Development of STEM Skills and its Relationship with Environmental Citizenship Education in Preschool Classrooms[1]

Desarrollo de habilidades STEM y su relación con la formación en Ciudadanía Ambiental en las aulas de Educación Preescolar

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Abstract

This research aims to show the results of a systematization of early childhood education experiences carried out in La Felicidad public school between 2018 and 2023. This was an educational project based on the STEM perspective, within a context dubbed living classroom. The results evidence a pedagogical model connected by an experiential and situated perspective that fosters STEM education during early childhood by undertaking pro-environmental actions deployed from urban ecological contexts, within the framework of the natural sciences. This is an innovative, practical, and contextual alternative that also facilitates the interaction between the school and the community. The conclusions indicate that the STEM approach can be interwoven with environmental citizen-ship education processes in the formal education context by means of living classrooms, in order to foster

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an active and conscious commitment to the environment. This applies not only to early childhood, but also to other levels. In addition, this work highlights the importance of the aforementioned integration in children, given their disposition to explore the world around them, which constitutes a unique opportunity to incorporate concepts from the natural sciences, mathematics, engineering, and technology through the lens of environmental care.

Keywords: early childhood, environmental education, STEM, experiential learning, participatory research

Resumen

El presente artículo de investigación tiene como propósito mostrar los resultados de la sistematización de experiencias llevada a cabo en el colegio público La Felicidad, en educación inicial, entre los años 2018 y 2023. Es un proyecto formativo dispuesto desde la perspectiva STEM, en un contexto denominado aulas vivas. Los resultados evidencian un modelo pedagógico conectado por una perspectiva experiencial y situada, que promueve en primera infancia la formación STEM mediante el desarrollo de acciones proambientales, desplegadas desde contextos urbanos ecológicos, en el marco de las ciencias naturales; una alternativa innovadora, práctica y contextual que además facilita el encuentro entre la escuela y la comunidad. Las conclusiones indican que el enfoque STEM puede entrelazarse con procesos formativos de educación en ciudadanía ambiental, en el ámbito educativo institucional formal, por medio de la creación de ambientes denominados aulas vivas, para fomentar un compromiso activo y consciente con el medio, aplicable no solo a la primera infancia, sino a otros niveles. Adicionalmente, se destaca la importancia que tiene dicha integración en los niños y niñas, por su disposición a explorar el mundo que los rodea, tejiéndose así una oportunidad única para incorporar conceptos de Ciencias Naturales, Matemáticas, Ingeniería y Tecnología a través del prisma del cuidado ambiental. Promoviendo esta unión, se establecen los cimientos para una ciudadanía éticamente responsable, resaltando la importancia de una orientación multidisciplinar en la formación en ciudadanía ambiental, en la cual los procesos educativos no se limiten a disciplinas separadas, sino a la incorporación de un enfoque holístico.

Palabras clave: Primera infancia, educación ambiental, STEM, aprendizaje activo, investigación participativa

Introduction

The issue that generates interest in the pedagogical initiative, analyzed through systematization, is related with the reflections of female teachers from the Initial Cycle for children aged four to six and their families regarding the environmental conditions affecting the education institution, such as the low quality of air, caused by mobile sources commuting through neighboring areas; the odorous pollution produced by an adjacent water canal and the industries near the institution; and the need to work on developing citizen commitment with environmentally friendly attitudes from an early age.

The STEM field has been little explored in early childhood. When implemented, it deals with the development of skills based on robotics, engineering and design, promoting different competencies (Brenneman, *et al.*, 2019; MacDonald, *et al.*, 2020; Zhi, *et al.*, 2021). There are few experiences linked to ecological contexts (Martínez, 2020), and there is no evidence of links to natural sciences in built environments.

This proposal is relevant because the first years of childhood lay the foundations for future STEM learning (Campbell, *et al.*, 2018; MacDonald, *et al.*, 2020), given children's proclivity to explore, analyze, hypothesize, and make sense of experiences through their natural disposition towards knowledge of the world (Bagiati, *et al.*, 2010; Katz, 2010).

Systematization may evidence the pedagogical knowledge of teachers who articulate an activity system (Cole, 2003) by means of *ecological mediations* within a space known as *living classroom* (LC), which facilitates life skills training from the STEM field by appreciating schools' green environment and generating environmental co-responsibility.

Next is the methodology section, which considers that systematization starts from a reconstruction of an experience, in order to identify the theoretical references from which the axes of analysis are outlined. These references are later used to support the experience.

Methodology

This research employs a critical perspective. It aims to identify the transformations that have historically occurred with the incorporation of a practice. The approach is qualitative since there is a holistic, contextual, and interpretive orientation with regard to the phenomenon. The systematization of experiences was assumed as a recovery of knowledge (Mejía, 2015). The practice is underpinned by a theory that must be made explicit (Jara, 2018). It starts with the organization and reconstruction of the experience, transits the theoretical definition of the underlying axes, and it ends with the thematic analysis of the information (Escudero, 2020). In this case, the recovery and transformation of the LCs was carried out in outdoor learning environments, which favors the development of knowledge and skills in natural sciences, tech-nol-o-gy, mathematics, and engineering, in kindergarten and preschool.

Systematization makes the knowledge emerging from the process explicit. The research question was *How can STEM skills be developed in kindergarten and preschool children aged four to six by means of environmental citizenship education in the living classrooms of the initial cycle of La Felicidad IED school?* The objective was to develop STEM skills in kindergarten and preschool children through environmental citizenship education within the living classrooms of La Felicidad IED's initial cycle.

Information collection techniques and instruments

The research started with a classification of the teachers' document *corpus*, *i.e.*, observations recorded in video and photographic format, working documents, *curricula*, the institutional education plan, and class planning. These documents were thematically classified, defining a series of categories (Table 1). Finally, seven conversations were held in relation to the documents' horizons of meaning, emerging categories, expectations, and the achievements and outcomes of the experience, identifying theoretical references.

Table 1

Document corpus

Documents	Document *corpus* typology
Observation formats	22 video recordings 73 photographic records
Working Paper	1. What are living classrooms? 2. The development of STEM skills in kindergarten children aged four and five through teaching and learning activities in the living classrooms of La Felicidad school 3. ***Green classrooms: Strategy for mitigating low air quality to the air in La Felicidad neighborhood, Bogotá*** 4. Living classrooms as a strategy to mitigate the effects of low air quality in La Felicidad neighborhood
School management documents	*Curriculum* grids Early childhood education planning grids

Participants

The main informants of the experience are the female early childhood teachers that manage the education project; children who attended kindergarten and preschool in 2018 (36 boys and 36 girls), 2019 (14 boys and 11 girls), 2022 (17 boys and eight girls), and 2023 (22 boys and 28 girls) and participated in the activities linked to the early childhood education *curriculum*; and their parents and grandparents, who, with their work and knowledge, were key participants in the recovery and maintenance sessions. Prior to the children's participation, informed consent was agreed upon, which is why anonymity is maintained.

Procedure

We used Jara's methodological structure (2018) with some adjustments, starting with an inductive process defined by the organization and reconstruction of the experience, which paved the way for the historical recovery and the process timeline, in addition to the theoretical definition of the axis of analysis by means of document *corpus* reviews and interviews with the teachers in the area, with whom the *corpus* was jointly analyzed. The axis of analysis that emerged from this stage was environmental citizenship education (ECE) in interrelation with the STEM approach. Based on this theoretical approach, a deductive phase was undertaken, with a new review of the document *corpus* and interviews, which allowed defining the pedagogical and didactic model of the experience. The analyses were thematic and founded upon the theoretical references of the established axis.

Results and discussion

The methodological approach followed to carry out this systematization, starting from reflective work with the teachers in the area (*i.e.*, the inductive phase, corresponding to the organization and reconstruction of the experience), implied defining the context and formulating a timeline, arranging the theoretical axes of analysis in the order presented later in this document.

Organization and reconstruction of the experience

This result, as a function of the inductive process, evidences the forms of knowledge that emerge from pedagogical practice during early childhood.

Context of the experience

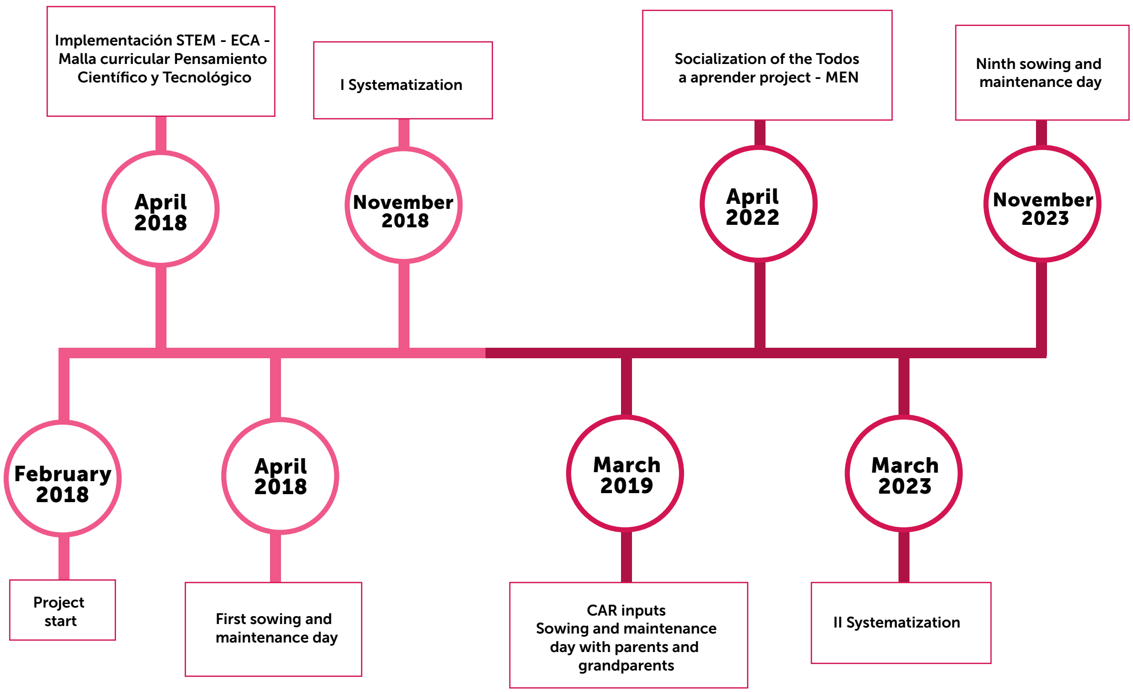
LCs are regarded as outdoor learning environments that stimulate students' creativity and curiosity through meaningful experiences. As an extension of classrooms, they facilitate contact with the natural environment and allow developing environmental education proposals while incorporating STEM knowledge. Every LC is connected to a classroom by means of a sliding glass door and features a metal structure that supports plastic baskets filled with soil, intended for growing aromatic plants, vegetables, and fruits. The structure facilitates the collection of water for irrigation.

Timeline

Figure 1 synthesizes the significant milestones of the project. These are key moments that involved outstanding transformations.

Figure 1

Synthesis of the project's significant milestones



Theoretical references: theoretical propositions of the axis of analysis

Based on the inductive analysis, two categories were formulated: the first was called *STEM-ECE* and the second *experiential learning*, following the proposed objective.

STEM-ECE foundations

The activities are framed within the natural sciences and involve math, engineering, and technology, linking axiological principles, dispositions, and knowledge in relation to the environment through infused knowledge (Swartz and Perkins, 1989), *i.e.*, they integrate STEM and ECE knowledge and skills, providing a more complete multidimensional view of phenomena within the same setting. The summarized inventory of activities, including some outstanding actions, is presented in Table 2.

Table 2
STEM-ECE activities

STEM	STEM-ECE
Mathematics	Classifying leaves: association principles Quantities: risk activities Quantities/weighing: preparation of recipes Living classroom measures: unconventional patterns Drawing insects: geometric patterns and representations
Technology and engineering	Preparation of recipes Representation of plants Adequation of substrates Drawing insects Arrangement of the classrooms by means of labyrinths

Experiential and situated learning

The activities involve reflecting on actions based on knowledge and the development of skills, as well as through solutions to real problems (Table 3), *i.e.*, the construction of knowledge in a real context that enables different authentic learning experiences (Kolb and Fry, 1975).

In the LCs, observation, modeling, and imitation support learning; children talk to other children and adults, examining new situations and identifying evidence of the phenomenon learned.

Theoretical perspective

Once the theoretical axis of analysis had been consolidated in the inductive phase, which was characterized by the organization and reconstruction of the experience, each of the elements was theoretically developed and discussed. This was done by first observing the STEM methodology as a possibility during the early childhood, continuing with ECE, and ending with the pedagogical initiative, regarded as the node that integrates the educational model implicit in the experience. As we were dealing with a deductive process, the theoretical relationships with the context of the LCs were simultaneously evidenced.

STEM methodology

In recent years, the interest in STEM education during early childhood has grown (Tippett and Milford, 2017; Yildirim, 2021). The analyzed experience constitutes a contribution to STEM education processes from the natural sciences. This is an interdisciplinary perspective that links natural science, technology, engineering, and mathematics in contexts of practice, connected with real situations and problems (Acuña, 2023; Sanders, 2009; Tippett and Milford 2017).

In the context of LCs, an infused type of learning takes place (Swartz and Perkins, 1989), *i.e.*, one that enables non-explicit knowledge within the curricular design (Table 2) and allows bolstering skills and attitudes that improve the understanding and explanation of a diversity of phenomena. The STEM field implies the integration of four disciplines, but the context of situated learning evidences that there are practices in which only two of the four disciplines are found. In this vein, other perspectives regarding early childhood consider that, if two of the four disciplines emerge, the experience may be considered to be STEM (Moomaw, 2013; Tippett and Milford, 2017).

In the case of the LCs, the experience shows an orientation towards integral education, where, in addition to the dispositions towards the environment, the children have had the opportunity to perform learning tasks that involve the four fields. In this sense, the experience dialogues with the integral perspective developed by Aldemir and Kermani (2017), who worked on the inclusion of children with diverse socioeconomic conditions, attempting to provide experiences in the four knowledge areas, *e.g.*, in mathematics, through measurements and the numerical sense; in engineering, with construction tools and toys; in science, around the concepts of the human body, climate, water, and movement; and, finally (unlike the LCs working with tools and activities oriented towards the use of technology), with iPads containing educational games. Both the science and technology activities included activities that involved the other fields. In summary, a STEM approach in the context of early childhood and LCs corresponds to a set of practices and lessons, as synthesized in Table 4.

It is important to acknowledge that a proposal with a STEM perspective for the early childhood leverages the critical period of preschool, during which there is a greater predisposition to curiosity (Soylu, 2016) and the development of mathematical and scientific skills – in addition to linguistic ones – that will favor other types of learning throughout life (Campbell *et al.*, 2018).

The main attribute in the case of preschool is that it facilitates the acquisition of basic notions and skills; specialized knowledge is not a priority. In any case, despite the importance of the development stage of preschoolers, efforts to implement the approach at this level are not extensive, even less so from the perspective of education for environmental citizenship.

Table 4

Early childhood STEM learning in LCs

	Natural science	Technology and engineering	Mathematics
Object for STEM in preschool	Science is a way of thinking. It consists of observing and experimenting, making predictions, sharing discoveries, asking oneself and others how things work. The three main components of the natural sciences are biology, physiology, and ecology.	Technology and engineering are ways of doing things. Technology consists of using tools, being inventive, identifying problems, and making things work. Engineering consists of solving problems, using a variety of materials, designing, and creating, in addition to building things that work.	Mathematics consist of making sequences (1, 2, 3, 4...) and patterns (1, 2, 1, 2, 1,2...) and exploring shapes (triangle, circle, square, rectangle), volumes (as in *containing more or less*), and sizes (l*arger than*... or *smaller than*...).
Indicators in LCs for the preschool level	The natural sciences include the study of living beings (what they are, how they survive, their lifecycles, the way they change). Little children need concrete experiences that allow them to observe, categorize, compare and contrast living beings, and observe and describe the seasonal changes of plants, animals, and their own lives.	Demonstrating and explaining the safe and correct use of tools and materials. Children of preschool age can begin to develop engineering concepts by designing, constructing, and testing solutions in the classroom – by constructing sandcastles and cities with blocks, by recycling and mixing. In preschool, technology corresponds to the use of tools and the development of fine and gross motor skills. Tools help children to develop visual-motor coordination.	Exploring and describing objects according to their attributes, classifying and counting materials, comparing quantities, understanding positions and relating objects, paying attention to the shape texture, color, and weight of an object, specifying its details.

The review of the experience in the LCs shows an integral context of actions wherein skills are not cultivated in one field alone, evidencing an interdisciplinary approach to learning, in which the content is combined with lessons from the real world as students apply science, technology, engineering, and mathematics within an artificially created space that establishes connections several aspects of their lives (Lantz, 2009), thereby providing a framework to foster conceptual understanding and reasoning (Tippet and Milford, 2017).

Environmental citizenship education (ECE) in living classrooms (LCs)

The systematization carried out evidenced an empowerment of children as responsible environmental citizens, by means of active and collaborative strategies that allow acquiring knowledge for civic participation in other stages of life.

ECE integrates different types of pre-existing education, such as environmental education (EE), education for sustainable development (ESD), science education (SE), and education for citizenship (EfC) (Hadjichambis and Paraskeva-Hadjichambi, 2020). In ECE, an environmental citizen is considered to be a subject committed to learning about the environment and getting involved in responsible environmental action, albeit from a participation that, in the case of children, implies observing, exploring, acting upon, informing and being informed about, and recognizing the diversity of phenomena in the world (González, 2003; Mrazek, 1996).

Environmental citizenship (EC) has been consolidated by means of the European Network for Environmental Citizenship (ENEC). There is an agreement that involves broadly identifying EC (Monte and Reis, 2022; Hadjichambis and Paraskeva-Hadjichambi, 2020). In this sense, it is defined as the generation of a responsible environmental behavior by citizens as agents of change in the private and public spheres and at the local, national, or global level, by means of individual and collective actions, towards the resolution of environmental issues, preventing the creation of new problems, achieving sustainability, and developing a healthy relationship with nature (ENEC, 2019).

EC includes the exercise of environmental rights and duties, the identification of the structural causes underlying environmental degradation and environmental issues, the promotion of a sustainable environment, the development of the willingness and skills for a critical and active commitment, and civic participation to address said structural causes, acting individually and collectively by democratic means and considering intergenerational justice. This is the basic definition that integrates a proposal for what has been dubbed *environmental citizenship education* (ENEC, 2019).

In early childhood education, this perspective is channeled through practices that facilitate responsible attitudes, i.e., those that imply knowledge, emotions, and favorable and critically assumed actions (Parra *et al.*, 2020). These attitudes should also enable the development of skills and competencies oriented towards achieving a level of environmental awareness with broad spatial and temporal reach, using active educational methodologies (Hadjichambis and Paraskeva-Hadjichambi 2020; 2022).

The starting point in appropriating the dispositions for an ecological awareness during childhood involves the development of environmental knowledge and values leading to the learning of a greater environmental responsibility (Parra *et al.*, 2020), through the participation of children and their families in recognizing local issues, starting with their sociocultural environment (Collado *et al.*, 2020; Hadjichambis and Paraskeva-Hadjichambi, 2020; Monte and Reis, 2022).

According to the aforementioned characteristics of ECE, for the early childhood, the STEM-ECE experience, by means of LCs, provides a scenario of practices with an ecological foundation in the context of natural science, through which the participants develop knowledge, skills, values, and attitudes that imply the learning of healthy relationships with nature and the recognition of environmental rights and duties. Here, students become agents with an impact on environmental issues, of course, from the local order, as the starting point for this process is the reflections of teachers, children, and their families regarding their context.

On the other hand, parents and grandparents participate by contributing with knowledge in the design of the action plan to activate the LCs, through cartographies for identifying the environmental issues in the area and the execution of the action plan, as well as through the organization and implementation of the LCs, extending their contribution by teaching the use of tools, planting, and seed germination. This shows that it is possible to bring the knowledge of families into the school context, thereby configuring knowledge funds. This experience is vital for children's development since it facilitates lasting appropriation in the way they interact with, take care of, live in, and incorporate the ecosystem to which they belong.

This experience fosters empowerment through the participation of children in the ecological dynamics created and the recognition of other manifestations of life of which they can become aware, as is the case of the conservation and care of the world by means of their actions. This experience is an example of how schools can contribute to making children active, participative, and responsible environmental citizens in their early stages while they acquire other lessons that bolster their dispositions towards life, such as STEM education, which can be connected to ECE.

Education via LCs highlights the importance of knowledge of the physical and natural words, not within the framework of a humanity-environment dichotomy, but within a human ecology that is related to the construction of citizenship. Verhulst and Colton (2004) emphasize that, in order to address the current environmental issues, as a necessary condition for sustainability, it is paramount to empower people to become environmental citizens.

Experiential and situated learning

The node of the practice carried out through the LCs corresponds to an experiential and situated perspective, aligned with the premises of sociocultural theory (Díaz-Barriga, 2006) based on the environment (Vecchi, 2013). Under this orientation, learning is not conceived as a product of individual cognitive changes but as obeying interaction patterns that take place in joint activity (Greeno, 2006) within a context. Thus, cognition is considered to be distributed, which implies that the cognitive processes initiated by children not only depend on themselves but also include others (Perkins, 1993).

The activity system generated through the LCs, *i.e.*, the scenario in which children test their cognitive and motor skills, is defined by physical conditions that dynamize conversational practices (Méndez, 2012), wherein there are exchanges between children, their families, and their teachers, which modify meanings related to the environment.

Children's tasks in this context of practice involve observing, using tools, sowing, working as a family, adapting substrates, weeding, and using aromatic plants, which highlights the potential of the educational situation for making students relate to the environment and understand its relationship with the STEM field.

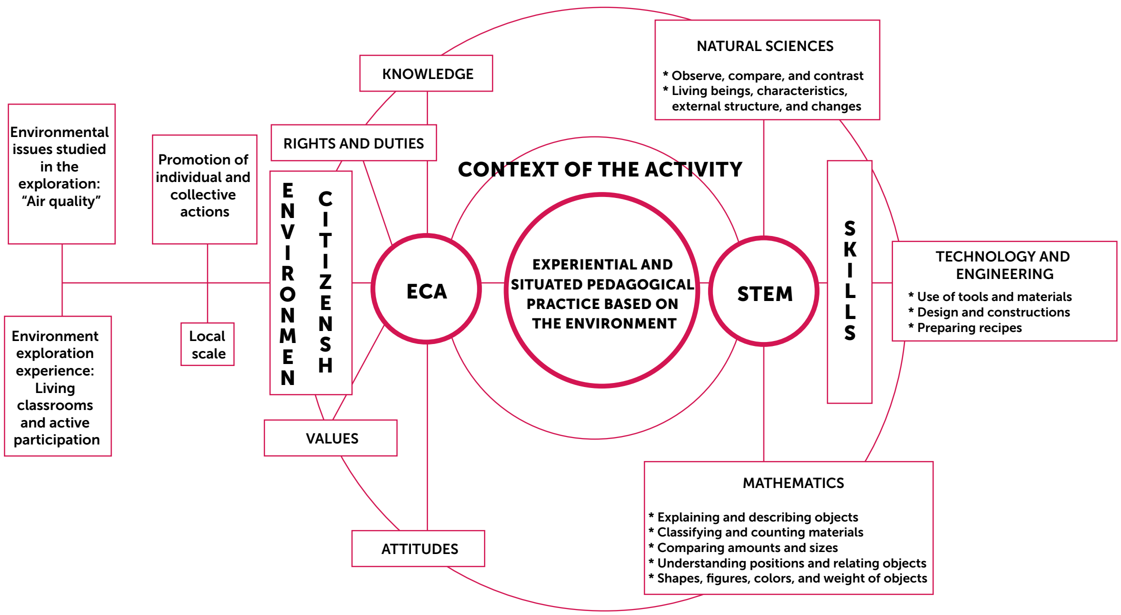
The knowledge is situated, part of the activity, and derived from a context and an institutional and local culture (Díaz-Barriga, 2006). The children integrate into the practice provided by the LC. Through their own explorations, they make it a place for STEM enculturation and the learning of practices steered by environmental ethics. This configures a context that may be interpreted as a place that facilitates the construction of an ecological identity, through children's participation in the environment (Vecchi, 2013). This is an educational agent; the places within the school are windows that allow reflecting upon the possibilities of occupying the same spaces in different ways.

Starting from this reflection and theorization of the experience's implicit learning, a model is reached which assumes an environmental education focused on research and action, as well as commitment and civic participation. This model is therefore suitable for the development of environmental citizenship (Hadjichambis and Paraskeva-Hadjichambi 2020).

Thus, as a model, we propose an adapted integration of the dialogue between ECE and the STEM approach, as depicted in Figure 2. The model is a curricular diagram, whose center reads *experiential and situated practiced based on the environment*, and it assumes a way of learning and teaching where skills are developed through ECE-STEM interaction. This model consists of an educational experience situated on the local scale, promoted via collective and individual actions, that is based on a problem localized in a community, with regard to air quality, and the experience unfolds through the creation of a scenario that allows exploring the environment and participation.

Figura 2

STEM-ECE model. Processes to be promoted during early childhood



One end of the Figure shows the components of ECE that are related to the experience: attitudes or the learning of dispositions towards the ecological medium are promoted, conceptual and procedural knowledge is addressed to design and maintain LCs, values for environmental care are developed, and awareness of environmental rights and duties is fostered. The other end shows the components of the STEM approach, based on knowledge from the natural sciences, technology, engineering, and mathematics, following the learning objectives of early childhood.

Conclusions

The systematization of the experience has shown that the STEM disciplines can be intertwoven with environmental citizenship education processes in the formal educational context, by means of the creation of natural environments, in order to foster active and conscious commitment to the environment. This applies not only to early childhood, but also to other levels. Of course, this highlights the importance of said integration in children, given their disposition to explore the world around them, which constitutes a unique opportunity to incorporate new concepts from natural science, mathematics, engineering, and technology through the lens of environmental care provided by living classrooms. Promoting this union lays the foundations for an ethically responsible citizenship.

This research underscores the importance of a multidisciplinary perspective in ECE as an approach not only for early childhood in school, but also with a broader vision for the education system, wherein educational processes are not limited to separate disciplines, but to the incorporation of a holistic approach that combines the natural sciences, technology, and even the arts, literature, and the social sciences. It is thus that a more complete and enriching understanding of the environment and the responsibilities in relation to it can be reached.

In methodological terms, we evidenced a learning that integrates and applies knowledge and techniques from the natural sciences, mathematics, engineering, and technology to real-life problems. The natural sciences offer an understanding of living beings, from which learning and dispositions – even axiological ones – are bolstered, evidencing children's need for concrete experiences that allow them to observe, categorize, compare, and contrast living beings. This implies that a teaching and learning process that pursues objectives such as those sought by this experience may be oriented by the application of active methodologies. Experiential learning has proven to be especially effective in STEM teaching when linked to ECE.

As for the teachers, the experience shows that, in early childhood education, they must seek opportunities to develop children's understanding with regard to scientific concepts in all content areas, as well as attempting to determine how this knowledge relates to other aspects of life, an issue that implies a political position in terms of the diversity of roles that can be assumed – not only as teachers, but as designers of experiences (Gómez and Niño, 2015).

That said, this research highlights the importance of family commitment in fostering ECE and its connection to STEM. It is evident that the participation of families in shared learning activities can help to acquire environmental knowledge and values.

Finally, we propose other scenarios for potential research and pedagogical practice, such as working on strategies aimed at the dialogue between the community and the school by means of families and proposals regarding knowledge funds, recognizing the knowledge that is outside the school context but serves the educational purposes of ECE.

On the other hand, applications could be carried out through LCs in elementary and high schools, designing and developing didactic sequences, incorporating the use of technology, but maintaining a tangible connection to the environment. Lastly, we propose focusing on studies in South America that recognize the development of STEM practices in relation to environmental citizenship, inquiring about their possible applications in early childhood education, within a framework such as that offered by the living classroom setting.

Contribución de autores

All authors made similar contributions at the different stages of this research: reconstruction of the experience, conceptualization, methodology, analysis, writing, corrections, revisions, and editing.

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