Incorporating STEAM Strategies to Develop Scientific Problem-Solving Skills in Infants

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Abstract

In early childhood, play and hands-on experiences are essential for promoting curiosity and the development of scientific thinking. The STEAM approach science, Technology, Engineering, Art, and Mathematics integrates these disciplines to foster comprehensive skill development from an early age. This study aimed to implement a mini-ecosystem as a teaching strategy to promote scientific competencies in preschool children. A total of 20 children aged 4 to 5 from the educational institution “Dulces Brotecitos” participated in the project. The research followed a qualitative case study design, with two months dedicated to preparing and operating the mini-ecosystem, followed by three months of classroom implementation. Data collection methods included non-participant observation, field notes, and photo and video recordings (Eshach & Fried, 2005). The results demonstrated that children spontaneously used their senses to explore everyday objects and phenomena, formulated hypotheses, and engaged in basic problem-solving activities. Their participation in experiential learning spaces, such as the pedagogical garbage station, construction games, and sensory tables, encouraged scientific inquiry and creativity. The mini-ecosystem also included a mini-laboratory, supported through collaboration with parents, community organizations, and private companies. These experiences strengthened early interest in science, including fields like robotics (Whitebread et al., 2012; Resnick, 2017). Overall, integrating the STEAM approach into early education not only fosters curiosity but also builds foundational skills for future learning (Pahnke et al.; Zollman, 2012; Beers, 2011). This project highlights the potential of interactive, play-based environments to cultivate scientific thinking in young children.

Keywords: Teaching Strategies, STEAM, Mini learning Ecosystem, Scientific Competence.

1 Introduction

The STEAM experience is proposed as an innovative learning strategy called the Mini-ecosystem, designed to develop scientific competencies in early childhood through interdisciplinary and playful learning environments. This approach integrates the areas of Science, Technology, Engineering, Arts, and Mathematics (STEAM) to promote the development of creative, sustainable, and verifiable solutions in young learners.

To implement this strategy effectively, six interactive sectors were established within the learning space: the Construction Sector, Sensory Tables Sector, Inquiry Sector, Pedagogical Garbage Sector, and the Robotics and Programming Sector (Yakman, 2008). These sectors provide diverse materials that are safe for children to handle and encourage active participation, exploration, and critical thinking.

Within the Mini-ecosystem, children are encouraged to identify real-world problems and autonomously choose the sector that best suits their problem-solving process. According to the Guide to Free Time in Educational Sectors from the Ministry of Education (Minedu, 2009), it is essential to observe which spaces allow children to feel most comfortable and safe, as these environments foster creativity, imagination, and self-expression.

Furthermore, the organization of the sectors with varied and accessible materials promotes an educational setting where reasoning, creativity, imagination, and critical thinking can be stimulated, as highlighted by Robinson (2011).

Particularly within the Inquiry Sector, the focus is on developing scientific thinking by encouraging observation, hypothesis formation, and inference-making through sensory experiences and guided challenges. As the National Research Council (2012) emphasizes, these skills are fundamental to fostering scientific curiosity from an early age.

Throughout the implementation, children aged four and five demonstrated great interest in their environment, frequently asking questions, expressing curiosity, formulating hypotheses, and drawing their own conclusions based on observation.

In this way, the Mini-ecosystem represents a meaningful STEAM-based educational strategy that supports the comprehensive development of scientific and creative competencies through exploration, problem-solving, and play.

Thiago: "why is your body like that (squid)?" (Example raised from the collection of comments from 5-year-old children of the EI. Dulces Brotecitos.)

Eyal: "surely with the ink he hides from his enemies" (Example raised from the collection of comments from 4-year-old children of the IE. Dulces Brotecitos).

Figure 1: Inquiry sector, note: Students in the Inquiry Sector, observing marine animals. Own elaboration

Figure 2: Research Sector, note: students observing the squid using their senses. Own Preparation

Figure 3: Research sector, note: students manipulating and discovering what the body of the squid is like. Own preparation

Figure 4: Research sector, note: students describing what the body of the squid is like. Own preparation

The STEAM educational approach must support the acquisition of 21st-century skills, as emphasized in the OECD's 2030 Learning Framework. According to Pahnke, O'Donnell, and Bascopé (2023), many successful educational practices are grounded in a constructivist view of learning that integrates three essential domains: cognitive, social, and behavioral. From this perspective, exploration and inquiry-based learning are fundamental pathways through which both children and educators can construct new knowledge and develop essential skills.

In this context, the implementation of inquiry-based STEAM sessions has proven highly beneficial, as it not only fosters the development of scientific competencies but also promotes key 21st-century skills. Through these experiences, children enhance their collaborative abilities, critical and creative thinking, effective communication, and decision-making skills. Moreover, these sessions encourage teachers to reflect on their own practices, helping them to discover meaningful insights about their performance and to redefine their role in the classroom not merely as instructors, but as co-learners who continuously grow alongside their students.

Massiel: "Then the butter comes out of the milk, and it is because the milk has fat" (Example raised from the collection of comments from 4-year-old children from the IE Dulces Brotecitos)

Figure 5. Research sector, note: students testing their hypotheses about whether milk has fat, through experimentation. Own Preparation

Figure 6. Inquiry sector, note: student testing his hypothesis about whether milk has fat, through experimentation. Own preparation

Figure 7. Research sector, note: student experimenting with straining milk after separating the fat through churning. Own preparation.

Figure 8. Research sector, note: student creating new flavors for homemade butter. Own preparation.

Within the Construction Sector, the proposed challenges were designed to involve strategic allies of the STEAM Mini-ecosystem, including the local Municipality and the private company ORICA Mining Services. As part of these activities, students participated in field visits and engaged in interviews with STEAM professionals, fostering a direct connection between classroom learning and real-world contexts. By addressing authentic, contextualized problems, this approach enables the integration of knowledge with lived experiences, significantly enhancing the meaning and relevance of learning.

As Carbajal, Gallego, Vargas, and Arroyave (2020) emphasize, meaningful learning stands in contrast to rote memorization. To truly promote understanding, it is essential to prioritize discovery, exploration, and hands-on experiences over repetition and mechanical tasks, as these can hinder the development of scientific competencies in early childhood.

In these Construction Sector experiences, students reconstructed and reflected on their field visits, using them as inspiration to create mini-scale prototypes that addressed real community problems or represented original solutions devised by the children themselves. One notable example was the visit to a construction site for a retaining wall in the community. During the visit, students observed the work being carried out, asked relevant questions, formulated hypotheses, designed prototypes, tested their models, and drew conclusions based on their observations and experiments.

This process not only reinforced scientific thinking but also strengthened problem-solving abilities, creativity, and the capacity to apply learned concepts to real-life challenges.

Gustavo: "The retaining walls serve to protect the population from landslides. My dad is a builder and he says they are important because otherwise people could be crushed to death" (Example posed from the collection of comments from 05-year-old children from the IE. Sweet Sprouts.)

Angely: "I saw a news story on TV, that with the rain a wall was falling" (Example posed from the collection of comments from 5-year-old children from the EI. Sweet Sprouts.)

Figure 9. Construction sector, note: students on field visit. Retaining wall work. Own preparation.

Figure 10. Construction sector, note: students, engineers, teachers finishing the field visit to the retaining wall work Own preparation.

The Pedagogical Dumpster is the sector in which children, based on the desire to satisfy the innate curiosity they have to know how things, objects, work; They can do it through the disassembly and assembly of electronic equipment. It is necessary to mention that this equipment was donated by the Municipality, and were examined so that their handling is not risky or dangerous for children. The Guidance Guide for the use of the science module for children from 3 to 5 years old, Minedu (2012) indicates: "We know then that they have capacities that are innate to them, such as curiosity, admiration, surprise and the tireless desire to investigate: observe, explore, experiment, question, investigate, seek answers to your questions, reason, discuss, share ideas and build your knowledge." In this sector, children have the possibility of discovering not only how these objects work; but to feel free to do so.

Liam: "I always wanted to know how computers worked, but my mom doesn't let me touch it at home" (Example posed from the collection of comments from 4-year-old children of the EI. Sweet Sprouts.)

Cielo: "I would love to be a professional in assembling computers, I like the way the cables look and also the keyboard; I think I can help many people when things go wrong" (Example from the collection of comments from 4-year-old children of the EI. Dulces Brotecitos.)

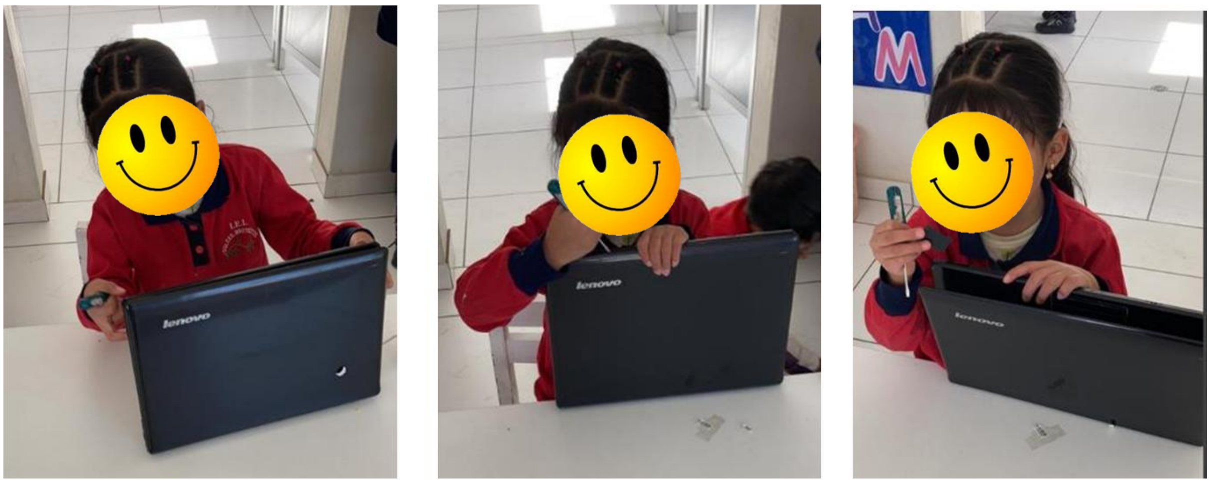

Figure 11. Pedagogical dumpster sector, note: student, in the process of disassembling a laptop. Own elaboration.

Sensory tables are materials that promote learning through discovery. Infants are amazed by natural phenomena and the discoveries they find in their play, such as: Why do some objects float and others don't? Why can I see colors when there is light? etc. “As we see, the many questions that children ask themselves after interacting with their reality in each “experiment” are what invite them to continue investigating and building their explanatory theories of what happens around them: they ask questions looking for answers, seeking to satisfy their curiosity and “take ownership” of the things that surround them. It is a way of getting to know your world” Carbajal, P; Gallego, A; Vargas, E; Arroyave, L. Scientific competencies in Early Childhood boys and girls. (2023).

Juan Adriano: “Wow, red and yellow together in the light give orange” (Example raised from the collection of comments from 04-year-old children of the IE. Dulces Brotecitos.)

Eduardo: “Look miss, I discovered how the green comes out, look friends; Just put the blue and yellow together on the table. I put double yellow so that it came out light green” (Example raised from the collection of comments from 04-year-old children of the EI. Sweet Sprouts.)

Figure 12. Sensory tables sector, note: students at the light table, experimenting with colors. Own elaboration.

Figure 13. Sensory tables sector, note: students at the light table, observing different objects. Own elaboration.

Robotics and programming contribute to the STEAM Miniecosystem strategy, the use of materials (Blue bots) as tools to develop skills in areas such as mathematics, communication, etc. Also making possible the development of socio-emotional skills such as empathy, self-control, resilience, collaborative work, decision making. “RE is conceived not only as an end in itself but as a way that allows problem-based learning, where students must collaborate to solve challenges in this way, their cognitive and communicative skills are enhanced around the meaningful learning of curricular contents” Moreno, V; Rodríguez, F(2023). *(Bers, 2018; Papert, 1980)*

Figure 14. Robotics and programming sector, note: Students making trajectories on the large grid. Own elaboration.

Figure 15. Robotics and programming sector, note: students carrying out trajectories programming the Blue Bots. Own elaboration

Figure 16. Robotics and programming sector, note: students carrying out different trajectories on cards with different challenges to reach a goal. Own elaboration

2 Development

The planet is currently facing a wide range of environmental challenges, which, due to the effects of globalization, no longer remain isolated within the borders of individual countries. It has become evident that the problems affecting one nation have direct repercussions on the entire world. For this reason, it is crucial to educate children from an early age to be sensitive, critical, and capable of responding appropriately to the everyday challenges of their environment.

In this regard, Pahnke, O'Donnell, and Bascopé (2023) emphasize that "a powerful and sustained implementation of future-oriented science, technology, engineering, and mathematics (STEM) education that focuses on critical issues such as those highlighted by the Sustainable Development Goals (SDGs), as well as the exploration of potential solutions, will provide young people, their teachers, and their families with the necessary tools to confront social and health problems that can negatively affect their lives."

In line with this vision, the Curricular Program of Initial Education (2017) highlights that children are "subjects of rights, who require specific conditions to develop; they are also active individuals, capable of thinking, acting, relating, and transforming their environment according to their needs." In this sense, the current global and local contexts, as well as educational guidelines for early childhood, demand an educational approach focused on the development of skills that empower children to become active agents of change, capable of participating in the search for creative and sustainable solutions to real-world problems.

The Initial Educational Institution "Dulces Brotecitos", officially established in 2019, initially operated as a non-formal education program with a capacity of 10 children per classroom. Currently, the institution serves 25 children per classroom. The school is located in an area characterized by families with limited economic resources, where many parents work informally or temporarily in mining and commerce. Additionally, the institution is situated within a district considered a direct impact zone of a major mining operation, home to one of the country's largest and most influential mining companies, as well as other important players in the mining sector.

Given this context, alliances with private companies and the local Municipality have been fundamental strategies for the development of this study. These entities are part of the broader Mini-ecosystem, which represents the environment where the children's families live, coexist, and work. Their involvement reflects a shared responsibility in the formation of future citizens individuals capable of living in harmony, facing challenges with reasoning, critical thinking, and creativity, and contributing to sustainable solutions for the well-being of their community.

3 Performed Activities

3.1 Formation of the STEAM Miniecosystem and implementation of the laboratory

Calling on parents from the educational institution to publicize the project and make them active participants in their children's education was one of the biggest challenges faced. They were involved by explaining with experiential examples in Workshops, the importance of forming a STEAM Mini-ecosystem.

From the formation of the Miniecosystem with parents, they are the ones who propose to involve the private company and the Municipality of the Commune. Discussions and presentations of student learning were held to achieve their incorporation. It is important to mention that the private company Orica Mining Service supports the district's schools serving students at the primary and secondary level with the purchase and coaching of a platform of Australian origin called Stempuk for STEAM education; However, upon learning about the project they were surprised because they did not know that it could be applied to infants and they committed to being active members of the project.

With the Miniecosystem formed, the implementation of the Laboratory in the school began. Closed spaces were adapted with furniture and materials to have the six learning sectors, where the STEAM learning experiences were carried out.

Figure 17. STEAM Mini Ecosystem Laboratory, note: entrance to the STEAM Miniecosystem Laboratory. Own elaboration

Figure 18. STEAM mini-ecosystem, note: mothers of school families, teachers, officials and mayor of the district Commune, official of Orica private company, children of the Educational Institution; members of Miniecosistema STEAM at the Inauguration of the Laboratory. Own elaboration.

3.2 Learning experiences in STEAM sectors

The experiences of the inquiry sector address contextual challenges such as the consumption of milk derivatives, with infant nutrition being an immediate problem to address. In this experience, children are challenged to find different ways to consume milk through its derivatives, specifically butter. They produce prototypes of homemade butter. Observation through all their senses made it possible for infants to ask questions about milk and its characteristics. “As we see, the many questions that children ask themselves after interacting with their reality in each “experiment” are what invite them to continue investigating and building their explanatory theories of what happens around them” The Guide to guidance for the use of the science module for children from 3 to 5 years old, Minedu (2012).

Massiel: “Look Yamileth, when you put the detergent in the milk, the fat escapes; like when my mom washes the dishes” (Example raised from the collection of comments from 4-year-old children of the EI. Dulces Brotecitos)

They formulate hypotheses against the challenge established through a question, they carry out experiments and verify their hypotheses, finally they conclude.

Bayolet: “Today I teach my dad to make butter by churning milk. He is not going to believe that we can make it with milk, always buy it from the store” (Example raised from the collection of comments from 5-year-old children of the IE. Dulces Brotecitos)

The marine world and the diversity of fauna that lives in it led the children to wonder if all those animals that live in the sea were fish. An experiential experience of dissection of a squid was carried out and from this the guided inquiry was carried out. The conclusions that the children reached from the experience were that not all marine animals are fish. As well as other important findings about the anatomy of the squid, the way they move in the sea, and something that caused an impact was the way they fed and defended themselves with the ink they produced.

Alejandro: “Squid are marine animals that are different from fish, I like that they have two large tentacles to hunt. Its mouth is shaped like a beak” (Example raised from the collection of comments from 5-year-old children of the IE. Dulces Brotecitos)

Field visits are part of the Miniecosystem strategy. The children visited the construction of the retaining wall in an area of the district, and conducted interviews with its workers with STEAM professions. Some of the most interesting questions they asked during the visit were:

Thiago: “What would happen if there was no wall?” (Example raised from the collection of comments from 5-year-old children of the EI. Dulces Brotecitos)
Bruce: “But if there is rain, where would the water fall? (Example raised from the collection of comments from 5-year-old children of the EI. Dulces Brotecitos)

In this experience, two main areas of STEAM were articulated, engineering and mathematics. The children replicated a prototype of a retaining wall with building blocks to stop the sand from crushing the dolls that represented the communal district sector.
The sensory tables allowed different experiential experiences to be carried out through spontaneous play. The children discovered that some objects floated and others did not. The hypotheses they raised are based on this experience and the relationship with their previous knowledge. The infants indicated that light objects that have no weight are those that float; while the heavy ones sink. They answered some questions asked by the teachers, such as

If you indicate that light objects are the only ones that can float, and heavy objects sink; So what happens to the big ships that sail on the sea? They began a guided inquiry process, where the experience was planned using aluminum foil, first experimenting whether the boat made with it floated and then crumpling it like a metal ball that sank. They answered the question: What happened? Rethinking your hypotheses:

Enrique: "What happens is that, not only should they be light but empty, like an empty bottle. That's how boats are and they float" (Example raised from the collection of comments from 4-year-old children of the IE. Dulces Brotecitos)
Lionel: "Boats have that thing that rotates, it gives them speed so they don't sink. Since swimmers move their arms like this (stroke gesture) they also move and do not sink. (Example raised from the collection of comments from 4-year-old children. "Dulces Brotecitos")

Figure 19. Research sector experience, note: children experimenting with different objects on the water sensory table. Own elaboration

Figure 20. Research sector experience, note: children writing and drawing their hypotheses about objects that do not float. Own elaboration.

Figure 21. Research sector experience, note: children testing their hypotheses with aluminum objects on the water sensory table. Own elaboration.

Robotics and programming as a teaching resource to develop skills were of high cognitive demand for the infants. “Constructionism, which emphasizes the value of ICT as powerful mental construction tools, useful for developing complex thinking in students; as long as their incorporation is encouraged through strategies where they build interesting and even fun learning products within the framework of innovation environments.” Vicar, C.
(2009). The challenges revolved around programming the bot to reach a target via a trajectory (the shortest and fastest). Children show a positive attitude and excitement when programming with Blue bots.
Infants make trajectories using their body on the floor grid, using pieces of concrete material marked with arrows or directionals; Finally, they program the bot to make the same trajectory, on the grid of the tables. They verbalize their actions by creating sequences, counting with numbers, verbalizing spatial location with terms such as forward, back to the right side, left to the other side.
The areas of Technology, as well as Engineering, Mathematics and Communication, are developed interdisciplinary; ensuring that children develop different skills.

4 Results and progress

The Curricular Program for Initial Education, established by Minedu (2017), proposes that children's competencies can be organized in an integrated manner through six fundamental areas: Personal-Social, Psychomotor Skills, Communication, Spanish as a Second Language, Mathematics, and Science and Technology.
Within the implementation of the Mini-ecosystem STEAM strategy, concrete results were observed in the development of these competencies:
In the Personal-Social area, children demonstrated the ability to coexist democratically by promoting and respecting agreements regarding the use of learning sectors. Through collaborative inquiry-based experiences, they were able to express their emotions, work as a team, and share their preferences, particularly in the Pedagogical Garbage Sector, where they interacted with diverse, everyday materials creatively and respectfully.
The Robotics and Programming Sector played a key role in the transdisciplinary development of skills in the areas of Communication, Mathematics, and Psychomotor Skills. Children verbalized and documented the actions involved in programming and guiding robots through various trajectories. They translated everyday challenges into mathematical language, incorporating concepts such as spatial orientation, directionality, counting units, and comparing quantities (e.g., greater than, less than). Additionally, they used their bodies as a primary strategy to physically navigate pathways marked on a floor grid walking, jumping, or advancing square by square further reinforcing spatial reasoning and motor development.
The experiences provided in the Sensory Tables, during field visits, and within the Pedagogical Garbage and Inquiry Sectors enabled children to develop essential competencies in the area of Science and Technology. Through activities such as observing with all five senses like the exploration of milk-derived squid-like materials or investigating questions like "Why do objects float?" children described the characteristics of materials, formulated hypotheses, tested their ideas, and communicated their conclusions. Furthermore, by safely dismantling and reassembling electronic objects, they not only satisfied their curiosity but also discovered fundamental principles of how these objects function and recognized the importance of handling them with caution and supervision.
Based on these experiences, it is evident that the Mini-ecosystem promoted the development of scientific competencies, as well as the comprehensive, transdisciplinary strengthening of skills across all curricular areas defined by the Initial Education Curricular Program, thereby contributing to the overall improvement of educational quality at the preschool level.
The Mini-ecosystem STEAM strategy is not only a pedagogical approach but an innovative educational model that supports teachers in meeting curricular standards. Through play-based challenges within diverse sectors, children develop 21st-century skills such as teamwork, critical and creative thinking, effective communication, and autonomy. Moreover, by addressing real-life, meaningful situations, this approach fosters children's sensitivity, decision-making abilities, and commitment to caring for and improving their world.

5 Analysis and Reflections

One of the greatest strengths of the STEAM Mini-ecosystem as a learning strategy lies in its ability to promote the development of social and personal competencies in early childhood. Through participation in the different sectors of the Mini-ecosystem, children demonstrated their ability to coexist democratically within shared spaces, such as the laboratory and activity areas. They actively participated in establishing and respecting agreements for sector use, expressed their identity through preferences and choices during play, and learned to respect the preferences and ideas of others. Furthermore, they successfully engaged in collaborative work, solving challenges through teamwork and dialogue.

As noted by Pahnke, O'Donnell, and Bascopé (2023), when individual actions are guided by explicit, reflective values, children not only act within their immediate environment but also develop a sense of global responsibility. In this process, their personal, local, and global identities are intertwined, empowering them to use STEAM knowledge as a tool for social good.

The systemic, interdisciplinary approach promoted within the Mini-ecosystem allows for the simultaneous development of scientific competencies and essential social skills that contribute to forming future citizens with civic responsibility and social commitment.

Additionally, the use of Robotics and Programming as teaching resources has demonstrated that even at the initial education level, children are capable of solving complex challenges through play-based learning. These experiences facilitated the integrated development of mathematical reasoning, communication skills, and psychomotor abilities, confirming that young learners can engage in problem-solving processes when supported by age-appropriate tools and methodologies.

Importantly, all proposed activities were intentionally aligned with the standards set forth in the Initial Education Curricular Program, ensuring that the integration of STEAM does not conflict with curricular requirements. On the contrary, these experiences reaffirm the relevance of STEAM as an effective educational strategy for improving learning outcomes in early childhood and serve as a model for teachers seeking to enhance educational quality.

This perspective contrasts with challenges reported in other contexts, such as Korea, where Sung, Lee, and Chun (2023) highlight a lack of alignment between STEM curricula and early childhood education, leading to missed opportunities during critical developmental stages. The authors emphasize the need to integrate tools such as KIBO, which are developmentally appropriate and designed to strengthen computational thinking and provide meaningful experiences with technology and engineering.

In this sense, the Mini-ecosystem represents a successful example of how STEAM can be integrated effectively into early childhood education, promoting not only cognitive and scientific development but also social, emotional, and civic competencies essential for forming responsible, creative, and critical citizens.

6 Conclusions

The learning strategy of the STEAM Mini-ecosystem is grounded in a systemic and holistic approach that prioritizes the development of scientific skills in early childhood. This approach recognizes that achieving meaningful learning outcomes requires the active participation not only of teachers but also of parents, community leaders, and private sector stakeholders. By involving these actors as co-educators, mentors, and decision-makers, the Mini-ecosystem fosters a collaborative educational environment that nurtures the formation of responsible and engaged future citizens.

The implementation of the six interactive sectors within the laboratory namely, Construction, Sensory Tables, Inquiry, Pedagogical Garbage, Robotics and Programming, and others serves as the core of the STEAM Mini-ecosystem strategy. These sectors provide rich, contextually relevant experiences that promote the development of scientific thinking in young learners. Through meaningful, inquiry-based activities grounded in real-world situations, children enhance key scientific skills such as careful observation, hypothesis formulation, experimental exploration, and evidence-based conclusion drawing. This process fosters a reflective and transformative learning experience that is action-oriented and child-centered, empowering children to become active agents in constructing their own knowledge.

Beyond these initial successes, it is crucial to consider and explore future research directions to better understand and optimize the implementation of the STEAM Mini-ecosystem in early childhood education. One important area for further investigation involves assessing the strategy’s impact on children with diverse learning needs and abilities, ensuring that the approach is inclusive and adaptable to all learners. Additionally, exploring how the Mini-ecosystem can be effectively tailored and applied to younger age groups, such as three-year-old children, will provide valuable insights into developmental appropriateness and curriculum design.

By addressing these challenges and deepening our understanding of the Mini-ecosystem’s applications, future studies can contribute to refining this innovative educational model, expanding its reach, and maximizing its benefits for early childhood learners across diverse contexts.

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