successfully applied in STEAM Education. - Benefits of active methodologies in STEAM Education approaches analysed.	- Robotics and mechatronics engage students in STEAM disciplines successfully. - STEAM Education benefits from active methodologies like project-based learning.	- Discusses the successful application of robotics and mechatronics in STEAM Education. - Classifies studies based on goals and benefits of PDR and STEAM Education.

- Shashidhar Belbase, Raj Bhesh, Wandee Mainali, Hassan Kasemsukpipat, Munkhjargal Tairab, Adeeb Gochoo, Jarrah, Ra Mainali, Wandee Kasemsukpipa, Hassan Tairab	- At the dawn of science, technology, engineering, arts, and mathematics.	International Journal of Mathematical Education in Science and Technology	International	2021	- Examined integrated STEAM education through literature review and document analysis. - Identified prospects, priorities, processes, and problems in STEAM education. - Explored STEAM initiatives in South Korea, US, China, and Singapore. - Analyzed themes like movement, curriculum integration, pedagogy, and challenges.	- Document analysis with review of literature, reports, and websites. - Thorough document collection from various sources like journals and books. - Gathering information from websites, books, journal articles, and conference proceedings.	- Identified prospects, priorities, processes, and problems of STEAM education. - Emphasized curriculum integration, pedagogical processes, and assessment in STEAM education. - Explored the implications of STEAM education on teacher development and training. - Discussed assessment practices in STEAM education, including project-based learning.	- Conclusions include prospects, priorities, processes, and problems of STEAM education.	- Analysis of prospects, priorities, processes, and problems in STEAM education. - Integration of arts into STEM disciplines to enhance learning. - Emphasis on project-based learning and problem-solving in STEAM education.

- Francisco Silva-Díaz - Gracia Fernández-Ferrer - Mercedes Vásquez-Vilchez - Cristian Ferrada - Romina Narváez - Javier Carrillo-Rosúa	- Emerging technologies in STEM education: A bibliometric analysis.	Bord'on, journal of pedagogy	Internationa l	2022	- Analyzed STEM education technologies from 2010 to 2020. - Used Scopus and Web of Science for bibliometric analysis. - Identified growth in scientific production post-2017.	- Bibliometric analysis based on Scopus and Web of Science data. - Used Zupic and Cater's flow for bibliometric studies.	- Growth in STEM education publications since 2017. - Dominance of virtual reality over robotics in central study areas. - High impact journals focus on educational technology and STEM. - Limitations include narrow sample scope, suggesting need for broader studies.	- Rapid growth in STEM education from 2017. - Dominance of male authors with a slight increase in female representation. - USA leads in production, with rising contributions from Taiwan, Turkey, Malaysia.	- Analysis of STEM education publications from 2010-2020. - Focus on emerging technologies like virtual reality and educational robotics. - Noteworthy increase in scientific production post-2017. - Emphasis on female participation trends in STEM research. - Distribution of documents by technology used, highlighting virtual reality.

Binar Kurnia Prahani , Khoirun Nisa , Maharani Ayu Nurdiana , Erina Krisnaningsih , Mohd Zaidi Bin Amiruddin , Imam Sya'roni	ANALYSE OF STEAM EDUCATION RESEARCH FOR THREE DECADES	Journal of Technology and Science Education	International	2023	- Analyzed STEAM education research over three decades globally and in South-East Asia. - Used VOSViewer, Excel, and word cloud generator for analysis. - Identified top cited papers, authors, and countries in STEAM research. - Highlighted keywords and trends in STEAM education.	- VOSViewer, Microsoft Excel, and word cloud generator for analysis - Descriptive analysis, network diagram, and word cloud visualization	- Document types: articles rank first globally, conference papers in South East Asia. - Top cited sources: 'Journal of Small Business Management' globally, 'Education Sciences' in South East Asia. - Most citations by author: Jeon M from the U.S.A. - Global region clusters: 4 clusters with 62 keywords; South Asia has 2 clusters. - STEAM research trends: Focus on program, project, environment, model, and implication.	- Provides insights for scholars interested in STEAM and education. - Encourages further research on STEAM education trends in specific regions.	- Analysis of STEAM education research trends over three decades. - Top cited papers from 'Journal of Small Business Management' and 'Education Sciences'. - Visualization analysis of global and South East Asia research clusters. - Document type analysis: articles, conference papers, editorials, and reviews. - Top countries interested in STEAM research: US, Thailand, South Korea.

Olalla García-Fuentes; Manuela Raposo-Rivas; María-Esther Martínez-Figueira	The STEAM educational approach: a literature review	Complutense Journal of Education	International	2023	- STEAM education integrates science, technology, engineering, arts, and mathematics. - Review of literature on STEAM approach from 2008 to 2019. - Majority of studies focus on creativity, motivation, and self-efficacy. - Challenges in implementing STEAM projects include economic and curricular limitations.	- Quantitative research methods were predominantly used in the paper. - Qualitative and mixed methods were also employed in some studies. - The research focused on the development, application, and evaluation of STEAM proposals. - Analysis of combining art with science, technology, or mathematics was common.	- 83.3% of investigations are quantitative, 12.5% qualitative, and 4.1% mixed. - Main objective is the development, application, and evaluation of STEAM proposals. - Most recurrent theme is the combination of art with science, technology, or math.	- Majority of STEAM studies are empirical, from the US and Korea. - STEAM research is prominent in the academic field.	- STEAM enhances creativity, motivation, and self-efficacy in students. - STEAM justifies the importance of integrating arts into STEM education.

Razi, A. & Zhou, G.	STEM, iSTEM, and STEAM: What is next? International	Journal of Technology in Education (IJTE)	International	2023	- Calls for curriculum reform in STEM, iSTEM, and STEAM domains. - Emphasizes professional development for teachers and student interest in STEM. - Highlights the need for further research and consensus in STEM fields.	- Curriculum reform involving STEM, iSTEM, STEAM domains and pedagogical practices. - Need for professional development for teachers and support for post-secondary institutions.	- Calls for curriculum reform, professional development, and consensus among scholars.	- Emphasizes need for curriculum reform, professional development, and research. - Highlights importance of administrative support, pedagogical approaches, and teacher training. - Addresses uncertainty and historical background of STEM, iSTEM, and STEAM.	- Need for curriculum reform with STEM, iSTEM, STEAM domains. - Importance of administrative support for successful STEM implementation. - Transition from STEM to iSTEM to STEAM and future considerations.

Chia-Yu Liu, Chao-Jung Wu	STEM without art: A ship without a sail	Thinking Skills and Creativity	china	2021	- Explored art elements in STEAM education through interviews with experts. - Identified strategies for incorporating art elements in STEAM activities. - Emphasized the importance of artsaesthetic, contextual understanding, and creativity in STEAM.	- Thematic analysis was conducted on semi-structured interviews with STEAM experts. - Phenomenological qualitative method was used to explore first-person perspectives. - Data was transcribed verbatim and thematic analysis was employed.	- Defined art elements in STEAM: arts/aesthetic, contextual understanding, creativity. - Extracted 10 factors affecting art elements and 10 suggestions for enhancement. - Thematic analysis revealed themes and sub-themes from expert interviews.	- Clarified and redefined three art elements in STEAM education. - Established factors affecting art elements and suggestions for enhancing them. - Emphasized the importance of art elements in activating STEM discussions.	- Strategies for incorporating art elements in STEAM activities. - Enhancing learners' emotional experiences and interest in STEM content.

Elaine Perignat, Jen Katz-Buonincontro	STEAM in practice and research: An integrative literature review	Thinking Skills and Creativity		2018	- Integrative review on STEAM education definitions, purposes, and learning outcomes. - Lack of consensus on STEAM definitions and arts education outcomes. - Examined 44 articles from 2007 to 2018 to advance STEAM research.	- Transdisciplinary, interdisciplinary, multi-disciplinary, cross-disciplinary, and arts-integration methods used. - Descriptive, empirical, and pedagogical framework articles were analyzed.	- Review included 18 empirical, 14 descriptive, and 12 pedagogical framework articles. - Sixteen articles focused on primary education, one on high school. - Authors were a mix of Art and STEM Educators, scholars, researchers.	- Lack of measured learning outcomes in creativity, problem-solving, and arts education. - Struggle with methods for integrating arts in STEAM disciplines.	- Clarification of STEAM education purpose, definitions, and learning outcomes. - Discordance between STEAM concept and practice, lack of creativity outcomes.
Lyn D. English	Advancing elementary and middle school STEM education.	International Journal of Science and Mathematics Education	EU	2017	- Complex STEM education debates, implementation challenges, and equity issues addressed. - Focus on STEM integration, discipline representation, equity, and extending to STEAM.	- The paper addresses STEM education perspectives, integration, discipline representation. - Recommendations for designing STEM-based learning experiences are provided.	- Addresses perspectives on STEM education, integration, discipline representation, equity, and STEAM. - Discusses pedagogical affordances in integrated STEM activities. - Highlights strategies for reducing disparities in	- Addressed core issues in STEM education and integration. - Highlighted the importance of equity in access to STEM education. - Emphasized the need for integrated STEM experiences for effective learning.	- Contributions include perspectives on STEM, approaches to integration, equity in access. - Emphasizes the importance of engineering education in STEM for students. - Recommendations for designing STEM-based learning

							STEM achievement.		experiences are provided.
Olalla García-Fuentes, Manuela Raposo-Rivas and María-Esther Martínez-Figueira	STEAM IN EARLY CHILDHOOD EDUCATION: CONTENT ANALYSIS OF THE OFFICIAL CURRICULUM	Lecturer. Journal of curriculum and lecturer training.	Spain	2022	- Study combines document analysis to classify curriculum objectives for STEAM. - Analyzes semantic relationships to identify key thematic areas. - Legislation shows significant alignment with STEAM disciplines. - Methodology includes coding and categorization for legislative text analysis.	- Mixed study combining document analysis and content classification. - Analysis of objectives, contents, and relationships within disciplines. - Documental and content analysis of official curriculum documents in Galicia.	- 43% of general stage objectives and 61% of area objectives relate to STEAM. - 71.2% of state-level contents are linked to STEAM disciplines. - 56% of general objectives in Early Childhood Education are STEAM-related. - The study found a reorganization of contents into 26 new thematic areas.	- Legislation shows increased presence of STEAM-related objectives and contents. - Lack of specific STEAM-related content in both state and autonomous legislation.	- Analysis of curriculum content for STEAM in Early Childhood Education. - Emphasis on STEAM initiatives and projects in educational systems. - Integration of art, music, and robotics in early childhood education.

10 Annex 5. Summary table of the articles selected for the study of the topic STEAM in Education.

AUTHORS	ARTICLE TITLE	JOURNAL	Country	PUBLISH DATE	SUMMARIZED ABSTRACT	METHODS USED	RESULTS	CONCLUSIONS	CONTRIBUTIONS
- Kaan Bati, Ikbal Yetişir, Ilke Çalişkan, Gökhan Güneş, Esma Gül, Debra Chapman	- Teaching the concept of time: A steam-based program on computational thinking.	Cogent Education.	Turkey	2018	- The paper explores teaching time concept through computational thinking in education. - Activities include understanding cycles, relationships, and complexity within a system. - Data collection and analysis involved 104 students in experimental and control groups.	- Concurrent-triangulation design with qualitative and quantitative methods. - Quasi-experimental method with pre-test and posttest control group.	- Data analysis codes from students' diaries revealed 'enjoyable' experiences. - Pretest and posttest scores were analysed using covariance analysis.	- Emphasized the importance of teaching time concept in science education. - Analyzed data sets to ensure distribution met variance analysis assumptions.	- Developed a program on computational thinking in science education. - Designed a Time Teaching Program focusing on STEM and computational thinking.

- Tzu-Hua Wang **- Jari Lavonen** **- Hsien-Sheng Hsiao** **- Jyun-Chen Chen** **- Jhen-Han Chen** **- Yu-Ting Zeng** **- Guang-Han Chung**	- An Assessment of Junior High School Students' Knowledge, Creativity, and Hands-On Performance	Sustainability	Taiwan	2022	- Explored STEAM knowledge, creativity, and performance in junior high school students. - Implemented PBL with CAIM to enhance learning outcomes and creativity. - Showed positive effects on creativity and academic performance in students. - Contributed to achieving Sustainable Development Goal 4 in education.	- Project-based learning (PBL) with cognitive-affective interaction model (CAIM) - STEAM Knowledge Examination Paper (STEAM KEP) for assessment	- PBL with CAIM enhanced STEAM knowledge, creativity, and hands-on performance. - EGs outperformed CGs in creativity, novelty, and overall performance. - Students in EGs showed better performance in valuable, useful, and elegant aspects. - EGs added components to improve boat function and design creativity. - EGs demonstrated higher academic performance in STEAM knowledge.	- PBL with CAIM enhanced STEAM knowledge, creativity, and hands-on performance. - Students in EGs showed higher creativity and innovativeness in product design. - EGs outperformed CGs in hands-on performance and product quality. - Creative abilities were crucial for students' performance and product outcomes.	- PBL with CAIM enhanced STEAM knowledge, creativity, and hands-on performance. - Positive effect on creativity, innovativeness, and creative abilities for students. - Provided reference examples for future development of STEAM activities.

- Kerry Chappell, Lindsay Hetherington	Creative pedagogies in digital STEAM practices: natural, technological and cultural entanglements for powerful learning and activism	Cultural Studies of Science Education	Denmark, Spain, England	2023	- Explores creative pedagogies in digital STEAM practices in school settings. - Utilizes ocean learning to enhance creative teaching and teaching for creativity. - Analyzes messy mixtures of natural, cultural, and technological environments in education.	- Postqualitative analytical approach with diffractive inquiry was used. - Diffractive switches and material-dialogic assemblages were developed for analysis. - Data collection involved interviewing, capturing photographs, and questionnaires.	- Explored messy mixtures of natural, cultural, and technological environments. - Developed four material-dialogic assemblages using diffractive analytic technique. - Offered insight into creative pedagogies supporting digital STEAM practices.	- Explored creative pedagogies in digital STEAM practices across school settings. - Applied postqualitative analytical approach to understand messy mixtures of environments. - Acknowledged project partners and contributors from Ocean Connections EU-funded Erasmus project.	- Research contributes to ocean literacy through creative pedagogies and digital technologies. - Analyzed data using diffractive analytic technique inspired by new materialist theory. - Explored messy mixtures of natural, cultural, and technological environments in learning.
- Xiaodong Huang - Chengche Qiao	Enhancing Computational Thinking Skills Through Artificial Intelligence Education at a STEAM High School	Science & Education	Beijing	2024	- Integrates AI education with STEAM model to enhance computational thinking skills. - Study evaluates effects on students' computational thinking skills, learning motivation. - AI education in STEAM model can guide multi-disciplinary knowledge combination.	- ANCOVA approach with pretest scores as covariates for analysis. - Statistical analysis of differences in CT skills, motivation, and self-efficacy.	- Experimental group showed higher self-efficacy and learning motivation scores. - Integration of AI education with STEAM model enhanced students' skills.	- AI education with STEAM enhances computational thinking skills and self-efficacy. - STEAM model promotes learning motivation and critical thinking in students. - The integration of AI education with STEAM is beneficial for students.	- Integrating AI education with STEAM model to enhance computational thinking skills. - Demonstrating the positive impact on learning motivation and self-efficacy.

- Cassie Quigley **- Dani Herro** **- Elizabeth King** **- Holly Plank**	- STEAM Designed and Enacted: Understanding the Process of Design and Implementation	Journal of Science Education and Technology	USA	2020	- Focus on STEAM curriculum design and implementation in elementary schools.	- Problem-based units for STEAM curriculum design and implementation. - Student inquiry promotion through teacher facilitation. - Technology integration with e-books and videos. - Discipline integration with math, science, and engineering references. - Student choice in assessment, study method, and partners.	- Teachers designing relevant problems aligned with STEAM model. - Teacher facilitation promoted inquiry and authentic tasks, challenging for teachers. - Mismatch between designed and enacted curriculum, highlighting need for support. - Clear need for grade-specific implementation model to support teachers.	- Teachers designing relevant problems align with STEAM model. - Teacher facilitation promotes inquiry and authentic tasks, challenging for teachers. - Integration of technology and disciplines offers authentic assessments and student choice.	- Connected learning theory guides STEAM instruction in problem-solving scenarios. - Technology options like video production and game design engage students.
- Shih-Yun Lu **- Chih-Cheng Lo** **- Jia-Yu Syu**	- Project-based learning oriented STEAM: the case of micro-bit paper-cutting lamp.	International Journal of Technology and Design Education	Taiwan	2022	- Focus on STEAM curriculum for elementary students integrating art. - Utilizes PBL with Chinese Paper-cutting and BBC micro:bit. - Positive impact on students' creative recognition and development. - Short-term course, suggests extending for long-term influence evaluation.	- Project-Based Learning (PBL) with Chinese Paper-cutting and BBC micro:bit. - Creative thinking instruction strategy employed in teaching process. - Program design teaching using Blocky for mathematical concept understanding.	- Project-based learning incorporating STEAM positively influences students' creative recognition. - Short-term STEAM course benefits cognitive facet of creativity, not emotional. - Paper-cutting art project enhances divergent thinking and problem-solving skills.	- PBL-oriented STEAM curriculum positively influences students' creative recognition. - Short teaching period limits emotional facet of creativity in students.	- Conceptualization, methodology, data curation, writing, review, editing, supervision.

- Ileana Greca - Jairo Ortiz-Revilla - Irene Arriassecq	- Design and assessment of a STEAM teaching-learning sequence for Primary School Education	Eureka Journal on Science Education and Outreach	Spain	2021	- Design and evaluation of STEAM teaching sequence for Primary Education. - Results show viability for scientific and integral development of students.	- Mixed methods research with qualitative observation and quantitative data analysis. - Iterative prototyping approach with three prototypes implemented in six groups. - Qualitative data collection through participant observation and student materials.	- The theoretical model used in the SEA design is viable. - High competency levels achieved in all competencies. - Evidence supports the relevance of iSTEAM for primary education improvement.	- The theoretical model for SEA design in i-STEAM is viable. - iSTEAM enhances competencies in primary education when implemented coherently. - The study provides general design principles for educators.	- Design and evaluation of a STEAM teaching-learning sequence for primary education. - Model used in the design is viable for scientific and integral development.
Hye Ran Kwack and Eu Jean Jang	Development and application of a STEAM program using classroom wall gardens	J. People Plants Environ	South Korea	2021	- Developed STEAM program using classroom wall gardens to promote divergent thinking. - Program led to high student satisfaction, understanding, and interest in science. - Surveyed students to analyze satisfaction and understanding levels post-program.	- Four types of classroom wall gardens were used in the program. - Materials and characteristics of each wall garden were analyzed. - Statistical program SPSS 25.0 was used for questionnaire analysis.	- High student satisfaction and understanding in STEAM program with wall gardens. - No significant difference in satisfaction by gender. - Grades 4, 5, and 6 students had better understanding than Grade 3.	- High student satisfaction and understanding in STEAM program with wall gardens. - Increased interest in science and connection with other subject areas. - Contribution to the development of STEAM education programs in agriculture.	- High student satisfaction and understanding in STEAM education program. - Increased interest in science and connection with other subject areas. - Contribution to the development of STEAM education programs in agriculture.

- Valeria Cabello **- M Loreto Martínez** **- Solange Armijo** **- Lesly Maldonado**	Promoting STEAM learning in the early years: "Little Scientists" Program	LUMAT: International Journal on Math, Science and Technology Education	Spain	- The research paper does not mention the specific publication date.	- Early education program in Chile promotes integrated STEAM learning. - Program strengths, weaknesses, and opportunities identified for future replication. - Integration of science with other disciplines crucial for student engagement. - Ethical procedures followed for data collection and participant anonymity.	- Authentic disciplinary learning methodologies with exploratory activities and expressive actions. - Gender-empowering approach in teacher selection and course design. - Ethical procedures followed for data collection, processing, and protection.	- Students positively engaged in learning processes through diverse artistic formats. - Integration of science with other disciplines in enriched experiences. - Participants showed commitment to hands-on learning and construction of models.	- Strengths include engaging students in diverse artistic formats. - Weaknesses involve teacher management of student behaviour and infrastructure challenges. - Opportunities focus on improving program articulation and inclusion of all children.	- Strengths, weaknesses, and opportunities in STEAM education for young children. - Program design, implementation issues, and gender-empowering approach in Chile. - Ethical procedures followed for data collection, processing, and protection.
- Chu-Yang Chang **- Zhengyi Du** **- Hsu-Chan Kuo** **- Chih-Ching Chang**	Investigating the Impact of Design Thinking-Based STEAM PBL on Students' Creativity and Computational Thinking	IEEE TRANSACTIONS ON EDUCATION	China	2023	- STEAM PBL enhances creativity and computational thinking skills in students. - Tri-phase DT-PBL framework integrates creative thinking, PBL, and DT effectively. - Results show significant improvements in creativity dimensions and CT skills. - Study explores the potential of integrating STEAM into PBL for students.	- Quasi-experimental research design with pretest and post-test unequal groups. - Utilized the New Chinese Version of the Torrance test and Beberas Challenge.	- Experimental group showed significant improvements in creativity and computational thinking skills. - Experimental group outperformed the comparison group significantly in creativity and CT. - Tri-phase DT-PBL approach enhanced students' creativity significantly compared to the comparison group.	- DT-PBL enhances creativity and computational thinking in seventh graders. - STEAM transdisciplinary learning effectively incorporates cross-disciplinary knowledge for students.	- Develops STEAM integrated PBL for creativity and computational thinking skills.

- Gulbin Ozkan **- Unsal Topsakal**	Investigating the effectiveness of STEAM education on students' conceptual understanding of force and energy topics	Research in Science & Technological Education	Turkish	2020	- Investigates STEAM education impact on 7th-grade students' science understanding. - STEAM approach enhances conceptual understanding and reduces misconceptions. - Study group showed significantly higher post-trial scores than control group.	- Experimental embedded mixed methods design with quantitative and qualitative data. - Control group to compare STEAM approach with regular science curriculum. - Data collected through Force and Energy Conceptual Test and interviews.	- STEAM education positively impacted students' conceptual understanding and reduced misconceptions. - Post-trial scores of the study group were significantly higher.	- STEAM education positively impacts students' conceptual understanding and reduces misconceptions. - Post-trial scores of STEAM group were significantly higher than control group. - Learner-centered environment in STEAM fosters students' conceptual understanding.	- Investigated STEAM education's effect on students' conceptual understanding of science. - Demonstrated positive impact of STEAM education on reducing misconceptions. - Showed higher post-trial scores in STEAM group compared to control. - Emphasized learner-centered environment support by STEAM education.
- Kyungeun Lim	Expanding Multimodal Artistic Expression and Appreciation Methods through Integrating Augmented Reality	Ijade	USA	2022	- Explores AR integration in art education, enhancing students' art expression. - Utilized Adobe Aero and Merge Cube for AR-based curriculum in classes. - Positive impacts on students' learning engagement, satisfaction, and spatial understanding.	- Integrated AR creation tool (Adobe Aero) and AR education tool (Merge Cube) - Designed lessons with multimodal delivery methods for learning effectiveness with AR - Explored 2D and 3D hybrid art creations in AR - Implemented digital storytelling with AR for students' learning engagement	- Expanded art expression through 2D and 3D hybrid creations in AR. - Positive impact on students' learning engagement, satisfaction, and spatial understanding. - AR allowed exploration of physical spaces and storytelling within them.	- AR-based curriculum expanded students' art expression in real and virtual spaces. - Positive impacts on students' learning engagement, satisfaction, and spatial understanding. - Students connected AR with education and art, enhancing visual analysis.	- Explored AR-integrated curriculum impact on students' art expression. - Positive impacts on learning engagement, satisfaction, and understanding of spatial structures. - AR allowed exploration of physical spaces and storytelling within them. - AR provided multiple perspectives and angles for art creation and appreciation.

- Alvaro Jordan - Aaron Knochel - Nicholas Meisel - Kelsey Reiger - Swapnil Sinha	Making on the Move: Mobility, Makerspaces, and Art Education	iJADE	USA	2021	- Review of Mobile Atelier for Kinaesthetic Education combining maker movement. - Emphasizes curricular spectacle, mobile makerspace, and strategies for novice users. - Explores thematic connections between maker movement, art education, and STEAM. - Encourages informal art education practices for kinaesthetic learning.	- Development of Mobile Atelier for Kinaesthetic Education with Material to Form curriculum. - Hosting scheduled and walk-in sessions for MAKE 3D platform.	- Development of Mobile Atelier for Kinaesthetic Education integrating art and maker education. - Mobile makerspace platform MAKE 3D facilitates hands-on activities for learners. - Curricular spectacle created through additive techniques in digital fabrication.	- Emphasizes kinaesthetic learning, design thinking, and place-based education in art. - Encourages informal art education practices through mobile makerspaces. - Explores the development of a mobile makerspace platform for art education.	- Development of Mobile Atelier for Kinaesthetic Education integrating art and maker education. - Emphasis on interdisciplinary learning, STEAM initiatives, and digital fabrication techniques.
- Robert Danielson, Elizabeth Grace, Alison White, Molly Kelton, Jeb Owen, Kristin Fisher, Anamaria Diaz Martinez, Maria Mozo	Facilitating Systems Thinking Through Arts-Based STEM Integration	Frontiers	USA	2022	- Arts integrated STEM program enhances systems thinking in rural communities. - Students showed improved understanding of ecosystem dynamics and zoonotic diseases.	- Mixed methods analysis for image and career selection tasks. - Data collection through written assessments and student descriptions.	- Arts integration enhanced systems thinking and career understanding in students. - Students showed improved connections between concepts and ecosystem dynamics. - Some students made broader career connections, indicating room for growth.	- Arts integration enhances systems thinking in STEM education. - Students improved understanding of zoonotic diseases and ecosystem dynamics. - Educators can merge arts and sciences to promote interconnectedness in STEM.	- Integrating arts into STEM curriculum to enhance systems thinking. - Using arts to promote understanding of zoonotic diseases and ecosystem dynamics. - Exploring how arts integration supports systems thinking on socio-scientific issues.

- **Suryanti, Mochamad Nursalim, Nadia Choirunnisa, Ivo Yuliana**	STEAM-Project-Based Learning: A Catalyst for Elementary School Students' Scientific Literacy Skills	European Journal of Educational Research	Jakarta	2023	- STEAM-PjBL model enhances scientific literacy in elementary students significantly. - Experimental group outperformed control group in post-test scientific literacy. - Study recommends adopting STEAM-PjBL model for teaching fundamental scientific concepts.	- Quasi-experimental methodology with 22 female and 26 male fourth-grade students. - STEAM-PjBL model for experimental group, conventional learning for control group. - Administered Scientific Literacy Test (SLT) followed by unpaired and paired t-tests. - Data analysis included Cronbach alpha, Shapiro-Wilk, Levene's tests, and T-tests.	- STEAM-PjBL significantly improved students' scientific literacy skills over traditional instruction. - Experimental group outperformed the control group in post-test scientific literacy. - Activities in STEAM-PjBL model enhanced scientific literacy through real-world issues. - Students in experimental group engaged in problem-solving with alternative energy sources. - Data analysis confirmed the validity and reliability of the study.	- STEAM-PjBL significantly enhances scientific literacy skills in elementary students. - Experimental group outperformed the control group, validating STEAM-PjBL effectiveness. - Students engaged in real-world problem-solving activities, improving scientific literacy. - Valid and reliable data analysis supports the impact of STEAM-PjBL.	- STEAM-PjBL model significantly improved students' scientific literacy skills. - Experimental group outperformed the control group in post-test assessments. - Activities included real-world issues, project design, data analysis, and conclusions.

- Chung, S. K., & Li, D	Issues-Based STEAM Education: A Case Study in a Hong Kong Secondary School	International Journal of Education & the Arts	USA	2021	- Integrates art education into STEM for authentic, interdisciplinary learning experience. - Discusses movement from STEM to STEAM, emphasizing inquiry-based learning.	- Integration of issues-based art education into STEM curriculum. - Encouraging art teachers to teach social justice issues.	- Integrating art into STEM enhances real-world learning and critical thinking. - Students learned math, engineering, and art through issues-based STEAM education. - Students used recycled materials to create moving sculptures addressing social issues.	- Integration of art into STEM enhances authentic, interdisciplinary learning experiences. - Issues-based STEAM education promotes social justice awareness and critical thinking. - Gender bias affects women's pursuit of STEM careers.	- Integrating art education into STEM for authentic interdisciplinary learning experience. - Encouraging art teachers to teach social justice issues in art rooms. - Teaching math, engineering, and art through issues-based STEAM education. - Using recycled materials to create moving sculptures addressing social issues.

- Nancy Dejarnette	Implementing STEAM in the Early Childhood Classroom	Journal of STEM Education	USA	2018	- Focuses on STEAM education in early childhood classrooms. - Explored impact on teachers' dispositions, self-efficacy, and STEAM implementation. - Revealed positive changes in teachers' attitudes and self-efficacy. - Teachers needed more professional development for full STEAM implementation.	- Identical pre- and post-surveys with 5-point Likert scale ratings. - Field observations conducted by the researcher as a participant observer.	- Positive impact on preschool teachers' dispositions and self-efficacy towards STEAM. - Initial limited rate of STEAM lesson implementation by teachers. - High engagement and cooperation of high-needs preschool children with STEAM. - Statistically significant increase in teachers' confidence and knowledge of STEAM. - Challenges in integrating STEM content despite positive teacher engagement.	- Positive impact on teachers' dispositions and self-efficacy towards STEM. - Teachers need more professional development to fully implement STEAM lessons. - Reluctance among teachers to independently implement STEAM lessons.	- Positive impact on preschool teachers' dispositions and self-efficacy. - Increase in engagement and cooperation levels of high-needs preschool children. - Professional development workshops led to a rise in self-efficacy. - Hands-on modeling of STEAM lessons reflected sociocultural and constructivist theories.

- Tibor Szabó **- Bernadett Babály** **- Helena Pataiová** **- Andrea Kárpáti**	Development of Spatial Abilities of Preadolescents: What Works?	Education Sciences	Slovakia	2023	- Spatial skills of preadolescents enhanced through STEAM-based educational program. - Developmental methods included two-and three-dimensional visualization tasks. - Pre-and post-hoc assessment design used to evaluate spatial ability.	- Employed two-and three-dimensional visualization tasks in real and virtual environments. - Used pre-and post-hoc assessment design with standardized spatial ability tasks. - Integrated non-intensive, modular teaching-learning program with regular curriculum for enhancement.	- Spatial skills of preadolescents can be enhanced through authentic tasks. - Slovak experimental programs developed spatial orientation and mental rotation skills. - Students improved performance in spatial tasks from pre-test to post-test.	- Spatial skills of preadolescents can be enhanced through authentic tasks. - Mental rotation and spatial reconstruction tasks are important for various professions. - Real-life situations in learning units contribute to successful spatial skill development. - Students improved spatial skills through a STEAM-based educational program.	- Conceptualisation, methodology, validation, formal analysis, research, resources, data curation.
- Erna Piila, Hannu Salmi, Helena Thuneberg	STEAM-Learning to Mars: Students' Ideas of Space Research	Education Sciences	Finland	2022	- Study on Mars-themed STEAM learning intervention for 5th and 6th graders. - Examined science knowledge outcomes comparing traditional STEM learning to STEAM approach.	- One-way repeated measures ANOVA to compare pre-and post-test scores. - Chi-square test for model fit and multivariate analysis of variance (MANOVA).	- Gender differences in learning outcomes were not significant. - High-achieving students showed the most improvement in test scores.	- Girls benefited more from Mars-module, academically high-achieving students improved significantly. - Gender and academic achievement influenced learning outcomes in the Mars-themed module.	- Examined learning outcomes of Mars-colonization themed STEAM-learning intervention. - Investigated improvement in science knowledge among 5th and 6th graders. - Explored gender differences in learning outcomes and academic achievement levels.

- Pamela Burnard **- Laura Colucci-Gray** **- Carolyn Cooke**	Transdisciplinarity: Re-Visioning How Sciences and Arts Together Can Enact Democratizing Creative Educational Experiences	Review of Research in Education	South Africa	2022	- STEAM education repositioned as democratized enactments of transdisciplinary education. - Democratizing creativity through transdisciplinary education across music, math, and science. - Emphasizes the importance of creative educators in the 21st century.	- Diffraction methodological and pedagogical tool is introduced. - Diffractive analysis from a posthumanist stance is undertaken.	- The paper discusses democratized enactments of transdisciplinary education. - It highlights the potential of transdisciplinarity in inspiring creativity. - The paper repositions STEAM education as democratized enactments of transdisciplinary education. - It emphasizes the integration of arts and sciences in educational practices.	- Emphasizes transdisciplinarity in democratizing creative educational experiences.	- Repositioning STEAM education as democratized enactments of transdisciplinary education. - Advancing the debate on new ways of thinking about transdisciplinary creativities. - Capturing the deterritorialization of disciplines and how transdisciplinarity is performed. - Exploring a wide range of diffractive possibilities of educational discourses.

- **Christina Zorenbohmer, Eva Missoni-Steinbacher, Peter Jeremias, Ulrich Öttl, Bernd Resch**	STEAM Stories: A Co-creation Approach to Building STEAM Skills through Stories of Personal Interest	GI_Forum	Austria	2022	- Co-creation approach for STEAM learning through personal stories of interest. - Young citizen scientists contribute to story phases for local engagement. - Spatial focus on story locations, uploaded to map-based platform.	- Co-creation approach for STEAM learning through personal stories. - Workshop-based educational approach integrating CS methods into STEAM framework. - Smartphone app for recording images and geolocated stories. - Technical implementation in ESRI environment for data collection. - Integration of CS methods with STEAM learning framework.	- Co-creation approach enhances STEAM skills through personal stories. - Workshop-based method integrates CS into STEAM educational framework. - Young citizen scientists contribute to all phases of story creation. - Data collection workshops aim to sustain engagement with digital technologies.	- Co-creation workshops empower young citizen scientists in STEAM fields. - Sustained engagement in digital skills and STEAM topics benefits participants.	- Introduces co-creation approach for enriching STEAM learning experiences. - Aims to foster young citizen scientists through personal involvement. - Focuses on building digital skills and sustaining engagement with STEAM topics. - Empowers workshop participants and generates sustained interest in STEAM topics.

- Qi Zhou, Jin Jiang, Xiaofeng Li, Huimin Hou, Shiqi Yue	Designing an Intelligent Firefighting Toy Car Using AR Technology and STEAM	Mobile Information Systems	China	2022	- AR technology enhances children's learning through smart firefighting toy car design. - Utilizes STM32F103 chip microcontroller for smart car design. - Aims to develop children's comprehensive capacity and practical technological capabilities.	- Functional Analysis System Technique (FAST) method for product functions. - Product Black Box Model for rationalizing and analyzing basic functions.	- Design of a smart car using STM32F103 chip for children's education - Integration of AR technology to enhance children's learning experience - Implementation of VR technology in the design of firefighting toy car - Utilization of L293D motor driver chip for motor drive control - Conversion of child's STEAM smart material demands into design features	- Intelligent firefighting toy car controlled remotely with STM32F103 microprocessor core. - Compact structure with ultrasonic sensor to prevent collisions and detect fires. - Suitable for fire protection in warehouses, explosive enterprises, and petrochemical firms.	- Creation of AR intelligent firefighting toy car laboratory integrating interdisciplinary knowledge. - Utilization of STM32F103 chip microcontroller for toy vehicle development.
- Fernández, R. C., & Romero, M. C.	Robotics and STEAM Projects: Developing Creativity in Primary Education Classrooms	Pixelbit	Spain	2020	- PIXEL-BIT research paper on educational robotics and creativity.	- Alignment of objectives between teachers and researchers before the school year. - Defining work methods in the classroom and data collection systems. - Informing families about the research impact on class development.	- Significant differences in creativity between students in pre and post-tests. - Three main phases: planning, program development, and evaluation.	- Conclusions include alignment of objectives, methodology, results, and discussion.	- Study outlines methodology, analysis, results, discussion, and conclusions. - Provides a fun, practical opportunity for children to explore and create. - Methodology used to analyze creativity and expert evaluations of products.

- Hongbo Xue	A New Integrated Teaching Mode for Labor Education Course Based on STEAM Education	International Journal of Emerging Technologies in Learning (iJET)	China	2022	- STEAM education enhances students' skills through interdisciplinary teaching methods. - Bayesian network model improves teaching effectiveness in labor education courses. - Traditional teaching methods are less effective compared to integrated teaching mode.	- Analysis of STEAM education concept in labor education curriculum. - Establishment of a college student labor education course online self-study model. - Introduction of Bayesian network mode and nondirective teaching mode.	- Students' academic scores significantly increased with STEAM-based integrated teaching mode. - Enhanced labor skills, self-learning capacity, team spirit, and participation.	- Integrated non-directive teaching and Bayesian model for effective college education. - STEAM-based teaching mode enhances labor education course outcomes.	- Analyzed STEAM education application in labor education curriculum. - Established a Bayesian network model for college student labor education. - Enhanced students' skills, self-learning capacity, and team spirit significantly.
- Jo Trowsdale - Richard Davies	- Creative pedagogies in digital STEAM practices	- The research paper discusses a distinctive STEAM education model. - The Trowsdale art-making model for education (TAME) approach is transparent and effective in supporting learning. - The TAME model offers a distinctive and effective approach for education. - The TAME approach is a form of STEAM education with a specific	England	2023	- Discusses a distinct STEAM model developed through innovative education projects. - Examines positive outcomes for pupils and teachers implementing the TAME model. - Argues TAME offers an effective model for STEAM and broader education.	- The paper draws on two studies: a five-year mixed methods study. - Participatory and collaborative qualitative study of Teach-Make.	- Positive educational outcomes for pupils and teachers' appetite for translation. - Clear curriculum model (TAME) and professional development improved teachers' planning. - Teachers reported positive impact on supporting learning, pupil progression, and enjoyment.	- The TAME model is effective and accessible for teachers. - Teachers reported positive impacts on learning progression and enjoyment. - Continued development of the TAME approach in schools is recommended. - Future research should assess the efficacy of each TAME element.	- The TAME model offers a distinctive and effective STEAM education model. - Integration of arts and STEM for real-world, complex issue-based curricula. - Positive educational outcomes for pupils and improved teacher planning skills.

		theoretical foundation.							
- Suthasini Bureekhampun **- Torfhun Mungmee**	STEAM education for preschool students: Patterns, activity designs and effects.	- Journal for the Education of Gifted Young Scientists.	Bankok	2020	- STEAM education for primary students integrating various skills and knowledge. - Designed moveable robots inspired by Beagle breed, evaluated by experts. - Aimed to enhance students' creative and innovative thinking skills. - Utilized pre-experimental design method with 5 groups of 15 children.	- Pre-experimental design method with one-shot-case study design. - Statistical software SPSS for mean, standard deviation, and Likert Scale.	- Design of three moveable robots inspired by Beagle breed. - Evaluation by three experts with high mean scores. - Learning achievement mean of 80.33% with proposed activities.	- STEAM learning enhances student interest in science through art. - Children showed creativity, emotional awareness, and imagination during activities.	- Design of three moveable robots inspired by Beagle breed. - Integration of knowledge areas to create innovative learning activities.

- José-Manuel Diego-Mantecón **- Zaira Ortiz-Laso** **- Zsolt Catedrático**	STEAM projects with KIKS format for the development of key competences	Communicate	Finland, England, Hungary, and Spain	2021	- Study on STEAM projects with KIKS format for key competences. - 267 students from four countries developed eight key competences. - Combination of STEAM projects and KIKS format enhances competences.	- Design of STEM projects with Thibaut's framework for implementation. - Integration of STEAM contents, problem-solving, research processes, design, and cooperation. - Projects required bilingual reports and non-native language videos for dissemination.	- Combination of STEAM projects and KIKS format enhances key competences. - Students improved scientific, mathematical, digital, and communication competences. - Use of technology, data processing, and dynamic geometry tools observed.	- Combination of STEAM projects and KIKS format enhances key competences. - STEM projects improve scientific and mathematical competencies in secondary students. - Digital competence and collaborative learning skills are developed through project implementation. - Various initiatives and resources promote continuous learning and key competences.	- Establishes relationship between STEAM projects with KIKS format and key competences. - Combines project-based STEAM learning with KIKS format for competency development. - Shows how project-based learning enhances math and science competencies. - Highlights the impact of prolonged participation in the implementation program.
- Laura Castro-Santos **- Puime Félix** **- Isabel Guillén** **- Lamas-Galdo**	- STEMbach Experiences at Higher Education	Open Education Studies	Spain	2023	- Describes STEMbach program for high school students in Galicia. - Aims to promote STEM careers and connect with college education.	- Different methodologies applied in STEMbach projects: Table 3 details them. - Projects had varying methodologies due to different university professors.	- Promoted STEM careers with constructive results in Galicia. - Projects included wave energy, steel behavior, and Spanish economy analysis. - Analyzed alloy compositions and cooling curves in educational projects.	- Positive results in promoting STEM careers through various methodologies. - Encouraged vocation towards scientific and technological research among high school students. - Projects enhanced students' knowledge and training in entrepreneurship and STEM fields. - Collaboration between University of A Coruna and high schools in Galicia.	- Describes STEMbach experiences in engineering, economics, materials, promoting STEM careers. - Projects include wave energy, steel behaviour, alloy composition analysis.

- Chien-Liang Lin - Chun-Yen Tsai	- The Effect of a Pedagogical STEAM Model on Students' Competence.	- The research paper is titled "The Effect of a Pedagogical STEAM Model on Students' Project Competence and Learning Motivation".	China	2021	- Study on pedagogical STEAM model enhancing project competence and learning motivation. - Model positively impacts students' perceptions and interdisciplinary competence. - Qualitative data supports the effectiveness of the pedagogical STEAM model.	The study used a special teaching plan called STEAM and checked how it worked by comparing two groups of students	Students who learned with the STEAM plan got better at doing projects and wanted to learn more than those who didn't. The STEAM plan also made it easier for students to mix what they learned from different subjects	The STEAM plan could be a good way to teach high school kids when you're mixing different subjects togetherThis plan seems to keep students interested and might even make them want to learn more as they go along	The paper shows that the STEAM plan can help students and might be used as a guide for teaching different subjects together in high school.
- Cassie Quigley - Dani Herro - Elizabeth King - Holly Plank	- STEAM Designed and Enacted: Understanding the Process of Design and Implementation	- J Sci Educ Technol (2020)	USA	2021	- Focus on STEAM curriculum design and implementation in elementary schools. - Emphasizes teacher facilitation, inquiry, and authentic tasks for STEAM education.	Teachers designed STEAM curriculum using problem-based units to promote student inquiry and integrate disciplines, with feedback and support provided by researchers. Observations and debriefing sessions were conducted to document the implementation and provide feedback.	Key findings included that teachers who designed relevant problems aligned with the STEAM model and that teacher facilitation promoted inquiry and authentic tasks.	The research highlighted the need for specific strategies to support teachers in discipline integration, teacher facilitation, and authentic tasks, as well as the development of grade-specific implementation models.	The study contributes to understanding how K-5 teachers can design and implement STEAM learning environments and defines curricular supports for STEAM education.

- Ileana Greca - Jairo Ortiz-Revilla - Irene Arriassecq	- Design and assessment of a STEAM teaching-learning sequence for Primary Education.	- The research paper is published in the Revista Eureka journal.	Spain	2021	- Design and evaluation of STEAM teaching sequence for Primary Education. - Results show viability for scientific and integral development of students.	The study combined qualitative and quantitative approaches, using a design-based research (IBD) methodology to assess a STEAM teaching-learning sequence for primary education. Data collection techniques included participant observation, field notes, and analysis of students' personal field notebooks for qualitative data, and numerical data from qualitative analysis for quantitative data.	The implementation of the STEAM sequence showed evidence of being viable for developing both scientific and comprehensive competencies in students. The study found that the theoretical and methodological choices were appropriate for achieving the intended educational outcomes.	The study concluded that the design-based research approach is useful for designing, implementing, and evaluating educational proposals to improve education, particularly in science.	The research contributed to the field by providing evidence of the relevance of iSTEAM for improving primary education students' competencies when implemented coherently and based on a solid foundation. It also offered design principles that could be useful for teachers wanting to design sequences based on the proposed theoretical model.

- Alexey Chistyakov, Sergei Zhdanov, Elena Avdeeva, Elena Dyadichenko, Maria Kunitsyna, Roza Yagudina	- Exploring the characteristics and effectiveness of project-based learning for science.	- The journal is EURASIA Journal of Mathematics, Science and Technology Education.	Russia	2023	- Explores project-based learning in science and STEAM education. - Analyzed 36 articles on PjBL effectiveness and characteristics. - PjBL enhances student learning outcomes and critical thinking skills.	The researchers conducted a literature review using the Eric database to find articles on project-based learning (PjBL) in science and STEAM education, analysing 36 articles through qualitative thematic review.	PjBL is an effective learning model for science and STEAM education, improving student learning outcomes and fostering important skills - No significant difference in project competence scores between the two groups.	This article contributes to the literature by providing evidence-based arguments for the benefits of PjBL and encouraging teachers to use PBL in their classrooms.	Teachers and curriculum designers are recommended to consider the importance of authenticity in PjBL to maximize its impact on learning
- Ahmad Dasuki, Mohd Hawari, Azlin Iryani, Mohd Noor.	- Project Based Learning Pedagogical Design in STEAM Art Education	- Asian Journal of University Education (AJUE)	Malasya	2020	- Explores Project-Based Learning in a multidisciplinary art classroom involving STEAM. - Highlights benefits, challenges, and recommendations for implementing PBL in art education. - Discusses findings, implications, and recommendations for arts curriculum and school systems.	The study used interviews, observations, and document analysis to explore teaching strategies in Project-Based Learning (PBL) for art education.	PBL improved teaching strategies and could potentially replace traditional teacher-led classrooms, emphasising student collaboration and problem-solving in art projects.	PBL in STEAM art education has challenges but offers benefits like enhancing soft skills, leadership, and creativity; recommendations are made to overcome these challenge,	The study contributes insights on the effectiveness of PBL pedagogical design in art education and its potential to improve student outcomes

- Pérez Torres - Couso Lagarón - D Marquez Bargalló - Miquel Torres - Digna Lagarón - Conxita Marquez Bargalló	- Evaluation of STEAM Project-Based Learning (STEAM PBL) Instructional Designs	Education Sciences	Spain	2023	The paper investigates how well different school projects in Spain teach students important skills in science, technology, engineering, arts, and math (STEAM) by looking at 46 projects. It finds that some projects are better than others at teaching all the skills, suggesting schools need to think about how they design these projects.	The research used a mix of qualitative and quantitative data to understand teaching practices and beliefs around STEAM PBL instructional designs in Catalonia, Spain.	The evaluation of 46 STEAM projects showed an imbalance in sophistication levels, with better performance in multidisciplinary criteria than in Science and Technology disciplinary criteria[	There is a need for standardised understanding and improvement in the design of STEAM projects to better serve educational purposes and integrate STEAM competences	The paper contributes to the field by mapping the sophistication of STEAM projects and identifying areas for design improvement.
- Jairo Ortiz-Revilla - James Albright - Marcela Silva-Hormazábal - Ángel Alsina	- Exploring the Impact of Integrated STEAM Education in Early Childhood and Primary Education Teachers	Education Sciences	Chile	2023	The study looks at how STEAM education affects Chilean teachers by checking their knowledge, feelings, and confidence about this teaching method, aiming to help design better training for them.	Adapted a tool to measure teachers' views on STEAM, validated it, and used it to survey 31 teachers before they learned more about STEAM	Found that teachers are not very familiar with STEAM but want to learn; they're moderately confident they can use it in class	Teachers' positive attitude is a good sign, but they need proper training to use STEAM effectively in their teaching	The study adds to our understanding by showing the need for teacher training in STEAM and how teachers' views can affect its use in class

- Roberto Capone, Lynda Ball, Eleonora Faggiano, Zelha Tunç-Pekkan, Nicolás Montés, Alberto Zapatera, Francisco Ruiz, Laura Zuccato, Sandra Rainero, Amerigo Zanetti.	- A Novel Methodology to Develop STEAM Projects According to National Curricula.	Education Sciences	Spain, Italy, Cyprus	2023	The paper presents a method to create STEAM projects, blending subjects like Science, Technology, Engineering, Art, and Mathematics, based on European school curricula[	The 'forward' and 'backward' methodologies were used to integrate STEAM disciplines with educational curricula	Developed a 'forward' STEAM project on sustainability and a 'backward' project themed around cooking, demonstrating the methodology's application	The methodology can adapt STEAM projects to various national curricula, making them transferable across different European countries.	The authors collectively contributed to conceptualization, methodology, validation, formal analysis, investigation, and writing

11 Annex 6. Summary table of the articles selected for the STEAM and Inclusion topic study.

AUTHORS	TITLE	YEAR	COUNTRY	JOURNAL	SUMMARIZED ABSTRACT	RESULTS	CONCLUSIONS	CONTRIBUTIONS
Marcia J Millet, Twianie Roberts	Preparing All Girls to Change the World through STEMM	2023		Open Journal of Social Sciences	- Increase female representation in STEM through mentoring and parental support. - Identify and support 20 girls interested in STEM from elementary.	- Increase female representation in STEM fields - Provide mentoring and support for pursuing STEM careers	- Increase female representation in STEM fields through mentoring and support. - Identify and engage 20 female students in STEM opportunities.	- Increase females in STEM careers through mentoring and support. - Identify 20 girls for STEM opportunities from elementary to high school.
Emilia López-Iñesta, Carmen Botella, Silvia Rueda, Anabel Forte, Paula Marzal	Towards Breaking the Gender Gap in Science, Technology, Engineering and Mathematics	2020			- Gender gap in STEM, impact on education and gender equality. - Pilot program and Girls4STEM project to promote STEM careers for females.	- Computing camps impact students' confidence and perception of themselves in computing. - Follow-up and future additional survey data are needed to determine the effectiveness of informal computing programs in retaining women in STEM.	- The pilot program had a significant impact on increasing the proportion of female students in STEM fields. - Continuous efforts are needed to address the gender gap in all STEM fields.	- Investigates the impact of computing camps on young women - Examines the long-term effects of informal computing programs on women in STEM

Gabriela Ortiz-Martínez, Patricia Vázquez-Villegas, M. Ileana Ruiz-Cantisani, Mónica Delgado-Fabián, Danna A. Conejo-Márquez, Jorge Membrillo-Hernández	Analysis of the retention of women in higher education STEM programs	2023	Humanities & social sciences communications	- Gender gap in undergraduate STEM programs, with only 17% women. - Factors influencing women's decision to pursue or abandon STEM careers.	- A slightly higher percentage of female students than male students dropped out of STEM careers. - Academic performance may not be the main reason for leaving a STEM career.	- Only 17% of women choose STEM careers. - Factors affecting women's decision to stay in STEM include inspiring faculty and a supportive environment.	- Historical data shows only 17% of women choose STEM careers. - Factors affecting women's decision to stay in STEM careers were identified.
Wan Ng, Jennifer Fergusson	Engaging High School Girls in Interdisciplinary STEAM	2020	Science education international	- Research investigates impact of STEAMpunk Girls Program on high school girls' learning - Program uses project-learning and design thinking strategies to increase girls' engagement with STEM	- Minority ethnic women's STEM pathways: pragmatic, persistent, precarious. - Identity development and management in STEM higher education.	- The STEAMpunk Girls Program had a positive impact on high school girls' learning. - The program increased girls' confidence and motivation in STEM.	- Increased confidence and motivation in high school girls - Positive impact of the STEAMpunk Girls Program on students and teachers
Tasos Barkatsas, Grant Cooper, Patricia McLaughlin	Investigating Female Students Stem-Related Attitudes, Engagement and Work-Intentions When Involved in a University Workshop Initiative	2019		- Investigated female students' STEM attitudes, engagement, and work intentions. - Used a survey on 221 students aged 11-16 in Australia.	- STEM in Situ workshops positively impact female students' STEM attitudes. - Findings can influence future STEM interventions for young women.	- Female engagement in STEM is declining at tertiary and secondary levels. - STEM interventions can promote engagement and interest in STEM.	- Investigating female students' STEM-related attitudes, engagement, and work intentions in a university workshop initiative. - Highlighting the outcomes of the STEM in Situ workshops on female students' attitudes and engagements with STEM careers.

Anthony Kenneth	Gap in STEM Education: Why is there a decline in women participation?	2022	International Journal of Research in STEM Education	- Gender gap in STEM education is observed worldwide. - Factors contributing to the gap include interests, awareness, mentors, and encouragement.	- Gender gap in STEM education is observed worldwide. - Factors contributing to the gap include interests, awareness, and mentorship.	- Women's career decisions in STEM influenced by interests - Factors contributing to the gender gap in STEM	- Women pivotal to scientific discoveries, underacknowledged in STEM histories. - Fewer representations of minority ethnic women in STEM higher education.
Rie Kijima, Mariko Yang-Yoshihara, Marcos Sadao Maekawa	Using design thinking to cultivate the next generation of female STEAM thinkers	2021	International Journal of STEM Education	- Design thinking workshop in Japan aimed to change female youths' perceptions of STEM - Workshop resulted in increased interest in engineering, creative confidence, and positive perceptions of STEM	- Increased interest in engineering among female youths - Greater creative confidence and positive perceptions of STEM	- Short design thinking workshop positively impacts female youths' interest in STEM - Design thinking approach increases creative confidence and empathy	- RK conceived, designed, analyzed, and wrote the manuscript. - MSM co-organised workshops, recruited design coaches, and users.
Kimberly K. Arcand, Sara Price, Lisa F. Smith, Brian Hsu	Women in STEM Interview Analysis: Encouraging Young Female Learners in STEM Pathways	2022	Communication, society and media	- Qualitative study on obstacles and challenges in STEM for females - Importance of mentorship, early engagement, and self-efficacy	- Five themes emerged from the data: influencers, educational experiences, hurdles, attitude changes, and recommendations. - Participants discussed attitude changes and the need for continued STEM initiatives.	- Importance of mentorship and support system in STEM - Need to engage young females in STEM activities	- STEM programs should address cultural issues and promote gender equality. - Attitudes towards women in STEM have improved, but challenges remain.

Heidi Blackburn, Jason A. Heppler	Women in STEM in Higher Education: A Citation Analysis of the Current Literature	2019	Science & Technology Libraries	- Diversification efforts in STEM education for women in the US. - Increased studies on women's experiences in STEM programs.	- The paper analyzes the literature on women in STEM in higher education. - The authors found no articles regarding citation analysis for this topic.	- No articles found on citation analysis for women in STEM. - Need for analysis in the area of women in STEM.	- Increased number of studies on women in STEM in higher education - Analysis of citation patterns in women in STEM literature
Claudia Alejandra Hernández Herrera	STEM women and their perceptions of their university career journey	2021	Nova Scientia	- Study on perceptions of STEM women in higher education - Challenges faced by women in STEM fields	- Women in STEM fields face challenges and discrimination. - Higher education institutions need to create more supportive environments for women.	- Higher education institutions need to eliminate hostile environments towards women students. - Actions should be taken to increase the number of women teachers.	- Access to quality education for women helps reduce the gender gap. - Increasing the number of teachers and promoting stays in productive sectors.
María Paola Sevilla, Virginia Snodgrass Rangel, Elsa Gonzalez	Understanding motivational beliefs of women in postsecondary STEM-vocational-technical education. Evidence from Chile	2023	Journal of Education and Work	- Study explores women's entry and persistence in male-dominated STEM vocational programs in Chile. - Different motivational patterns emerged depending on the economic sector women were preparing to work in.	- Different motivational patterns of EVT beliefs emerged for women in STEM-related VTE programs. - Institutional and government policies should consider these motivational profiles to improve women participation.	- Different motivational patterns emerged for women in STEM-related VTE programs. - Institutional and government policies should consider these motivational profiles.	- Increase females in STEM careers through mentoring and support. - Identify 20 girls for STEM opportunities from elementary to high school.

María Amparo Oliveros Ruiz	STEAM as a tool to encourage engineering studies	2019		- Survey on female engineering students in Mexico to investigate motivation and performance. - Proposal to include STEAM model in engineering schools to increase female enrollment.	- The survey revealed the factors influencing students' decision to pursue engineering. - Family, cultural background, and personal aspirations were found to be important factors.	- Women are increasingly informed and have a greater ability for mathematics when choosing a career in engineering. - The presence of successful women in engineering is important for inspiring more women to choose this field.	- Determining factors that define the motivation of women in STEM careers. - Proposing the inclusion of a STEAM model in engineering schools to increase enrollment of women.
Rahmat Kusharyadi, Erika Yohanna Seventina Siahaan	Women in STEM in Higher Educations: Good practices of attraction, access, and retainment in higher education	2023	Womens History Review	- Women in STEM in higher education: practices for attraction, access, retention - Acknowledgment to LPDP and PUSLAPDIK for financial assistance.	- Increase female representation in STEM fields - Provide mentoring and support for pursuing STEM careers	- Attraction, access, and retainment practices for women in STEM. - Acknowledgment to LPDP and PUSLAPDIK for financing and support.	- Increase females in STEM careers through mentoring and support. - Identify 20 girls for STEM opportunities from elementary to high school.
Adams, E. C., Oduor, P., Wahome, A., Tondapu, G., & Nairobi, K.	Reflections on two years teaching earth science at the women in science (wisci) steam camp	2022	Journal of Women and Minorities in Science and Engineering	- WiSci STEAM camp aims to address barriers faced by women in STEM. - NASA's participation in the camp helped inspire girls to explore Earth science.	- Growth in confidence in core components of the SERVIR curriculum - High interest from participants to choose a STEM career	- The WiSci STEAM camp helps support young women on their journey to STEM careers. - The camp had a positive impact on participants' confidence and interest in STEM careers.	- The WiSci STEAM camp supports young women on their journey to STEAM careers. - The NASA SERVIR team introduced hands-on Earth science applications to participants.

Sofie Areljung, Anna Günther-Hanssen	STEAM education: An opportunity to transcend gender and disciplinary norms in early childhood?	2021	Contemporary Issues in Early Childhood	- STEAM education gaining ground in many parts of the world - Opportunity to transcend gender and disciplinary norms	- The paper discusses the potential of STEAM education in early childhood. - It explores how STEAM education can transcend gender and disciplinary norms.	- STEAM education can transcend gender and disciplinary norms in early childhood. - It is gaining ground in higher stages of the educational system.	- STEAM education transcends gender and disciplinary norms - Provides opportunities for early childhood development
Ermira Idrizi, Sonja Filiposka, Vladimir Trajkovikj	Gender impact on STEM online learning- a correlational study of gender, personality traits and learning styles in relation to different online teaching modalities	2023	Multimedia Tools and Applications	- Study explores gender differences in online and traditional STEM learning. - Female students excel in traditional courses, while males slightly exceed in online courses.	- Female students outperform male students in traditional STEM courses. - Male students slightly outperform female students in online STEM courses.	- Female students in STEM can outperform male students in traditional courses. - Male students slightly outperform female students in online courses.	- Examines gender differences in online and traditional STEM learning - Identifies patterns of women's success and access to STEM online courses
Tessa Elizabeth Sadie Charlesworth, Mahzarin R. Banaji	Gender in Science, Technology, Engineering, and Mathematics: Issues, Causes, Solutions	2019	The Journal of Neuroscience	- Gender gaps in STEM are not due to innate ability differences. - Gender gaps in STEM arise from differences in perceived values and opportunities, as well as implicit and explicit biases.	- Gender disparities persist in STEM fields - Implicit bias is a key factor in gender gaps	Understanding and addressing the complex issues surrounding gender in STEM are important because of the possible benefits to STEM and society that will be realised only when full participation of all capable and qualified individuals is guaranteed.	- Gender disparities persist in STEM fields - Implicit bias is a significant factor contributing to these disparities

Roxanne Hughes, Jennifer Schellinger, Barbara Billington, Brenda Britsch, Alicia Santiago	A Summary of Effective Gender Equitable Teaching Practices in Informal STEM Education Spaces	2020	- Intersectional identity lens needed for studying girls in STEM - Gender equitable strategies to support girls' STEM identities	- Research on gender equitable practices in STEM education - Strategies to address gender inequity in middle school girls	The authors summarizes research on gender equitable practices for middle school girls in the last decade and addresses the disconnect between research and practice by presenting the findings in a way that educators can immediately act on.	- The paper presents six strategies for promoting gender equity in STEM education. - These strategies have shown positive influences on gender inequity in STEM.
Sorina Mihaela Bălan, Camelia Stanciu	Gender Stereotypes and STEAM Education	2021	- Girls are stereotyped as focused on appearance and emotive. - Efforts are being made to promote STEAM education.	- Paper discusses gender stereotypes in STEAM education and societal mentality. - Presents results of gender workshops to create gender-aware content.	In this paper, the results of sensitive gender workshops are presented to provide illustrations of stereotypes as an input for the creation of value-added content with gender awareness and continue sensitizing teachers about gender stereotypes in approach to learning that uses Science, Technology, Engineering, the Arts and Mathematics in education.	- Boys are more oriented towards STEAM education - Girls are not as interested in STEAM education

Maria Ampartzaki, Michail Kalogiannakis, Stamatios Papadakis & Vasiliki Giannakou	Perceptions About STEM and the Arts: Teachers', Parents' Professionals' and Artists' Understandings About the Role of Arts in STEM Education	2022	Lecture notes in educational technology	- Limited implementation of STEAM approach in education - Lack of support and resources for educators implementing STEAM	- Survey explored opinions of teachers, parents, artists, and STEM professionals - Results showed limited implementation of STEAM, lack of resources, and support	In this article , the authors conducted a survey to explore the opinions of teachers, student-teachers, parents, artists, and STEM professionals about STEAM, and the results showed that although teachers, students, and STEAM professionals knew about the STEAM approach, only a few had the experience of implementing it, the major difficulties educators faced in implementing STEAM relate to understanding the methodological principles of this approach and the lack of educational resources.	- Limited implementation of STEAM approach by educators and professionals. - Lack of support and resources for implementing STEAM in education.
	Women in Science	2019	UNESCO				

- Shashidhar Belbase, Raj Bhesh, Wandee Mainali, Hassan Kasemsukpipat, Munkhjargal Tairab, Adeeb Gochoo, Jarrah, Ra Mainali, Wandee Kasemsukpipa, Hassan Tairab	- At the dawn of science, technology, engineering, arts, and mathematics.	2021	International	International Journal of Mathematical Education in Science and Technology	- Examined integrated STEAM education through literature review and document analysis. - Identified prospects, priorities, processes, and problems in STEAM education. - Explored STEAM initiatives in South Korea, US, China, and Singapore. - Analyzed themes like movement, curriculum integration, pedagogy, and challenges.	- Identified prospects, priorities, processes, and problems of STEAM education. - Emphasized curriculum integration, pedagogical processes, and assessment in STEAM education. - Explored the implications of STEAM education on teacher development and training. - Discussed assessment practices in STEAM education, including project-based learning.	- Conclusions include prospects, priorities, processes, and problems of STEAM education.	- Analysis of prospects, priorities, processes, and problems in STEAM education. - Integration of arts into STEM disciplines to enhance learning. - Emphasis on project-based learning and problem-solving in STEAM education.

- Rachael Pearson	- Title: STEAM STEAM Education and the Whole Child: Examining Policy and Barriers	2021	USA	International Journal of the Whole Child	- Whole Child education nurtures students in critical skills for the future. - STEAM programs align with Whole Child approach, fostering inquiry and skills. - Research highlights barriers to implementing high-quality STEAM programs in schools.	- Discusses barriers to implementing high-quality Whole Child STEAM programs. - Highlights the importance of STEAM education for student development. - Emphasizes the need for further research on STEAM education. - Provides strategies for promoting high-quality STEAM education in schools.	- Emphasizes the need for high-quality STEAM programs in schools. - Discusses barriers and funding issues hindering the implementation of STEAM programs. - Advocates for flexible, interdisciplinary curriculum to nurture student creativity.	- Emphasizes high-quality STEAM programs for diverse student needs. - Discusses barriers and funding issues in implementing Whole Child STEAM programs. - Advocates for policy changes to enhance curriculum flexibility and interdisciplinary learning.
- David Aguilera **- Jairo Ortiz-Revilla**	- STEM vs. STEAM Education and Student Creativity: A Systematic Literature Review	2021	International	Education Sciences	- STEM and STEAM education impact student creativity positively. - Review of 14 educational interventions from 2010-2020. - No clear definitions of STEM and STEAM in some studies.	- STEM and STEAM education lack clear definitions in studies. - Positive effects on student creativity were observed in both approaches.	- STEAM education doesn't surpass STEM in promoting student creativity. - Lack of clear definitions in STEM and STEAM approaches.	- Review of STEM and STEAM interventions on student creativity. - Evaluation of creativity through process, environment, and person. - Data extraction on STEM and STEAM education impact on creativity. - Systematic literature review on STEM and STEAM interventions.

- Shih-Yun Lu **- Chih-Cheng Lo** **- Jia-Yu Syu**	Taiwan Project-based learning oriented STEAM: The case of micro-bit paper-cutting lamp.	2022	- International Journal of Technology and Design Education	- Focus on STEAM curriculum for elementary students integrating art. - Utilizes PBL with Chinese Paper-cutting and BBC micro:bit. - Positive impact on students' creative recognition and development. - Short-term course, suggests extending for long-term influence evaluation.	- Project-based learning incorporating STEAM positively influences students' creative recognition. - Short-term STEAM course benefits cognitive facet of creativity, not emotional. - Paper-cutting art project enhances divergent thinking and problem-solving skills.	- PBL-oriented STEAM curriculum positively influences students' creative recognition. - Short teaching period limits emotional facet of creativity in students.	- Conceptualization, methodology, data curation, writing, review, editing, supervision.

12 ANNEX 7. Keyword network image of STEM/STEAM and education research