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Robotic Christmas Activities with Beebot: A STEM Application for Preschool Education

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Abstract

This study aimed to explore the application of STEM as a learning tool in preschool education, focusing on creating engaging and effective teaching experiences. The research was conducted in a kindergarten in Greece, involving 44 students from both morning and full-day sections. The study employed a didactic intervention themed around Christmas, utilizing Beebot, an educational robot, to facilitate six activities over one week. These activities were designed to maintain children's interest by embedding them in a topical and meaningful context, encouraging critical thinking and teamwork. The research method involved hands-on activities where children operated Beebot to complete missions, fostering their digital skills and collaborative abilities. The intervention aimed to introduce young learners to abstract concepts through concrete experiences, enhancing their understanding of magnetism, number sequences, and environmental awareness. The study also emphasized the importance of teamwork, as children worked in groups to achieve common goals, thereby improving their social skills and learning performance. In conclusion, the study demonstrated that integrating STEM activities in early childhood education is imperative for developing critical thinking and adaptability in young learners. Educational robotics, like Beebot, proved to be an effective tool in creating an engaging learning environment, paving the way for the development of future flexible and innovative citizens.

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INTRODUCTION

Incorporating STEM education in early childhood development offers numerous benefits that significantly influence future academic performance. ICT skills training starts very early, from early childhood, and includes digital games and learning applications, cooperative play, or problem-solving activities with robots (Weber et al., 2023). Early exposure to STEM concepts fosters critical thinking, creativity, and problem-solving skills, which are essential for success in school and beyond (Intisari et al., 2024). Research indicates that children who engage with STEM education early on demonstrate higher levels of science and visual literacy, which are crucial for effectively understanding and communicating scientific concepts (Ramulumo, 2024). This foundational knowledge enhances their academic performance in STEM-related subjects and equips them with the skills needed for the modern workforce (Ramulumo, 2024). Integrating STEM in early childhood education (ECE) through play-based learning and digital tools can enhance children's appreciation of the world and provide meaningful learning experiences (Preston, 2023). Teachers' professional development in STEM integration is also vital, as it boosts their confidence and ability to deliver effective STEM education, positively impacting children's learning outcomes (Movahedazarhouligh et al., 2023). Despite challenges such as the need for curriculum adaptation and teacher training, the benefits of STEM education in ECE are evident. It prepares children to think critically and creatively, valuable skills throughout their educational journey and in life (Intisari et al., 2024).

Best practices in implementing STEM activities, as identified in various studies, ensure that children acquire meaningful experiences, further enhancing their cognitive development and academic performance (Ghazali et al., 2024). Integrating STEM education in early childhood supports immediate learning goals and lays a strong foundation for lifelong learning and success in various academic and professional fields. Implementing STEM education in early childhood settings is essential as it aligns with 21st-century learning approaches, emphasizing the development of cognitive skills from a young age (Ghazali et al., 2024). Research indicates that STEM-based learning enhances cognitive abilities as children engage in activities that require them to remember, understand, apply, analyze, evaluate, and create, thereby improving their overall cognitive development (Fauzan et al., 2023).

A problem-based STEM curriculum incorporating the engineering design process has increased children's engagement and persistence in activities and the number of engineering behaviors they display (John et al., 2018). This approach promotes cognitive development and nurtures curiosity and problem-solving skills as children learn to tackle challenges through structured problem-solving methods. STEM action plans in kindergarten are essential for fostering early childhood development in critical thinking, sustainability, and professional growth for educators. The integration of "Science Talks" in kindergarten classrooms, as explored by Zhang et al., demonstrates how collaborative action research can enhance student learning and teacher development through a Problem-Based Learning approach (Zhang et al., 2024). It aligns with Campbell and Speldewinde's findings that early childhood STEM education, when oriented towards sustainability, can empower children to become independent learners who are responsive to their environment, suggesting a whole-of-kindergarten approach to systemic STEM education (Campbell & Speldewinde, 2022).

During the COVID-19 pandemic, Zhang et al. evaluated a hybrid STEM curriculum that significantly improved critical thinking skills such as interpretation, explanation, inference, and self-regulation among kindergarteners, highlighting the effectiveness of digital tools in early education (Zhang et al., 2024). Emembolu et al. emphasize the importance of early exposure to STEM careers, suggesting that action research can be used to design and evaluate programs that improve children's knowledge and perception of STEM fields, potentially influencing their future career choices (Emembolu et al., 2020).

Additionally, involving teachers in the curriculum design process enhances their self-efficacy and knowledge in STEM teaching, translating into more effective classroom implementation and positive student outcomes (John et al., 2018). Despite the challenges in promoting cognitive development in preschool, best practices identified in previous studies provide educators with guidelines to effectively plan, implement, and evaluate STEM activities, ensuring that children gain meaningful experiences (Ghazali et al., 2024). Overall, STEM action plans in kindergarten play a pivotal role in shaping young children's cognitive and problem-solving abilities, preparing them for future academic and life challenges. Especially for young children, STEM is consistent with how they think and approach knowledge in their daily lives through their play, exploration, and active participation through their experimentation with various and diverse materials (Samara & Kotsis, 2023b; Samara & Kotsis, 2023c).

STEM activities in kindergarten are designed to introduce young children to science, technology, engineering, and mathematics in an engaging and developmentally appropriate way. These plans often incorporate play-based learning and interdisciplinary activities to foster curiosity and creativity among preschoolers. For instance, a teaching intervention on magnetism uses STEM to help children ask investigative questions and form interpretations about the world, aligning with the Greek curriculum for kindergarten (Samara & Kotsis, 2023a). Similarly, educational robotics and STEM methodologies teach children about the global food system and food waste, enhancing their digital skills and competencies (Tallou, 2022).

Capobianco and Rupp's study on engineering design-based instruction in higher grades underscores the importance of planning and implementing integrated STEM curricula. These curricula can be adapted for younger learners by focusing on problem identification and planning while ensuring the inclusion of science concepts within design tasks (Capobianco & Rupp, 2014). These studies suggest that well-structured STEM action plans in kindergarten can enhance cognitive skills and environmental awareness and lay the groundwork for sustained interest and engagement in STEM fields.

Lastly, integrating STEM through play is emphasized, as it provides a greater understanding of science concepts than direct instruction. Pre-service teachers are trained to design lesson plans that incorporate enjoyable experiences, which are crucial for developing science concepts in kindergarten (Rasyid et al., 2021). These action plans are critical for laying a solid foundation in STEM and promoting lifelong learning and adaptability in young children. The Beebot floor robot is easy to program and suitable for preschoolers. Beebot introduces kindergarten students to aspects of computational thinking and can be used as a basis for teaching various cognitive subjects, such as physics, mathematics, language, and literature (Bowen et al., 2023). Only a few research and analytical studies exist in the literature on implementing interdisciplinary STEM action plans in kindergarten (Samara & Kotsis, 2023a). The current study aims to supplement this lack and address the gap in the literature regarding interdisciplinary STEM action plans in kindergarten by developing and evaluating a didactic intervention that integrates STEM activities into the curriculum.

The primary objective is to assess how STEM-based learning can enhance young children's cognitive abilities and critical thinking skills through experiential and engaging activities. The study also evaluates the effectiveness of using simple and varied materials in STEM practices that can be applied in any kindergarten setting, making STEM education accessible and adaptable to diverse educational environments. Additionally, the research aims to explore the role of teacher involvement in curriculum design and its impact on their self-efficacy and knowledge in STEM teaching, ultimately leading to more effective classroom implementation and positive student outcomes. By focusing on these objectives, the study contributes to developing a comprehensive STEM learning plan that supports immediate educational goals and long-term cognitive and professional growth for students and educators alike.

RESEARCH METHOD

The research method employed a unique didactic intervention specifically designed to seamlessly integrate STEM (Science, Technology, Engineering, and Mathematics) into preschool education. Integrating STEM into preschool education is increasingly recognized as essential for fostering foundational skills in young children. Research highlighted the potential of early STEM education to engage children authentically with the world around them, as demonstrated by the Treehouse Project, where prekindergarten children constructed a treehouse, integrating science, engineering, and mathematics with developmentally appropriate technology use (Damjanovic & Ward, 2024). The importance of STEM in early childhood is further underscored by studies showing its impact on critical thinking skills. For instance, a hybrid STEM curriculum implemented during the COVID-19 pandemic significantly improved kindergarteners' critical thinking skills, such as interpretation, explanation, inference, and self-regulation (Zhang et al., 2024). Additionally, early childhood educators employ pedagogical strategies to cultivate algorithmic thinking skills, using methods like question and answer and unplugged activities, which primarily target lower-order thinking skills, foundational for developing programming competencies (Abanoz & Kalelioğlu, 2024). A bibliometric analysis of early STEM education research reveals a concentration of studies in developed countries. It emphasizes the need for multidisciplinary approaches and broader geographical representation in research (Su & Yang, 2023). Furthermore, the development of tools like the Children's STEM Habits of Mind Questionnaire (CSHMQ) provides a means to assess and enhance STEM process skills in preschoolers, highlighting the positive correlation between these skills and children's age, thus supporting the planning and adaptation of STEM instructional practices (Yang et al., 2024). These studies illustrate the multifaceted benefits of integrating STEM into preschool education, from enhancing critical thinking and algorithmic skills to fostering a lifelong engagement with STEM disciplines, thereby preparing children for future educational and career opportunities.

This intervention was themed around Christmas and was implemented in a kindergarten in Greece, where the researcher was actively involved. The study involved 44 kindergarten students from both morning and full-day sections. The intervention, a hands-on approach, comprised six activities conducted over one week, with Beebot, an educational robot, serving as a central tool. These activities were designed to engage children in a meaningful and topical context, leveraging the holiday theme to maintain their interest and encourage active participation. The children, including those as young as four, were tasked with operating Beebot to complete various missions, which required them to think critically and act accordingly.

The research explored the effectiveness of integrating STEM activities in early childhood education, mainly through educational robotics. The study's design fostered a sense of collaboration, allowing for the observation of children's interactions with Beebot and their ability to work together in groups to achieve common goals. This approach facilitated digital skills development and promoted teamwork and problem-solving among the young participants. Overall, the research method was structured to provide experiential and engaging learning opportunities, aligning with the broader objective of fostering critical thinking and adaptability in young learners.

1. Activities

The present educational practice was implemented using Beebot as an educational tool for the interdisciplinary approach of the thematic unit "Christmas." The action was implemented in the 4th kindergarten of Arta, Greece, where the kindergarten teacher-researcher served. The sample educational intervention consisted of 22 students in the compulsory morning section and 12 in the full-day section. It was mixed, i.e., it consisted of some students from the morning section and some from the second-morning section of the kindergarten. The activities were implemented during the one teaching hour when the kindergarten teacher entered the mandatory morning section and continued during the operation of the all-day section, for which the researcher-kindergarten teacher was responsible. A total of 6 actions were implemented in one week (total: 10 teaching hours). The educational intervention was implemented in the Greek language, and the objectives had to be according to the Greek Early Childhood Education Curriculum (2023).

1.1 Activity 1

1. Thematic Unit: Language. Subsection: Child and communication

The children have to:

a) Formulate and summarize arguments to support opinions. Analyze spoken language into individual phonological units/entities, such as words, syllables, and phonemes, and manipulate them consciously.
b) Formulate and summarize arguments to support opinions

2. Thematic section: Child and Science. Subsection: Mathematics

The children have to:

a) Understand the relations of proximity (near-far) and series or succession (front-back, up-down, etc.) in an organized way (e.g., squared floors). To understand the relationships of proximity (near-far) and order or succession (front-back, up-down, etc.) in organized (e.g., squared floors).
b) Investigate relationships between numbers and sets, symbols, shapes, etc., and forms of their symbolic representation.
c) Verbally enumerate (recite/pronounce), read, and write numbers from 0 to 8 using words and symbols.

3. Thematic section: Child and Science: Subsection: Natural Sciences

The children have to:

a) Recognize essential morphological and other characteristics of living and non-living organisms.

4. Thematic unit: Child, body, creation, and expression. Arts. Subsection: Music

The children have to:

a) Sing in unison in an informal choir.

Materials-inside: Beebot, laminated track, printed color photos of forest animals, fir trees, and icicles
Pedagogical management: Work in small groups of 3-4 children.
Time: 2 teaching hours
Activity description:
Beebot follows the arrows to reach Santa Claus, hidden in the forest of fir trees. It passes through obstacles (fir trees, snow, forest animals) to reach its goal. When it finally finds Santa Claus, it is faced with a new challenge: to get its presents, it must correctly answer questions about the lives of the animals it encountered on the way to Santa's house, the composition of water, what snow is made of (concepts of melting - freezing, temperature - low, high -) and in questions about fir trees:
- What is the color of the fir tree?
- Do fir trees shed their leaves in winter?
- Which song do you know about the fir tree? Sing it...!
- How many syllables does the word "fir" consist of? Find the number symbol on the reference table.
- What do squirrels eat?
- What is the bear's favorite food?
- What color is the bear?
- Do deer have horns?
- Is the temperature on the ice high or low?
- What sport can we do on the ice?
- How does ice melt?
- What song do you know that refers to the fox?
- Does the wolf eat plants or animals?
- Do you know any fairy tales that refer to the wolf?

Each team decided on the route Beebot would follow to reach its goal, justifying its choice and marking it with arrows. The children of each group moved the bee in turn. In the end, each group counted how many steps Beebot took to reach its goal and symbolized the result (a child from group 1 wrote the number 15, which corresponds to the steps taken by the Beebot, and so did the following groups. Thus, the number of bee steps was compared between the groups, and the children used the appropriate vocabulary: equal to, more than, less than.

1.2 Activity title: Find the letters and put them in the correct order to write the words "Christmas" and "New Year."

1. Thematic Unit: Language. Subsection: Child and communication:

The children have to:

a) Formulate and summarize arguments to support opinions. Analyze spoken language into individual phonological units/entities, such as words, syllables, and phonemes, and manipulate them consciously.
b) Match the phonemes with the corresponding letters.
c) Position the body correctly and appropriately use the means and materials to produce writing (tripod grip).

Materials inside: Beebot, laminated track, small pieces of paper for each letter, A4 paper.
Pedagogical management: Work in small groups of 3-4 children
Time: 2 teaching hours
Activity description:
On the track where Beebot moves, the letters of each word were scattered, which the students had written phonologically and with the help of the reference table with the letters (e.g., Which letter starts the word "Christmas." Beebot had to move correctly by finding and "writing" these words with their movement. Each group took on one word, and each child played in turn. At the same time, each group checked its answers with the help of cards where the kindergarten teacher wrote the words, especially the younger children who have not yet mastered phonological awareness to a satisfactory degree.

1.3 Activity title: I make pairs of the exact words

1. Thematic Unit: Language. Subsection: Child and communication:

The children have to:

a) Formulate and summarize arguments to support opinions. Analyze spoken language into individual phonological units/entities, such as words, syllables, and phonemes, and manipulate them consciously.
b) Match the phonemes with the corresponding letters.
c) Position the body correctly and appropriately use the means and materials to produce writing (tripod grip).

Materials-inside: Beebot, laminated track, small cards for the words
Pedagogical management: Work in small groups of 3-4 children
Time: 2 teaching hours
Activity description:
On the track, the children wrote the words bell, angel, wizard, fir tree, and triangle in Greek and scattered them. Then, their classmates instructed them to guide Beebot in finding a word and then finding its match. At the same time, the children should say with which vowel the word the bee is looking for begins.

1.4 Activity title: I move the little bee by finding the Christmas melody

1. Thematic section: Child, body Creation, and expression. Subsection: Arts: Music

The children have to:

a) Recognize a variety of musical genres from a vast repertoire of national and world musical heritage
b) Sing in unison in an informal choir

Materials-inside: Beebot, laminated track, printed color images with the words
Pedagogical management: Work in small groups of 3-4 children
Time: 1 teaching hour
Activity description
The following images have been placed on the track: fir tree, Santa Claus, Triangle, bell tower, drum, starry night. When children hear a part of the melody from the song "The Fir," they should recognize it and direct the bee to the corresponding picture. The same happens when they listen to the melodies of the songs in Greek: "Santa Claus is Coming, Tonight," "Jingle Bells," "Snow in the Belfry," "The Little Drummer," Holy Night." The children of each group move the bee to reach the melody they heard. When the bee reaches its destination, all the children sing the specific melody, e.g., when the little bee reaches the little drummer, the children sing the song of the same name.

1.5 Activity title: I count the stars for the bee to reach the manager

1. Thematic Unit: Natural Sciences: Subsection: Mathematics

The children have to:

a) Verbally enumerate (recite/pronounce), read, and write numbers from 0 to 8 using words and symbols.

Materials-inside: Beebot, laminated track, printed color images with the words
Pedagogical management: Work in small groups of 3-4 children
Time: 1 teaching hour
Activity description:
There are scattered stars numbered from 1 to 8 on the track, and the bee must follow them to reach the manger.

1.6 Activity title: The bee finds the objects the magnets attract to reach the manager

1. Thematic unit: Child and Sciences: Natural sciences

The children have to:

a) Identify differences and similarities of objects based on their morphological characteristics and formulate assumptions about their construction material.

b) Study simple natural phenomena (indicative: floating - sinking, thermal effects, mixing - solubility, magnetism, light - shadow.

c) Discover the attractive magnetic properties between magnets and magnetizable materials.

d) Group the materials according to whether they are magnetized or not

e) Make predictions about various simple natural phenomena and their effects and form models based on their observations

Materials inside: Beebot, laminated track, printed color pictures with objects attracted by magnets and objects repelled by them, magnets, and objects of different materials (metal, glass, wool, clay, etc.).
Pedagogical management: Work in groups
Time: 2 teaching hours
Activity description:
First, children express their opinions about which of the objects given to them are attracted and repelled by the magnets. Then, they verify or negate their answers, experimenting with the magnets, and each group presents the results of their experimentation to the plenary through a child representative.
Images of objects attracted to and repelled by magnets are placed on the track. Beebot plays the role of a magician who must pass through the objects attracted by the magnet to reach the manager. The child who makes the bee move each time should verify his answer by testing the object attracted to a magnet.

2. Data Analysis

2.1 Activity 1

This activity focuses on guiding Beebot to Santa Claus, with children solving questions related to natural sciences, animal characteristics, and environmental features like the snow.
After discussing among themselves in their groups, the children determined, using arrows, the route their bee would follow to reach Santa Claus (Figure 1).
Each group answered the questions about the animals the bee encountered on the way, the first, and the snow. When a child was struggling, his team helped him.

Figure 1. The first group places the arrows to determine Beebot's path to reach its goal.

Four groups were created. The first group took the longest route (Figure 2).

Figure 2. The first group follows the route.

Figure 3. The route followed by the second group.

The second and third groups followed shorter routes (Figures 3 and 4), but the fourth group followed the shortest route (Figure 5).

Figure 4. The route followed by the third group.

To Santa's question, "Is the temperature in the snow high or low?" a child of the third group answered that it was "high," while another child in the group answered that it was "low" "because it is cold."

Figure 5. The route followed by the fourth group

At the end of the activity, the results of the steps taken by the bee were compared. The bee of group 1 took the longest route, as 15 steps were recorded, while the bee of group 4 took the shortest route of 5 steps. The bees in groups 2 and 3 recorded equal steps (7) (Figure 6).

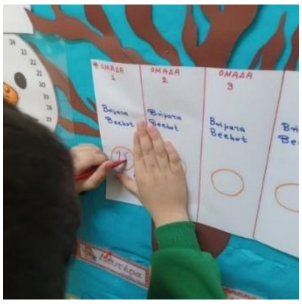

Figure 6. The representative of each group records the steps taken by Beebot

2.2 Activity 2

Activity 2 involves forming and spelling words like "Christmas" and "New Year" using phonological awareness and guiding Beebot along a path to complete the task.

Figure 7. Children write the word charts to create their tracks.

The children created the track where Beebot would move (Figure 7).

Picture 8. The bee "writes" the word "CHRISTMAS" in Greek

Each group then guided Beebot to make a path to form the word they were tasked with writing. The first group had taken on the word CHRISTMAS (Figure 8).

Picture 9. The bee “writes” the word “NEW YEAR” in Greek

The second group had adopted the word NEW YEAR (Figure 9).

2.3 Activity 3

This activity requires children to find pairs of similar words and guide Beebot to the correct match, enhancing language development.
The children had no difficulty finding the pairs of similar words. They seemed to distinguish the words from their first graph (Figure 10).

Figure 10. The track where Beebot moves to find the pairs of similar words. In the present image, it finds the pair of words "BELL."

2.4 Activity 4

Activity 4 integrates music. Beebot was directed toward pictures corresponding to Christmas melodies that the children had to recognize.

Figure 11. The track where Beebot must move while listening to the Christmas melody. In this

picture, it moves towards the "little drummer" after hearing the corresponding melody.

The children recognized the Christmas melodies and moved Beebot to the corresponding picture. It was a delightful activity for the children, as they also sang and danced to their favorite Christmas tunes.

2.5 Activity 5

Activity 5 involves counting and mathematical skills, with Beebot moving through stars labeled with numbers.

Figure 12. The track with scattered numbered stars, which Beebot must cross in sequence (star 1 to star 8)

Figure 13. A child (toddler) finds the number symbol 3 on the reference board to locate the corresponding symbol on the Beebot track and move it accordingly.

Children had no difficulty in guiding Beebot from number 1 to number 8. So did toddlers, except for some who had to consult the number reference board to find the next number symbol on the track (Figure 12, Figure 13).

2.6 Activity 6

Activity 6 explores magnetism. Beebot navigated between objects attracted or repelled by magnets, teaching basic physical science concepts.

Figure 14. First group magnet experimentation material

Children of both groups experimented with similar materials: magnets, wood, glass, metal, wool, paper, and plastic (Figure 14, Figure 15).

Figure 15. Materials for experimenting with magnets of the second group.

Then, after talking about the objects in the track pictures, the children moved Beebot quickly to reach the manager (Figure 16).

Figure 16. Beebot track, photos of objects of various materials attracted and repelled by magnets

RESULTS & DISCUSSION

The children successfully followed various routes to guide Beebot to its destination. Particularly popular and exciting for the children was comparing the number of steps Beebot took in each group, as they took it as a competitive game. Their answers to the activities to move Beebot to the next step were primarily based on logical arguments, even the answers of the youngest children. A lovely activity for the children was creating a track on their behalf. They were invited to develop their artistic talents, vital for preschool children's expression. The same applies when music is involved in the educational process, where they have to recognize the musical melody to guide Beebot to the corresponding image.

Children could also find the pairs of words starting with the same phoneme without difficulty. Also, the children were ok with guiding Beebot around the track from number 1 to number 8. After experimenting in groups with materials attracted and repelled by the magnets, children could easily guide Beebot on the track, passing only objects attracted to the magnets in the manger. Summarized in the context of this study, various activities are associated with each component of STEM:

Science*:* Science-related activities include recognizing essential morphological and other characteristics of living and non-living organisms. This involves observing and understanding the natural world, a fundamental aspect of scientific exploration. ***Technology****:* Programming a programmable robot, Beebot, is an essential technological activity. Children engage with Beebot to learn basic programming and problem-solving skills necessary for technology education.

Engineering*:* While specific engineering activities are not explicitly detailed in the provided contexts, engineering in early childhood education typically involves designing and constructing projects. It might include planning and building structures, which encourages critical thinking and creativity. ***Mathematics****:* Mathematics activities investigate relationships between numbers, sets, symbols, and shapes, which help children develop numerical literacy and an understanding of mathematical concepts.

These activities are designed to be engaging and suitable for young children, fostering an early interest in STEM through interactive and playful learning experiences. Introducing robotics in the educational process is particularly important for students. Abstract ideas and scenarios take concrete shape as students automatically observe the effects on their constructions through the programming commands they use (Kazakoff et al., 2018). The current educational intervention was based on this concept. Beebot introduced young children to the concept of magnetism, the sequence of numbers, musical perception, and the plant and animal environment.

Educational Robotics has emerged as a unique learning tool that can provide hands-on and fun activities in an engaging learning environment, provoking students' interest and curiosity (Eguchi, 2010). In the present research, Beebot has kept the interest of young children undiminished, taking the whole educational process as a game. They were pushed into the world of inquiry to find answers to their questions and verify or negate their alternative ideas, for example, in the activity where they had to find the objects that were attracted or repelled by magnets.

Also, the programming of Beebot was a common interest of the group members and teamwork in which the children participated with consistency and respect for each other since their goal was to achieve the common goal, i.e., for Beebot to reach its destination. Similarly, research showed that groups of students taught through the robot showed better learning performance and increased teamwork skills (Mosley et al., 2016).

CONCLUSION

The application of STEM as a learning tool for experiential, engaging, and effective teaching in education is imperative for our time to achieve the creation of tomorrow's thinking and flexible citizens. The sooner this process begins, the closer we get to this goal. The present research is an effort to add to the STEM practices that can be applied in any kindergarten using simple and varied materials. A didactic proposal was also presented on how to design and implement STEM activities at the interface of the curriculum for early childhood education, which can be used by in-service teachers in the country and school they serve, enriching it and adapting it to the interests and needs of their students.

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