*EDU REVIEW* | Vol. 13, No. 2, 2025 | ISSN 2695-9917
*The International Education and Learning Review / Revista Internacional de Educación y Aprendizaje*
https://doi.org/10.62701/revedu.v13.5470

# INTEGRATING MONTESSORI INTO STEAM IN EARLY CHILDHOOD EDUCATION: A Systematic Review

Integración de Montessori en STEAM en Educación Infantil: Una revisión sistemática

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**KEYWORDS**
*STEAM*
*Montessori*
*Early Childhood Education*
*Preschool*
*Preschool teacher*
*Systematic Review*
*PRISMA*

**ABSTRACT**
*This systematic literature review explores how STEAM education is implemented through the Montessori Method for children aged 3 to 6. Following PRISMA protocols, 11 studies (2006–2023) were analysed, focusing on pedagogy aspects, curriculum, activities, teacher training, and child development. The findings highlight strong connections between Montessori pedagogy and STEAM, revealing positive impacts on children's learning and teachers' professional growth. Future research should explore how Montessori-based training can enhance educational practices, especially regarding teachers' action research and the integration of STEAM in early education.*

**PALABRAS CLAVE**
*STEAM*
*Montessori*
*Educación infantil*
*Preescolar*
*Docente de preescolar*
*Revisión Sistemática*
*PRISMA*

**RESUMEN**
*Esta revisión sistemática de la literatura analiza la implementación de la educación STEAM mediante el Método Montessori en niños de 3 a 6 años. Siguiendo los protocolos PRISMA, se analizaron 11 estudios (2006–2023) centrados en aspectos pedagógicos, currículo, actividades, formación docente y desarrollo infantil. Los resultados muestran una fuerte conexión entre la pedagogía Montessori y STEAM, con impactos positivos en el aprendizaje infantil y el desarrollo profesional docente. Futuros estudios deberían explorar cómo la formación Montessori puede mejorar las prácticas educativas, especialmente en proyectos de investigación-acción y en la integración de STEAM en la educación infantil.*

Recibido: 08/ 07 / 2025
Aceptado: 21/ 10 / 2025

## 1. Introduction

From birth, children absorb information from their surroundings, forming the basis for multisensory learning (Love and Sikorski, 2000). This action of gathering information from the environment with all the senses and the goal of 'cultivating the child's own natural desire to learn' (Love and Sikorski, 2000, p.2), following the child's natural flow is the basis of the multisensory learning approach created by Dr. Maria Montessori (Stark, 1976). Her method implements a mixture of visual, auditory, tactile, and kinesthetic didactic materials (Shams and Seitz, 2008), organised and developed according to the child's developmental needs in a prepared environment.

Today's children inhabit a world rich in STEAM (Science, Technology, Engineering, Art, and Mathematics) elements. The Montessori's educational areas in the Casa dei Bambini environments are aligned to STEAM content, and the potential of merging the pedagogy and didactics of the Montessori Method with STEAM education content is unimaginable, considering the spread position of a group of Montessori teachers against the integration of technology-based material in the environment as a potential threat to Montessori integrity (Jones, 2017; Love and Sikorski, 2000). However, concerns persist about integrating technology into traditional Montessori settings due to philosophical purity and educators' lack of confidence in STEM subjects (Elkin and Bers, 2014; Love and Sikorski, 2000).

Debates also revolve around the optimal age for introducing STEAM materials, with research indicating early exposure's impact on future learning trajectories, particularly for girls (Elkin and Bers, 2014; Bian et al., 2017). The gender gap in STEAM fields requires attention, especially during early childhood education where social skills develop (Luttenberger et al., 2019). Addressing the gender digital gap necessities equipping teachers with technology skills across all educational levels, ensuring preparedness for a digitally driven society (Juárez et al., 2012; Migliorino and Jeffrey, 2004; Redecker, 2017).

## 2. Theoretical framework

Understanding the historical evolution of educational paradigms is crucial for contextualizing the Montessori Method within broader educational discourse. Since the inception of cognitive science, educational systems have predominantly focused on knowledge transfer and its societal implications (Mintz, 2016). With the advent of the Industrial Revolution, public education underwent a transformation, emphasizing efficiency and standardization in learning processes (Ramakrisnan et al., 2012). In response to the mechanistic nature of traditional education, humanistic approaches emerged with scholars such as Rousseau, Pestalozzi, Dewey, and Piaget advocating for child-centred pedagogies (Dinda and Nugraha, 2023). The Montessori Method, a product of this paradigm shift, posits the child as the primary agent in the learning process, rejecting the notion of passive knowledge acquisition (Montessori, 1949).

Simultaneously, the scientific revolution of the late eighteenth and early twentieth centuries catalysed a division between arts and sciences in Western education (Snow, 1961). This dichotomy deepened with the institutionalization of specialized disciplines in universities, culminating in the formal recognition of STEM (Science, Technology, Engineering, and Mathematics) education in the early twenty-fist century (Gonzalez and Kuenzi, 2012). However, scholars recognize the need to integrate humanistic disciplines into STEM education to foster holistic learning experiences (Zhu and Goyal, 2019).

### *2.1. The Montessori Method*

The Montessori Method emphasizes the intrinsic significance of a child's psyche and spirit in the learning process, asserting that individuals are born with an inherent wisdom, shaping their journey of development (Lillard, 2019). Dr. Maria Montessori's pioneering work delves into the pivotal stages of early childhood, underscoring the transition from unconscious absorption to conscious interaction with reality. Central to this process are the Sensitive Periods, characterized by transient phases of heightened sensitivity towards specific environmental stimuli and ability development (Standing, 1957). These periods, universal and observable across cultures, play a fundamental role in guiding the natural learning trajectory of every child (Montessori, 1949; Montessori, 1956).

During the formative years from birth to six, a child undergoes profound physical and psychological transformations. The concept of Sensitive Periods explains this developmental journey, wherein each period signifies a unique focus of sensitivity towards acquiring a particular skills or characteristic (Montessori, 1956). These periods, marked by their transitory nature and overlapping nature, are essential in shaping the individual's holistic development (Lillard and McHugh, 2019; Standing, 1957). Understanding and accommodating Sensitive Periods are pivotal in educational practices. Educators, serving as guides rather than instructors, must respect and nurture each child's innate developmental blueprint by providing an environment that contribute to bodily and psychic growth, educators facilitate the child's journey towards self-realization and societal integration (Montessori, 1946; Montessori, 1987).

The Montessori Method emphasizes systematic observation as a cornerstone of educational practice, enabling educators to track children's developmental progress and tailor learning experiences accordingly (Montessori, 1987). Observations inform the design of prepared environments, structured around distinct areas and materials meticulously arranged to facilitate independent learning (Montessori, 1948).

As a product of the observation process, the prepared environment has to be arranged by areas guaranteeing that the material is correctly arranged (sequence and completion) and providing quality and authenticity. The material has to be pristine, adapted to the mechanics and cognitive development of the child, and as real as possible, avoiding using materials that replace the original object. The presentation of the material follows the three-period lesson structure, fostering language acquisition and skill development with minimal verbal intervention (Standing, 1957). This structured approach ensures clarity and efficacy in learning experiences, empowering children to engage with materials autonomously.

### *2.2. STEAM Education*

The evolution from STEM to STEAM education signifies an important paradigm shift, reflecting a broader understanding of the educational landscape. Rooted from the foundational principles of STEM (Science, Technology, Engineering, and Mathematics), STEAM integrates the arts into its framework, recognizing the importance of creativity and aesthetics in education (Gonzalez and Kuenzi, 2012).

The trajectory of STEAM education traces back to the formalization of STEM education in the early twenty-first century, with the National Art Education Association (NAEA, 2021) advocating for the integration of arts and design principles into STEM instruction (Liao, 2019). This evolution is a response to the changing demands of the modern workforce, emphasizing the cultivation of innovative thinking and interdisciplinary collaboration (Marmon, 2019).

In STEAM education, teachers adopt the role of facilitators, guiding students through exploratory learning experiences (Karplus, 1976). This student-centred approach emphasizes discovery and inquiry, fostering not only content mastery but also critical thinking and problem-solving skills (Stroud and Baines, 2019). The implementation of STEAM education requires collaborative curriculum planning, recognizing the interconnectedness of subjects and the need for transdisciplinary approaches (Yakman, 2006). Teachers focus on central concepts and practices, fostering empathy and creativity among students (Bush and Cook, 2019).

Considering collective improvement, the Problem-Solving Cycle (PSC) serves as a model for professional development, facilitating collaboration among educators and addressing challenges in STEAM education implementation (Borko et al., 2015). Through structured workshops and collaborative problem-solving sessions, teachers enhance their pedagogical practices and curriculum design.

### *2.3. Science and the Gender Gap*

The research by Gibert and Valls (2022) sheds light on the under-representation of women in STEM fields, particularly in ICT courses where males outnumber females. Negative comments, lack of female role models, gender stereotypes, and girls' self-perception in STEM subjects contribute to this disparity. Moreover, studies emphasize the intersectionality of gender with other suppressed groups, highlighting the struggles faced by women from diverse backgrounds in STEM (Crenshaw, 1989; Grabe, 2020).

Addressing intersectionality is crucial in understanding and addressing the lack of women's representation in STEM fields. Incorporating intersectionality adds depth to research in education, particularly concerning its applications in addressing systemic inequalities (Ireland et al., 2018).

Toussaint's work (2022) underscores the under-representation of black women in mathematics and other STEM areas despite making strides in the field.

The process of encouraging young girls and minorities to pursue STEM begins at a young age. AI professionals and scientists who serve as role models can inspire the next generation of girls. Building and maintaining networks of support are essential in fostering an environment conducive to encouraging girls to pursue science studies (Gibert and Valls, 2022).

### *2.4. Research on STEAM and Montessori in Early Childhood Education*

In recent years, there has been a growing interest in integrating STEAM content into early childhood education, particularly within the context of Montessori environments. This section aims to provide an in-depth analysis of existing research in this area, highlighting key findings, methodologies, and implications for practice.

Several studies have explored the implementation of STEM content in preschool settings without necessarily adhering to the Montessori pedagogical framework (Bers, 2008; Clements, 1998; Cubelic and Larwin, 2014; Fessakis and Mavroudi, 2013; Palmér, 2017; Zuckerman et al., 2005). These studies show positive examples of how STEM subjects can be introduced and integrated into early childhood education, displaying benefits such as the development of mathematical concepts, problem-solving skills, and social skills.

While numerous publications explore the integration of technology in Montessori classrooms, the majority focus on secondary and primary school, with limited research targeting preschoolers (Altamirano et al., 2020; Castiglione, 2016; Fehr, 2020; Jones, 2016; Lorenzo-Vila, 2021; MacDonald, 2016; Prozesky and Cıfuentes, 2014). This highlights a gap in research concerning technology integration within the Montessori approach at the preschool level.

Studies have also investigated educators' abilities, beliefs, and training related to STEM activities, emphasizing the importance of teacher preparation and pedagogical approaches (Bermúdez et al., 2023; Clarke-Midura et al., 2023; Jones, 2017; MacDonald, 2016; Prozesky and Cıfuentes, 2014; Relkin and Bers, 2019; Sackett, 2016; Sullivan et al., 2017;).

Numerous studies have shown positive interventions in preschool settings, including those focused on digital technologies, mathematics, and science. For example, Zuckerman et al. (2005) developed an effective approach for integrating programming and engineering concepts into Montessori early education. Fessakis et al. (2013) found that children enjoyed engaging in learning activities while developing mathematical and problem-solving skills. Cubelic and Larwin (2014) examined the impact of iPad applications on emergent literacy skills acquisition.

Some studies have specifically focused on understanding how low-income families and minority groups engage in STEM learning within preschool contexts (Bermúdez et al., 2023; García-Valcárcel-Muñoz-Repiso and Caballero-González, 2019). These studies highlight the importance of culturally responsive approaches to STEM education.

Two master's theses, by Fehr (2020) and by Jones (2016), offer positive examples of implementations by focusing on the basic elements necessary for integrating STEM/STEAM content within Montessori environments. These studies point out the importance of considering the Montessori curriculum and principles while introducing technology and engineering activities.

While there is growing research interest in integrating STEM/STEAM content into early childhood education, more studies are needed to explore pedagogical approaches within the Montessori framework and to address the integration of arts into STEM education. Additionally, research should continue to focus on culturally responsive practices and the needs of diverse learner populations in preschool settings.

The following literary systematic review focused on the analysis of publications based on educational practices of STEAM content implementation framed in the Montessori Method in preschool period implementation. To organize and dive into each study, a series of research questions are set, as well as a list of aims that will guide the research.

- RQ1: What are the Montessori aspects that are considered to work with the STEAM content in early childhood education (3-6)?
- RQ2: What is the STEAM content selected and how is it implemented according to the pedagogical and didactic approach from the Montessori Method?

- RQ3: What theoretical and experimental considerations inform the development of the study or the project?
- RQ4: What are the characteristics and difficulties related to a STEAM training, based on the Montessori approach, in the early childhood education teachers' training?
- RQ5: Which are the outcomes and observations obtained after the implementation?
- RQ6: How is the STEAM content in the Montessori Method working on personal development, social skills and strategies to tackle the gender gap from the early years?

Overall, examine the existing literature about researches centred on educational practices and experiences while implementing STEAM content guided by Montessori Method principles in early childhood education (3-6 years old), will contribute to a better comprehension of the intersections between the STEAM content and the Montessori Method, pointing to the potential synergies, challenges, gender considerations, current theories and pedagogical approaches adopted for the preschool implementation.

## 3. Method

This study adopted a systematic literature review approach, adhering to defined stages to ensure methodological rigour and transparency (García-Peñalvo, 2022), following the three phases outlined by Kitchenham (2004). The study adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Protocols (PRISMA-P) checklist (Page et al., 2021), adapted to studies of social science-based revision in education. The final table contains 13 items that offer additional guidance. Data collection followed a structured spreadsheet format, including key information such as review name, publication details, and additional notes.

For this systematic review, journal articles were sourced from four databases: Web of Science, Scopus, ERIC, and Dialnet. The search was limited to publications in English and Spanish, and focused on an international scope. The time frame selected spans from 2006—the year STEM was formally introduced—to 2023. The database search was conducted in October 2023, targeting titles, abstracts, and keywords. To ensure comprehensive coverage, a list of keywords was compiled for use in Boolean searches across the different databases. The initial search was performed in Scopus, yielding 106 articles using the following Boolean string:

"Montessori" AND "STEAM" OR "STEM" AND "preschool" OR "early childhood education" AND PUBYEAR > 2006 AND PUBYEAR < 2024 AND (LIMIT-TO(DOCTYPE, "ar")) AND (LIMIT-TO(LANGUAGE, "English") OR LIMIT-TO(LANGUAGE, "Spanish"))

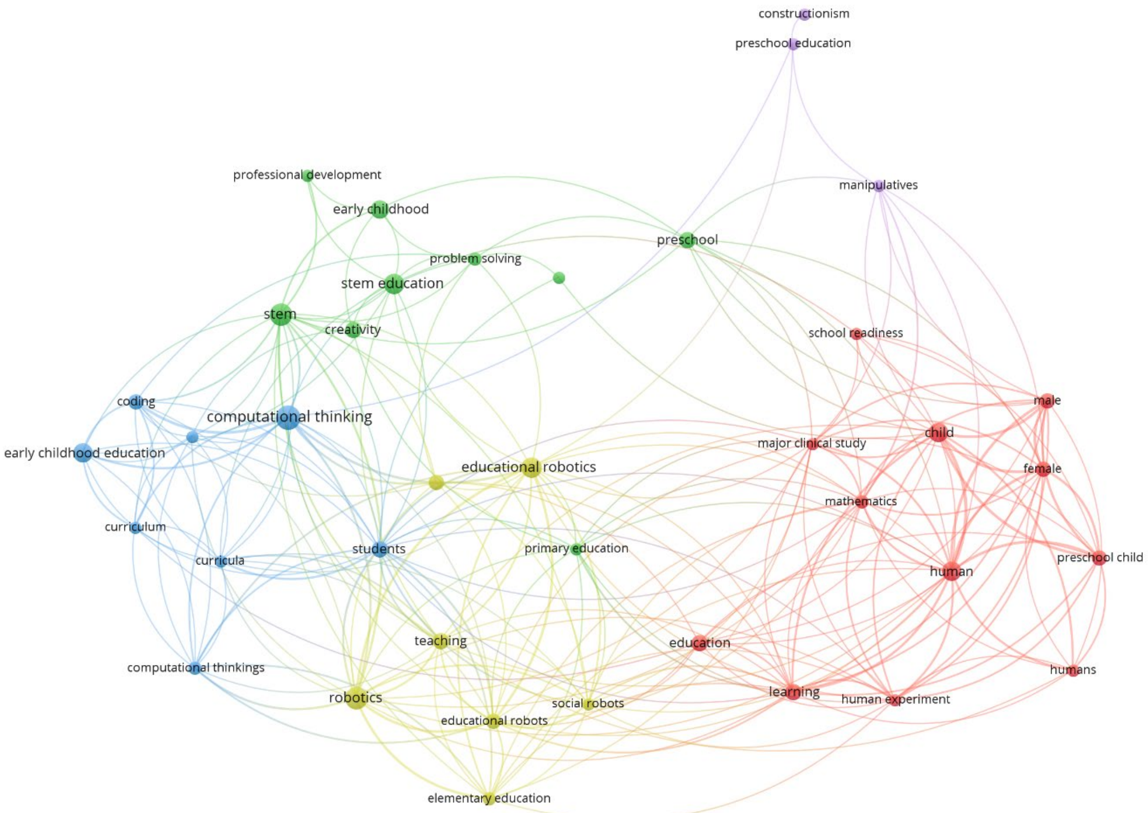
Subsequently, an attempt was made to generate a bibliometric network using VOSviewer based on the bibliographic data retrieved from all databases. The data were normalized and enriched with missing elements such as keywords, abstracts, DOIs, and URLs, following guidelines from Singh and Singh (2020). For data management, Citavi was used to generate a consolidated RIS file. This file was then converted into a JSON format and further processed in Visual Studio Code for visualization purposes.

An additional effort was made using Postman to retrieve bibliographic metadata via API queries; however, it was found that the missing data from the original sources remained unavailable through this method. The alternative of using VOSviewer to extract data directly from article DOIs was not pursued, as many records lacked functional or complete DOI information. To meet VOSviewer's requirements, a thesaurus file was created to harmonize terms and remove stop-words, following the recommendations of van Eck and Waltman (2023). Despite updates, discrepancies appeared between the network map and the thesaurus, with some abstracts and keywords not included in the visualization. These issues indicated that VOSviewer's performance may be limited by the structure of bibliographic files, particularly those from Dialnet, which sometimes resulted in incomplete visualizations.

Given these limitations, the final decision was to base the bibliometric analysis solely on the Scopus dataset from the initial search, as its files proved fully compatible with VOSviewer. This allowed for a coherent mapping of co-occurrence terms extracted from article titles, abstracts, and keywords.

In the resulting visualization, terms are grouped and colour-coded into five distinct clusters, with each link representing the strength of co-occurrence. The network layout displays proximity relationships between terms, while the size of each node reflects the frequency of its appearance—the larger the circle, the more frequently the term is referenced (Figure 1).

**Figure 1.** VOSviewer network visualization map of co-occurrent terms for the search strategy




Note. Visualization created using VOSviewer Version 1.6.19.

The analysis led to an initial observation, neither the term STEAM nor Montessori appears within the network visualization. This absence may be attributed to the relatively recent emergence of the term STEAM (introduced in 2012), as well as the continued dominance of STEM (coined in 2006). Regarding the omission of Montessori and other pedagogy-related terms, this likely reflects the limited volume of research integrating STEM content within a Montessori educational framework.

The most prominent keywords directly linked to STEM include: computational thinking, robotics, educational robotics, STEM education, early childhood education, preschool, teaching, problem solving, professional development, young children, social robots, curricula, and coding.

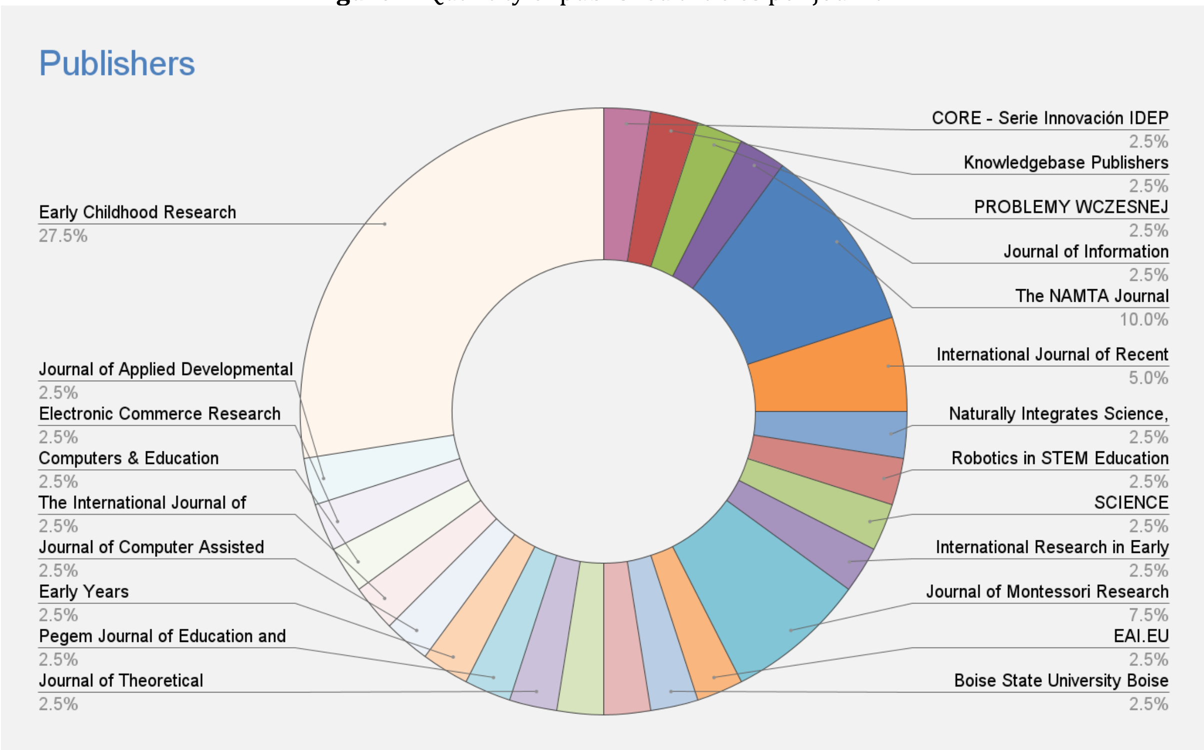
Among the network clusters, the one centred around the term human appears most relevant to the Montessori pedagogical approach. This cluster features terms that reflect hands-on, child-centred learning, such as: students, child, education, learning, teaching, school readiness, mathematics, preschool child, primary education, and elementary education. Additionally, there are overlaps with STEAM-related terminology including educational robotics, social robots, and robots.

After numerous attempts to use the terms identified in the bibliometric analysis—which yielded either duplicate entries or no relevant results—it was determined that only the terms STEM and Montessori produced a sufficient number of publications to support the continuation of the research process.

### *3.1. Search Strategy*

The search strategy involved querying multiple databases, including Web of Science, Scopus, ERIC, and Dialnet. Due to the low number of retrieved articles and as a result of 35% the publications were from ScienceDirect database, a second search was done in it (Figure 2).

**Figure 2.** Quantity of published articles per journal




Note. Visualization created using Excel based on the search data results Note. Own work, 2024.

The searches were restricted to publications in English and Spanish languages and the period covered was from STEAM proposal in 2006 to 2023 (Yakman, 2006). A third and final search via other method was carried out, having a database created by referred articles (Table 1).

**Table 1.** Overview of the results of each database search

| Database | Language | Boolean search string | Date of search | Obtained records |
|---|---|---|---|---|
| Web of Science | English | ((((TS=(Montessori)) AND TS= (STEAM OR STEM)) AND DT=(Article)) AND PY=(2006-2023)) | 12-10-2023 | 6 |
| Scopus | English | TITLE-ABS-KEY (montessori AND stem) AND (LIMIT-TO (DOCTYPE , 'ar')) | 12-10-2023 | 4 |
| ERIC | English | AB 'Montessori' AND AB 'STEM' | 12-10-2023 | 1 |
| Dialnet | English and Spanish | 'Montessori' AND 'STEAM' OR 'STEM' | 12-10-2023 | Spanish 140<br>English 26 |
| ScienceDirect | English | Montessori AND STEAM OR STEM | 23-11-2023 | 137 |
| Other methods | English and Spanish | - | 06-12-2023 | Spanish 4<br>English 63 |

Note. Own work, 2024.

### *3.2. Selection Criteria*

The selection criteria protocol was established as a guiding framework for screening the publications retrieved during the search process. It was structured into inclusion and exclusion criteria, each consisting of specific, predefined, non-redundant, and unambiguous elements (Higgins et al., 2022).

*Inclusion criteria*

IC1: The publication expresses studies about STEAM contents in the Montessori Method approach in early childhood education (3-6).

IC2: The publication reports the implementation of a project based on the Montessori Method implementing STEAM content.

IC3: The publication is in English or Spanish.

IC4: The publication documents the implementation of the Montessori didactic and pedagogy in presenting an activity or material based on STEAM content.

IC5: The publication provides details about a study, quantitative and qualitative, descriptive, correlational, experimental methods, and learning and teaching experiences.

IC6: Peer-reviewed articles are considered.

IC7: The publication presents a study or project that focuses on the early childhood educators' formation in the development of STEAM content with the Montessori Method.

*Exclusion criteria*

EC1: The publication is not early childhood education or early childhood teachers training related.

EC2: The publication is not a primary study, a research synthesis, or an implemented project in an educative context.

EC3: The publication is not an article.

EC4: The full text is not available.

EC5: The publication does not dive into the Montessori Method in connection with STEAM or STEM contents.

EC6: The publication is based on a different area of study.

EC7: The publication date is not from 2006 till 2023 included.

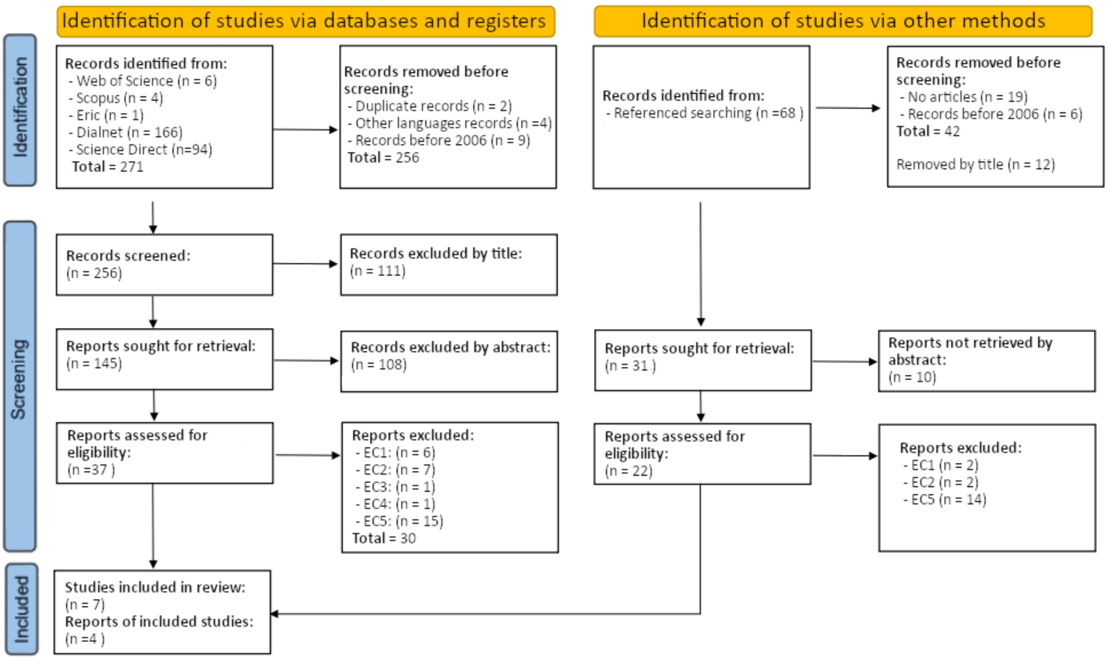
### *3.3. Selection Process*

To ensure transparency and replication, the PRISMA 2020 flow diagram is implemented. As the review consisted of two different vias (Figure 3), the diagram selected is the PRISMA 2020 flow diagram for new systematic reviews, including searches of databases, registers, and other sources (Page et al., 2021).

To simplify the selection process in one PRISMA flow diagram, the identification of studies via database and registers includes the total of found publications of 271, from which 256 were filtered to the following step. In the screening, 111 were removed due to title, and 108 due to abstract. Lastly, there were 37, from which 30 were excluded by different exclusion criteria, the main ones were the different context and area of study. The final number of articles to be analysed was 7.

The identification of studies via other methods provided a list of 68 publications, from which 19 were not articles, 6 were not from 2006 to 2023, and 12 were removed by title. A total of 31 were retrieved from which 10 were filtered by abstract. Of the 22 eligible articles, 18 were excluded, mostly due to not diving into the Montessori Method in connection with STEAM or STEM contents. Combining both processes, the final number of included articles was 11.

**Figure 3.** PRISMA 2020 flow diagram




Note. Visualization based on the PRISMA 2020 flow diagram template for systematic review from T*he PRISMA 2020 statement: an updated guideline for reporting systematic reviews* (Page et al., 2021).

## 4. Results

Analysing the sample of 11 articles (Table 2), Turkey is the country with higher number of research on the subject, focusing on the teachers´ training and the process of improving STEM content taught in early childhood education. There are three published studies from the researchers Çakır and Yalçin, which are based on Montessori and STEM with their focus on teachers' perspective of STEM activities and Montessori pedagogy (2020; 2021; 2022).

**Table 2**. List of the final selected articles

| Author | Title | Year | Country |
|---|---|---|---|
| Çakır and Yalçin | Pre-School teacher candidates' views on STEM applications based on Montessori approach. | 2020 | Turkey |
| Çakır and Yalçin | The investigation of the effect of Montessori approach-based STEM activities on the problem-solving skills of pre-service preschool teachers. | 2021 | Turkey |
| Çakır and Yalçin | The effect of Montessori approach-based STEM education on pre-service school teachers' self-directed learning. | 2022 | Turkey |
| Namukasa and Aryee | Pedagogical knowledge for teaching mathematics in montessori schools. | 2021 | Canada |
| Fernández-Olivera et al. | Estudio de una propuesta lúdica para la educación científica y matemática globalizada en infantil. | 2016 | Spain |
| López and Sorribas | Transformación metodológica de la Escola Montessori de Rubí desde una perspectiva STEAM y de género. | 2020 | Spain |
| Orosco and Serqué | Materiales sensoriales Montessori en el desarrollo de la noción de seriación en infantes de cinco años. | 2018 | Peru |
| Owen and Davies | Maintaining an empowered school community: Introducing digital technologies by building digital literacies at Beehive Montessori School. | 2020 | Australia |
| Şimşek and Tuğluk | Making learning visible in the 21st Century: Examining the use of digital assessment tools in Montessori education. | 2021 | Spain/ Turkey |
| Silvis et al. | Children caring for robots: Expanding computational thinking frameworks to include a technological ethic of care. | 2022 | US |
| Vatavu et al. | Touch interaction for children aged 3 to 6 years: Experimental findings and relationship to motor skills. | 2015 | Romania |

Note. Own work, 2024.

### *4.1. Qualitative Results*

In this section, the 11 articles are analysed based on systematic research questions to obtain relevant data for analysis.

*RQ1: What are the Montessori aspects considered to work with STEAM content in early childhood education (3-6)?*

In the research Çakır and Yalçin (2020; 2021; 2022) the authors focus on the classic aspects of the Montessori Method that can be traced in the STEM education. In the subject related to the development of the child as a person and in a social context, the Montessori approach can be characterized as a way of life, a way of being, and with a focus on the future, which is rooted in personal exploration and goal achievement in a manner that is meaningful to every child. The learning process is a natural process in which children develop according to their pace and following their inner voice. Moreover, the studies highlight aspects such as child development, self-confidence, initiative, problem-solving, creativity, concentration, and collaboration. These studies emphasize aligning Montessori principles with STEM education aims and preparing materials suitable for children's developmental stages.

These classic aspects of the Montessori Method are part of the framework of the school in which the research and project are implemented in the study of Owen and Davies (2020). Complementing these elements, the authors point out to the importance of making updates according to the context and the development of the digital technologies while being adapted to the school guidelines provided by the recognized Montessori organizations, such as the American Montessori Society and the Association Montessori International.

The study of Namukasa and Aryee (2021) emphasizes a constructivist approach within a multi-aged environment, where learners develop independence and self-reliance through interactions with concrete materials. This study highlights the importance of choice in learning and the role of the teacher in creating a conducive environment.

The project and research of López and Sorribas (2020) integrates student-centered pedagogy with a constructivist approach, focusing on individualized learning experiences and the holistic development of learners, while Fernández-Oliveras et al. (2016) emphasizes experimentation as a basis for learning within a Montessori framework.

Considering the work with tangibles and material presentation from the Montessori pedagogy, Orosco and Serquén (2018) highlight the use of Montessori sensorial materials to enhance cognitive development and problem-solving skills in mathematics, as well as Owen and Davies (2020) focusing on the integration of real-world experiences and hands-on activities, adapting to developments in digital technologies while maintaining alignment with Montessori principles.

From the observation aspects of the Montessori method, Şimşek and Tuğluk (2021) emphasize the importance of observing children's sensitive periods and providing proper stimuli, while focusing on individualized learning plans and daily observation routines.

In the research of Silvis et al. (2022), the authors recognize the Montessori value of caring for the environment as an element to develop with children while incorporating the work with robots, while in the study of Vatavu et al. (2015) focuses on providing relevant activities connected to children's interests and implementing gamification features to motivate learning, in line with Montessori principles.

*RQ2: What is the STEAM content selected and how is it implemented according to the pedagogical and didactic approach from the Montessori Method?*

In the research by Çakır and Yalçin (2020; 2021; 2022), STEM activities are based on Montessori principles and utilize everyday materials such as sponges, plastic bottles, straws, Legos, and starch. Pre-service teachers undergo training on STEM education and the Montessori approach, then create and present activities focusing on problem-solving skills. The goal is to motivate and develop problem-solving skills among pre-service teachers as well as to introduce science in their professional lives.

The aim of the study of Namukasa and Aryee (2021) is to understand the use of Montessori-specific lesson plans and materials for teaching mathematics. Teachers follow a scripted presentation method during training and adapt it based on their in-service experiences and peers' collaboration process.

The research of Fernández-Oliveras et al. (2016) integrates mathematical and scientific knowledge through different activities based on experimentation with elements used for cooking in the kitchen, aiming to prepare salt dough. During the implementation of the game called Coci-ciencia, there are steps followed to induce logical-mathematical thinking in the groups. The educators guide the children to theorize about the materials used in each activity. The children select the seriation of materials and tools to work with, and finally there is an instance to think about the results, remarking the influence of the order in the results.

The adaptation of the curriculum in the publication of López and Sorribas (2020), dives in STEAM content and the implementation of workshops focusing on robotics, puzzles, creative writing, music, and more. Among the workshops provided are robotics, enigmas, escape rooms, Lego, experiments, artistic techniques, creative writing, sports activities, music, and instruments. This approach emphasizes the development of finding solutions to a challenge while creating a final product.

The publication of Orosco and Serquén (2018) focus on the Montessori sensorial materials to improve numeral seriation in mathematics, emphasizing hands-on learning and cognitive development and analyse how the Montessori material could affect the improvement of it. The sensorial Montessori material, such as the pink tower or the red rods, has the peculiarity that they promote the work of a specific isolated quality (ex., the pink tower works the seriation from big to small). Whereas Vatavu et al. (2015) observe children's interaction with touch-screen devices (smartphone and tablet), incorporating gamification to keep children motivated and relevant to their interests. The approach focuses on hands-on exploration and adaptation to modern technology.

The study and project of Owen and Davies (2020) implement digital technologies in a Montessori environment, using a critical friend method for professional development. The approach focuses on integrating technology while maintaining alignment with Montessori philosophy and the active participation of the educators along the implementation.

In the publication of Şimşek and Tuğluk (2021), the authors analyse the use of digital assessment tools (SAP Fiori and Transparent Classroom) in Montessori education, emphasizing the importance of educators trained in Montessori principles and the incorporation of proper assessment tools in their daily work.

The article of Silvis et al. (2022) focuses on robotics and children's interaction with the robot Cubetto, using thematic mats to facilitate learning and interactions. The approach emphasizes hands-on learning and problem-solving, as well as the development of participants' communication skills.

*RQ3: What theoretical and experimental considerations inform the development of the study or the project?*

Many of the studies emphasize the importance of introducing science education in the early years of children's education. This is based on the premise that early exposure to STEM subjects can have a lasting impact on children's learning and development (Çakır and Yalçın, 2020; Fernández-Oliveras et al., 2016). The publications often highlight the effectiveness of the Montessori approach in promoting STEM education during the preschool years. The Montessori method is valued for its child-centred, hands-on approach, which aligns well with the principles of STEM education (Çakır and Yalçın, 2020; Namukasa and Aryee, 2021).

The need for teacher training in STEAM and Montessori is identified as an essential step for educators to effectively implement STEM activities in early childhood settings (Çakır and Yalçın, 2020; Şimşek and Tuğluk, 2021). Facing this scenario, various challenges in implementing STEM education in early childhood are remarked, such as a lack of proper pedagogical materials and limited teacher training. However, they also propose solutions, such as developing new teaching methods, providing specialized training for educators, and adapting existing curricula to include STEM content (Çakır and Yalçın, 2020; López and Sorribas, 2020).

Some studies focus on integrating digital technology into early childhood education while keeping the principles of the Montessori approach. This involves careful consideration of how technology can enhance learning without replacing traditional hands-on experiences (Owen and Davies, 2020; Vatavu et al., 2015). There is also an emphasis on assessing children's learning and development in STEM subjects. This involves developing proper assessment tools and techniques that are aligned with the principles of early childhood education (Silvis et al., 2022; Şimşek and Tuğluk, 2021).

*RQ4: What are the characteristics and difficulties related to a STEAM training, based on the Montessori approach, in the early childhood education teachers' training?*

Studies such as those by Çakır and Yalçin (2020; 2021a) highlight the challenges in integrating STEM education and the Montessori method into early childhood education. Despite a growing number of studies in the field, there is still a shortage of teachers with the necessary knowledge and training in both areas (Çakır and Yalçin, 2020). Similarly, the training of educators in the Montessori approach before entering service is considered essential, emphasizing the need for exposure to materials and activities during their education (Çakır and Yalçın, 2021). In addition, the authors remark Aslan-Tutak et al. 's work (2017) pointing out that STEM education is interdisciplinary, teacher candidates may lack knowledge beyond their own expertise, needing additional training in diverse subject areas.

Furthermore, Çakır and Yalçın (2022) stress the importance of self-directed learning skills in children and the need for teachers to provide this knowledge. However, during their literature review, they found that the ability of self-directed learning was low, indicating a need for teacher training to address this fundamental skill.

Emphasizing the importance of teacher training courses, Fernández-Oliveras et al. (2016) indicate the need to offer engaging resources and practical experiences tailored to specific contexts and age groups. Practical training phases and direct observation methods are highlighted as effective components of teacher development programs. Moreover, López and Sorribas (2020) stress the importance of continuous teacher training and development to address changes in educational contexts. This includes proactive measures such as annual budget allocation for training, collaboration with experts, and fostering a reflective community among teachers.

Considering the implementation of reform initiatives, such as changes in mathematics teaching or curriculum, presents challenges for teachers who must adapt to new methods and practices. Preparation and support are essential for teachers to effectively implement these changes (Namukasa and Aryee, 2021).

Pointing out the incorporation of digital technologies in the classrooms, Owen and Davies (2020) remark that is a decision of the educator, while teacher training should equip educators with the necessary skills to integrate technology intelligently without compromising the Montessori approach. As well, the study of Şimşek and Tuğluk (2021) highlights the importance of including digital assessment tools in Montessori teacher training to enhance communication and cooperation among educators. However, teacher beliefs about these tools, including perceptions of difficulty and time consumption, may pose challenges to their adoption.

The publication of Silvis et al. (2022) highlights the importance of integrating care and maintenance principles into teacher training for computational expression glossary, while incorporating principles from Montessori education and the Positive Technology Development (PTD) framework to ensure responsible use of technology in early learning settings.

*RQ5: Which are the outcomes and observations obtained after the implementation?*

The implementation of STEM activities with pre-service teachers yielded positive results, indicating insights into effective implementation methods and implications for preschool education (Çakır and Yalçin, 2020). Pre-service teachers highlighted the adaptability of materials to children's psychomotor skills, safety measures, and material selection based on objectives and subjects. Additionally, they emphasized the importance of providing scientific knowledge to children in a purposeful manner, supporting early development.

STEM activities based on the Montessori approach positively influenced problem-solving skills among pre-service teachers (Çakır and Yalçın, 2021a). Quality analysis revealed improvements in problem-solving skills, determination, motivation for learning, and self-confidence. Group interactions during activities also enhanced social and communication skills among pre-service teachers.

Integration of STEM education within the Montessori framework led to significant improvements in self-directed learning skills among pre-service teachers (Çakır and Yalçın, 2022). The study demonstrated enhancements in self-confidence, perseverance, self-planned learning, and self-assessment, indicating the effectiveness of the approach in fostering personal, social, and professional development.

Montessori teacher knowledge in mathematics aligns with the foundations of mathematics educational reform, particularly in promoting problem-solving and enhancing affective outcomes (Namukasa and Aryee, 2021). However, further exploration of teacher knowledge sub-categories is necessary to inform the implementation of reform in instruction and teacher education.

Implementation of hands-on learning approaches, supported by teacher testimonials, led to positive outcomes in acquiring knowledge and expertise in creating ludic materials for science and mathematics education (Fernández-Oliveras et al., 2016). Observation methods and educational research records contributed significantly to pre-service teacher education.

Engaging teachers in critical reflection on daily practices led to positive changes aligned with school pedagogy (Owen and Davies, 2020). In addition, the use of critical friend strategies and existing pedagogical practices facilitated the integration of digital literacies consistent with Montessori pedagogy.

While digital assessment tools had both positive and negative impacts on teachers' work, collaboration among teachers was indirectly developed, contributing to the development of twenty-first-century skills (Şimşek and Tuğluk, 2021). The findings remark that teachers' attitudes towards digital tools influenced their perceptions of workload and usability.

Incorporating care and maintenance principles into computational expression glossary training highlighted the importance of socio-ecological considerations in early childhood education (Silvis et al., 2022). Young children demonstrated an understanding of their responsibility towards the environment through tangible programming activities.

Research on touch-screen interaction patterns in young children provided insights into their cognitive and motor development (Vatavu et al., 2015). Observations suggest that children improve their interaction skills with touch screens as they grow older, emphasizing the need for consideration in interface designs.

*RQ6: How is the STEAM content in the Montessori Method working on personal development, social skills and strategies to tackle the gender gap from the early years?*

Focusing on the development of personal and social skills, the Montessori approach aims to develop various personal and social skills in children, including self-confidence, initiative, independence, problem-solving, critical analysis, creativity, concentration, organization, sense of responsibility, cooperation, and respect (Oğuz and Köksal-Akyol, 2006, as cited in Çakır and Yalçin, 2020; Çakır and Yalçın, 2021a; Özdağ, 2014, as cited in Çakır and Yalçin, 2020; Çakır and Yalçın, 2021a). Moreover, the research by Çakır and Yalçin (2020) highlights the positive impact of the Montessori approach on children's social skills and behaviour, fostering elements of justice, equality, positive emotions, and playfulness with peers. Similarly, Namukasa and Aryee (2021) emphasize the importance of social readiness influenced by Montessori teaching methods.

The use of Montessori materials promotes self-determination in students, allowing them to learn at their own pace with guidance from educators, which aligns with basic human needs according to the self-determination theory (Lillard, 2019, as cited in Namukasa and Aryee, 2021). Additionally, materials aligned with the Montessori philosophy help children develop collaborative work skills, productivity, questioning ability, analysis, and respect for themselves and others (Çakır and Yalçın, 2022).

Moreover, the Montessori activities focus on promoting joy in skill development, providing children with enjoyable learning experiences that facilitate their progress and development (Fernández-Oliveras et al., 2016; Orosco and Serquén, 2018).

Addressing the gender gap, López and Sorribas (2020) emphasize the importance of promoting STEAM education from a gender perspective in early childhood. The school focuses on motivating girls from a young age and providing activities that spark their interest in scientific and technological fields, aiming to address the gender gap in these areas. Moreover, activities at the school are designed to promote gender equality, with workshops and activities dedicated to highlighting the achievements of notable women in various fields. While Silvis et al. (2022) adopt a feminist perspective in their study on children's interactions with computational tools. They advocate for a critical examination of canonical approaches to computing that may perpetuate gender differences and emphasize the importance of ethical interactions with technology. In the case of Vatavu et al. (2015) research suggests that boys and girls aged 3 to 6 develop touch-screen interaction skills at a similar pace, providing valuable insights for interface designers in addressing gender-related differences in digital technology abilities.

## 5. Discussion

According to the Montessori aspects that are selected in the 11 researches, there are some studies that point to specific Montessori elements to justify the pedagogical process or a characteristic of the and the material (Fernández-Oliveras et al., 2016; López and Sorribas, 2020; Orosco and Serquén, 2018; Silvis et al., 2022; Şimşek and Tuğluk, 2021; Vatavu et al., 2015), while other researchers provide an extensive framework in order to guide them along the development and the implementation of the research (Çakır and Yalçin, 2020; 2021; 2022; Namukasa and Aryee, 2021; Owen and Davies, 2020).

In some cases, the element provided as a theoretical framework is not explained in depth, or the interpretation of the approach is disconnected from the fundamental aims of the Montessori Method. Such as in the work of Vatavu et al. (2015) when, after the analysis of some earlier works, the researchers point out that 'recommendations to use gamification are one instance of the general concept to motivate children by making activities relevant to their interests or life events' (Montessori, 1964, p.57, as is cited in Vatavu et al., 2015). There are several opinions and discussions about the games and the play in the Montessori environment, as well as how to implement them (Elkind, 1983). The use the word gamification, based on Deterding et al. (2011), the word 'gamification is an informal umbrella term for the use of video game elements in non-gaming systems to improve user experience' (p.1), provide of insight about the imprint the researchers selected including the second reference to the Montessori work (1964), 'we recommend designers to provide gratifications to children that are able to motivate them by making activities relevant to their interests or life events' (p.72, as is cited in Vatavu et al. 2015), when, gratification is provided as a reward it is a serious and even negative didactical approach in the development of young children (Montessori, 1948; Montessori, 1949).

In the articles, the words used for the science and mathematical content are STEM instead of the selected word for this research, STEAM. The study by López and Sorribas (2020) selects to use STEAM, and it can be observed in the planning of the workshops that aim to develop 'artistic techniques, creative writing, sports, music and instruments' (p.127). Even when researchers contemplate aspects connected to STEAM, such as development or creativity (Madden et al., 2013), they select to work with STEM (Çakır and Yalçin, 2020; 2021; 2022).

The same analysis could be applied to the subjects related to STEM, such as Mathematics, Physics, Chemistry, ITs, Robotics, and so on, and the researchers would not imply STEM or STEAM in their study (Fernández-Oliveras et al., 2016; Namukasa and Aryee, 2021; Orosco and Serquén, 2018). In some other cases, the aim is connected to a feature, ability, or tool, and the researchers do not connect them to STEM or STEAM (Şimşek and Tuğluk, 2021; Vatavu et al., 2015).

The teachers´ knowledge of the material or subject is a major factor in implementing STEAM content in the classroom. In the study of Namukasa and Aryee (2021), the reference to Montessori training and how the teachers learn to use material from an in-depth understanding of the characteristics and usage of each object and the development of the presentation scripts provides a systematic approach to implementing new STEAM materials in the preschool setting.

Working on the Çakır and Yalçin (2020; 2021; 2022) studies, the referred works show that Montessori Method and the STEM education are subjects selected in various studies carried out in Turkey (Akaygün et al., 2017; Buldu and Erden, 2017; Çakır and Yalçın, 2021b; Durakoğlu, 2011; Eratay, 2011; Günşen, 2017; Kayılı and Arı, 2011; Oğuz and Akyol, 2006; Özgün, 2019; Uğraş, 2017). The dates of the articles studied by the researchers are dated back when STEM education rose in popularity in 2006, and there has been extensive work on the subject in preschool settings and how to implement it. The same happens with the Montessori Method and its positive impact in the early years. Even when researchers do not explore STEM or STEAM, there are numerous Turkish articles that work on science during preschool and the teachers' education in the subject (Aydemir et al., 2017; Timur and Taşar, 2011; Timur and Taşar, 2021; Ünlü and Dere, 2018; Yaman and Yalçın, 2005).

In some cases, the country's background cannot provide quality training or options in these approaches, as the study of Çakır and Yalçin (2020a) reflects on the uncommonness of the Montessori approach in Turkey. In the discussion of the results in the study of Çakır and Yalçin (2021a), the researchers highlight the reflection from one pre-service teacher pointing to the economic implications of implementing the Montessori approach in Turkey. This situation was examined by the authors, comparing it to the results in the work of Sak (2015), where not only preschool teachers claimed the economic and infrastructure situation but also the mindset and framework of the teachers already in service: 'I don't think it is possible for a teacher to be so child-centered when he/she was trained in a teacher-centered way' (p.16).

This is not a solely problem from Turkey; it is a situation that repeats around the globe. From the work of Lillard (2019), the implementation and training in the Montessori Method require in-depth courses provided by 'highly teacher-trainers who adhere tightly to Montessori's system (AMI courses)' (p.958). There are several poor implementations of the approach, making it harder to consolidate a proper process. The same problem is faced by STEAM education; there are many implementations that are too costly, or the educators are not managing the literacy to work on it properly, Sullivan and Strawhacker (2021) point to the fact that 'innovative technologies to support STEM learning such as iPads, robotics kits, and computers are expensive, and often the cost of these materials (let alone the cost of training and professional development for adults on how to use them effectively) makes them out of reach for many parents and educators' (p.88).

In the projects of López and Sorribas (2020) and Owen and Davies (2020), the training of the teachers is considered the main strategy to achieve a real change, but the researchers point out that it is imperative, in a first place, to understand the pedagogical practices, the curriculum, the school ideals, and the professional requirements of the teachers. Furthermore, the teachers must take responsibility for the projects and actively take part in the different phases.

An aspect that must be incorporated, or improved, is the use of the observation as a research tool to boost teachers' practices and prepare pre-service teachers during their studies (Fernández-Oliveras et al., 2016; Namukasa and Aryee, 2021; Owen and Davies, 2020; Şimşek and Tuğluk, 2021).

In the projects implemented in the Beehive school (Owen and Davies, 2020) and in the Rubi Montessori school (López and Sorribas, 2020), as well as in the researches that worked with the pre-service teachers' education, the conclusions and observations along with their experiences provided insight, which is part of the whole educational framework that has to be tackled in order to maximized the influence of STEAM content implemented in a Montessori Method approach. They point to the training and actualization of the teachers in service and the pre-service teachers' education, Çakır and Yalçın (2022), specifically mention the need to provide educators with knowledge as they oversee 'nurture the future generation' (p.156). In the case of in-service teachers, the implementation of new technologies or pedagogical strategies has to be analysed and adapted to the on-going activities and the school ideals (Owen and Davies, 2020).

Even when the gender gap is a reality and intersectionality depends on the situation, the subject is not theoretically covered, and only two studies contextualized their framework considering this matter (López and Sorribas, 2020; Silvis et al., 2022). It is a fact that the gap starts to expand later in life, but it is during this period that children need positive input and encouraging examples to guide them later. The importance of role models in early childhood as well as having the chance to explore and experiment are the foundations for girls and minorities to excel and have all the future alternatives when deciding what to continue studying (Callaghan et al., 2020). With the focus on the influence of education on children's lives, educators are a major contributor to these later decisions in life, as 'being involved as teachers is also a way of being role models for the next generation at bachelor and master levels' (Gibert and Valls, 2022, p.9).

Working on the aspects of the development of the person and the social skills, there are a series of elements observed in the work of Vatavu et al. (2015) as animism, which stands for 'unanimated objects have conscious life and feelings according to children's perceptions of these objects' (p.71). Also, artificialism, when objects or natural processes are believed to be manipulated by human control, and magical thinking refers to the conviction that there is a causal connection between events that are not logically or reasonably linked. There are records of children expressing phrases such as: "I´m sorry", "Will you please go through the loop?", and "look, this ball listens to me! It is not like the other, naughty ones" (Vatavu et al., 2015, p.71). The researchers express the chance of using the potential of these observables to encourage the effective use of the devices, for example, by saying to the child that if the tablet falls, it will hurt. In the Montessori Method fantasy and deception are aspects that must be worked on in a proper manner, considering the characteristics of each child, especially the child's intellectual growth. As Elkind (1983) explains, there is a time when children no longer believe in a fantasy, and the earlier ideas are no longer acknowledged by them.

## 6. Conclusion

The aim of the systematic literary research was to investigate the existing literature about research based on educational practices and experiences in school contexts during the preschool period in the implementation of STEAM contents based on the Montessori Method, identifying the connection between the two education paradigms, the outcomes, how they can influence a person's development, and the gender gap implications.

The selection of certain Montessori ideas, or the complete development of a Montessori Method framework along with the 11 analysed studies, provide insight about the extent to which the approach can be implemented in a preschool setting, in the activities, and in the material in the classroom. Moreover, these examples show the capability of the pedagogy to merge and adapt to the different contexts and necessities of the schools as well as encourage teachers, in service or pre-service, to improve their classroom practices while incorporating the role of the educator as a guide.

In parallel, considering a successful incorporation of STEAM in the classroom, educators have to be able to understand the developmental periods of children. This information is the basis for adapting and planning the material and the activities. Teachers must analyse the aims of the use of the material in the group, considering the limitations. Furthermore, to offer STEAM material in a Montessori pedagogical framework, teachers first have to learn and master its use, create a presentation script focused on the three Period Lesson, practice the presentation, and, with time, continue improving and adapting it to children´s needs. Additionally, there is a necessity to adapt teachers' training and education programmes with STEAM content and the Montessori approach to provide teachers with the knowledge and tools to be able to implement them in the classroom. Another program improvement is the work with theories, and more importantly, with the practice of action research, observations in the classrooms, project development, and cooperative work between educators to improve and update their work. Educators are the component that can change the educational experience of the next generation while improving children's developmental processes through quality teacher practices.

The current situation of working with STEAM materials and arranging the classroom for a Montessori approach is a matter of adapting materials and searching for alternatives to arrange low-cost STEAM implementations. For the Montessori materials, even when the sets can be bought, there are extensions that can be made, especially considering the involvement of the community in creating them. In addition, when the educational system does not provide STEAM education or Montessori approach education, the pre-service teachers and teachers in service who want to learn about them can find guidance from well-established communities to work in a problem-solving cycle as well as to promote group strategies to overcome situations and help each other while learning and during the implementations.

The studies show that STEAM content in the preschool setting is fundamental knowledge and experiences when the educational system intends to provide children with quality and challenging stimuli, basic for the acquisition of new content and to elaborate on an idea of the world. Early-year education (3–6 years old) is the time to present science and technology to children to provide tools and explore all the choices for their future while tackling the still existent gender gap.

In conclusion, STEAM education and the Montessori Method share characteristics that ease their combination for early-age children´s education, as both aim for similar aims in the social and individual development of children during preschool. They are based on providing meaningful and enriched experiences to children through a hands-on, student-centred learning and teaching pedagogical approach, and both set their focus on the potential of humanity to work for improvements.

Limitations of the review include a scarcity of studies specifically focused on preschool-aged children within a Montessori STEAM context; language barriers may have affected the inclusion of relevant literature, particularly non-English or Spanish publications.

Future research should prioritize studies that examine STEAM integration within the Montessori Method for preschool-aged children. Teacher training programs should be adapted to incorporate STEAM content and Montessori principles, focusing on practical application and ongoing professional development. Moreover, efforts should be made to address gender disparities in educational settings through targeted interventions and positive role modelling from an early age.

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