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Strategies for Implementing STEM Education in Preschool Education

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Abstract

The role of kindergarten is to efficiently prepare preschoolers for their encounter with the real world. This includes developing their skills, competencies, problem-solving abilities, as well as acquiring knowledge about themselves and their surroundings. STEM education can be a reliable ally in this process. The STEM perspective integrates four areas: S-Science, T-Technology, E-Engineering, and M-Mathematics. It employs an interdisciplinary approach that uses these sciences as access points for fostering investigation, dialogue, and critical thinking in children, relying on a constructivist, integrated and applied learning-by-doing approach. Teaching activities based on the STEM concept encourage open research, investigation, identifying problems, and proposing solutions. A formative, ameliorative psychopedagogical experiment conducted during the 2023-2024 school year aimed to identify the impact of STEM-specific didactic strategies in the Sciences domain on preschoolers' scientific investigation skills. The research sample included 21 middle group children from Mărceni Bicaz Kindergarten, part of Regina Maria Bicaz Secondary School, in Neamț County. Through experiment, monitoring and statistical-mathematical techniques, data were collected, presented, analysed, and compared using an observation grid during pre- and post-experimental evaluations to highlight the impact of these strategies on developing scientific investigation skills in preschoolers.

Key words: Interdisciplinarity; scientific investigation skills; STEM education; strategies

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1. Introduction

Just as reality functions as an interconnected system, knowledge about reality must be gained holistically, identifying and leveraging interdependencies (Tytler, 2020). Through STEM education, combining S-Science, T-Technology, E-Engineering, and M-Mathematics, preschoolers are enabled to exhibit behaviours as final outcomes outlined in early education development dimensions (*Curriculum for early education*, 2019), namely logical operations, problem-solving, understanding structural and functional characteristics of the environment). STEM, a relatively new concept. "The acronym was coined by Dr Judith Ramaley in 2001, as assistant director of the human resources directorate at the US National Science Foundation" (Tytler, 2020, p.1). It has both supporters, skeptics, and opponents (Breiner et al., 2012). For a long time, the four sciences were taught separately.

The introduction of STEM unified these subjects into a cohesive framework, leading to more productive learning and practical outcomes. The key to success in society is to equip students with the knowledge and skills necessary to cope with and solve problems in a rapidly changing world. Students are challenged to critically engage with problems, ask meaningful questions, and discover solutions through hands-on activities (Hutchinson, 2018). Mistakes are encouraged as valuable learning opportunities, fostering perseverance and resilience, and we will need to identifying not just the cause but also the right solution (Bruzzone, 2018). Additionally, children are taught to listen to others' perspectives, share knowledge, and use their newfound skills to contribute positively to society (Jacoby, 2018). The STEM approach originated in the United States during the 1980s as an educational goal and evolved into a movement to reimagine the learning process through interdisciplinary integration. This approach represents one of the most significant educational transformations in recent decades, becoming a cornerstone of contemporary education reform (Breiner et al., 2012). Over time, it expanded to STEAM, incorporating the Arts (A), which enhanced the interdisciplinary framework with a transdisciplinary perspective (Nhil, 2021).

2. What is STEM, and what makes it unique?

STEM aims to provide a holistic education to all students, irrespective of location, gender, academic performance, educational needs, or economic background (Bouchrika, 2024), integrating science (S), technology (T), engineering (E), and mathematics (M) to move beyond isolated, fragmented, and incomplete approaches to knowledge and practical application (Ozkan & Kettler,2 022). Based on educational research and practice, educators can use a six-step algorithm to implement STEM activities effectively (Chiș, 2020). Below is an example of this process applied to a project called *The Projector* (technology-focused):

1. *Focus* – at this phase, the educator presents a clear and accessible central question or problem to the children and relevant to STEM education (e.g.: Build a projector from the materials provided - rolls of paper, foil, elastic bands, markers, various images - technology);

2. *Detail* - this phase involves exploring solutions to the problem while integrating knowledge and skills from various disciplines and implicitly a lot of information, skills or key processes that children must already access, process, correlate (e.g. "How can we use the created tool to project images?")

3. *Discovery* - during this phase, the educator analyses how children identify gaps in their skills and engage in active research, guided by open-ended questions. It is the phase which refers to active research and intentional, heuristic leadership towards the discovery of the solution (e.g. After observing a real projector, children attempt to build one. The teacher asks questions like, "How many materials do we have available? (mathematics)," "Where should we start? How could we achieve this? "What do you think could make it work or fail? (technology, engineering) What do you think we could design? (science) to guide children to learn the technique of building the projector".

4. *Application* – it is the phase when children apply their accumulated knowledge and skills to create their own solutions and execute the steps to solve the problem. This is often the most enjoyable part of the activity: e.g. Draw the outline of a fish or flower (science) on a piece of plastic wrap (engineering, technology), place the plastic wrap over a paper roll so the drawing is centered, and secure it with an elastic band. Position a flashlight at the other end of the tube to create a projector that projects the image onto a light surface (engineering, technology).

5. *Presentation* - this step emphasises sharing solutions, providing and receiving feedback, and reflecting on the process: e.g. Children discuss their findings, share how they solved the problem, and explore what didn't work and why; how many solutions they have identified; what were the right solutions to make a projector; how they managed to make the projector work; how many times they made a mistake and where; what else they could design in the future);

6. *Link* - in this final step, children reflect on the activity, the feedback received, and their learning process. Based on this reflection, children will be able to self-correct and improve their own skills, abilities and knowledge (e.g.: Learn to use the projector and use light in projecting images; Explain whether the process was challenging; How many difficulties they encountered; How they overcame them; How they felt in the activity; If they still want to work this way; How many times?).

The dynamics of interdependence within STEM are illustrated in Figure 1.

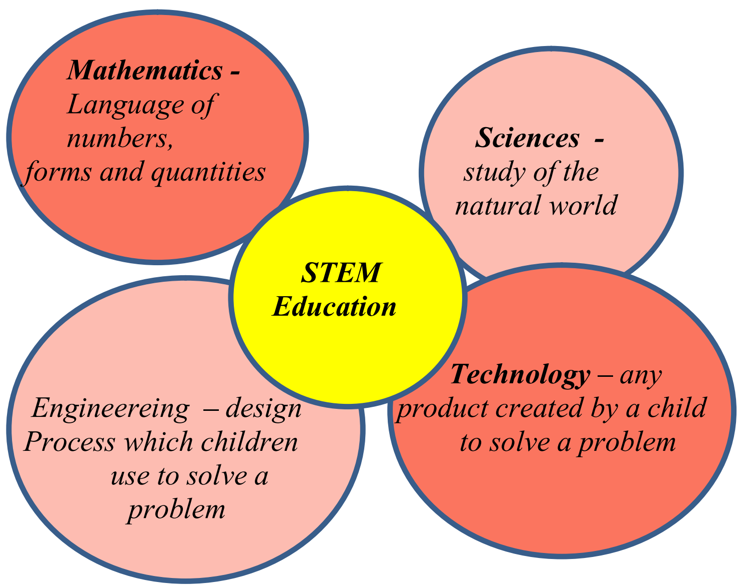

Figure 1. Interactions and interdependencess in STEM

We outline various categories of activities tailored to STEM education in kindergarten, as described by Bobeș (2020):

1. *Experiments: Understanding Cause and Effect*

Examples include: bringing snow into the classroom to observe it melting; closing a window to eliminate external noises.

2. *Games: Combining Exploration and Play for Learning*

- Skill-based games: activities guided by the teacher, such as fitting large shapes into smaller ones, filling and emptying containers.
- Sensory games: using touch to identify objects placed in a box, such as geometric figures, small toys, vegetables, fruits, or items with varied textures.
- Curiosity Club: engaging children with questions like, *Why do we stick to the Earth*? or *Why is it so cold at the Poles?*

3. *Investigations:* encouraging exploration by comparing objects to identify similarities and differences; asking and answering questions during investigations using tools like microscopes or magnifying glasses.

A review of the literature highlights several advantages of STEM education in kindergarten (Bouchrika, 2024; Cristea, 2020; Ismail, 2018; Leung, 2023; Martín-Páez et al., 2019; Sungur et al., 2023; Wan et al., 2020; Zdybel et al., 2019):

- laying the foundations of scientific skills: searching for information, analysing and using data, solving problems with mathematical concepts, conducting environmental research, and communicating findings (Johnson & Sondergeld, 2023; Maass et al., 2019);
- fostering social competencies: enhancing communication, teamwork, and active citizenship (Maass & Straser, 2024; Steffensen, 2024; Maass et al., 2022);
- ensure the formation of the ability to integrate STEM components: connecting theoretical knowledge to real-life contexts and correlating ideas across science, technology, engineering, and mathematics;
- arousing interest, curiosity, encouraging perseverance, develops creativity and imagination by blending science with engineering, technology and mathematics.

However, *STEM education in kindergarten also has limitations*, presented below (Diana et al., 2021; Estonando, 2017; Sungur et al., 2023; Toma, 2022):

- challenges in designing effective STEM activities (Sungur et al., 2023);
- difficulties in linking abstract concepts to real-life contexts (Diana et al., 2021);
- risk of superficial cognitive gains and insufficient consolidation of skills;
- lack of diverse and age-appropriate educational materials in adequate quantities for preschoolers and for all children;
- high time consumption on STEM strategies, constrained by curricular schedules;
- group management challenges: maintaining attention, fostering collaboration, and encouraging participation from shy or less confident children;
- increased effort required from both children and teachers, including the need for sustained practice and willpower.

Based on these insights, we identify key differences in approach between STEM education (as a modern methodology) and traditional educational practices (Popescu, 2018).

Class Organisation

- *Traditionally*: In a conventional setup, preschoolers sit in rows on chairs, side by side, with their focus directed to the front, where the teacher is positioned. The expectation is for them to pay attention solely to the teacher. In moments of personal challenge or confusion, they seek answers from either the teacher or the peer next to them.
- *STEM Education*: The classroom is dynamic, with children scattered across different areas, grouped based on study topics and available resources. They face each other, engage in direct communication, and participate in meaningful dialogue. Together with the teacher, who acts as a partner, they collaboratively discover solutions.

Role of the Preschooler

- *Traditionally*: preschoolers primarily listen to the teacher's explanations, attempting to memorise and reproduce the information shared. They passively receive ideas and work independently.
- *STEM Education:* preschoolers actively exchange ideas, cooperate to solve tasks, express their own perspectives, provide arguments, and ask questions to deepen their understanding.

Role of the Educator/Kindergarten teacher

- *Traditionally*: the teacher delivers lengthy explanations, imposes viewpoints, and assumes an authoritative, almost parental role.

- *STEM education:* the educator acts as a facilitator and moderator, helping preschoolers understand and articulate their perspectives. They collaborate as a learning partner with the children.

How learning is achieved

- *Traditionally*: learning is predominantly based on memorisation and the reproduction of information. It fosters competition among children with the aim of ranking them.
- *STEM Education:* learning emphasises the development of practical skills and competencies. It is achieved through collaboration and cooperative activities.

Assessment

- *Traditionally*: focuses on measuring and evaluating knowledge—what the preschooler knows. It emphasises quantity (how much they know) and categorises children.
- *STEM Education:* evaluates competencies—what the preschooler can do with the knowledge acquired. It tracks individual learning progress and prioritizes qualitative elements such as values and attitudes.

The purpose of the research was to evaluate the impact of implementing STEM-specific teaching strategies in science education on the development of scientific investigation skills in preschool-aged children. The research objectives are following:

O1: assessing the pre-experimental level of preschoolers' scientific investigation skills;

O2: identifying and selecting STEM-based teaching strategies suitable for developing preschoolers' scientific investigation skills in science-related activities;

O3: systematically integrating selected STEM teaching strategies into science activities to enhance preschoolers' scientific investigation skills;

O4: assessing the post-experimental level of preschoolers' scientific investigation skills;

O5: highlighting the impact of STEM teaching strategies on the development of scientific investigation skills in preschoolers.

The research hypothesis is: The implementation of STEM-based teaching strategies in science activities significantly contributes to the development of preschoolers' scientific investigation skills.

3. Methodology

3.1. Participants

The experimental group was formed by a number of 21 children (middle group; 4-5 years; 9 girls and 12 boys) from the Mărceni Bicaz Kindergarten, with a normal program, structure of the Regina Maria Bicaz Secondary School,Neamț county.

3.2. Methods and instruments

The study uses a combination of formative-ameliorative psycho-pedagogical experiments, pedagogical observation, and statistical-mathematical techniques for analysis. The primary research tool is an observation grid comprising five observational indicators (I), each aligned with *targeted capacities (C)* outlined in the Early Childhood Education Curriculum (2019): the ability to identify phenomena in the immediate environment *(C1) – Identification and exemplification of cause-effect relationships (I1);* ability to form new experiences, starting from past experiences *(C2)* - *Using previously acquired information (I2);* ability to manifest mathematical skills for problem solving *(C3)* - *Solve problems starting from sorting and representing data (I3);* ability to carry out environmental research activities using appropriate tools and methods *(C4) – Using the senses and various tools to investigate the environment and acquire information (I4);* ability to capitalise on the characteristics of the living world, Earth and Space *(C5) – Expressing opinions about experiences, actions and phenomena in the immediate environment (I5)*.

3.3. Procedure

During both pre- and post-experimental phases, data were collected using the observation grid. Capacities were recorded as either present or absent using a binary “Yes/No” marker. For present capacities (marked “Yes”), the level of manifestation was scored on a five-point Likert scale, such as: *very rarely* (0 points); *rarely* (1 point); *occasionally* (2 points); *often* (3 points); *very often* (4 points). Therefore, the maximum score per grid was 5x4=20 points, indicating a high level of *scientific investigation skills.* Scoring tiers were as follows: 1–6 points: *minimal skill manifestation*; 7–13 points: *moderate skill manifestation*; 14–20 points: *high skill manifestation*. Ten observation grids were completed during the pre-experimental phase (one per day) and another ten during the post-experimental phase. A comparative analysis of the two data sets provided insights into the impact of STEM-based teaching strategies implemented during the formative-ameliorative intervention period.

The research was conducted between September 2023 and June 2024, encompassing the following three steps:

Step 1: Pre-experimental Evaluation (Pre-test): September 2023.

This phase focused on *diagnosing* the development level of scientific investigation skills in children from the middle group of Mărceni Bicaz Normal Kindergarten, part of Regina Maria Bicaz Secondary School, Neamț County. Observation was the primary method employed, using an observation grid with five indicators to assess the children’s scientific investigation skills.

Step 2: Implementation of the Progress Factor (Formative-Improvement Phase): October 2023–May 2024

During this phase, a progress factor was introduced into the activities for the research group. Specific content from Environmental Knowledge and Mathematical Activity lessons was delivered using tailored STEM teaching strategies in kindergarten settings, both during teaching-learning and assessment.

The literature highlights valuable insights into STEM education strategies (Tytler, 2020, pp. 2–3). Based on these principles, Table 1 presents the design and integration of specific STEM teaching strategies into Environmental Knowledge and Mathematical Activity lessons in the Science Field for the middle group during the experimental intervention.

Table 1. Specific STEM teaching strategies in the activities of
Environmental Awareness and Mathematical Activity, Science Domain

Themes	*Learning activities*	*Capitalised teaching strategies*
Let's get to know each other better!	• relationships, operations, and logical deductions in the immediate environment: *What do we have in common with others? What makes us unique?* • comparing experiences, actions, and events: reflect on personal experiences—*How am I different from... or What did I do yesterday?* • identifying/illustrating/explaining the connections between causes, effect, and phenomena - *The Curious Little Ones.* • experiments: *Cause and effect, Observe and Describe, Taste Good* and *Touch and Feel!*	*Teaching methods and procedures*: game, didactic game, comparison game, role play, conversation,demonstration, mosaic method, game exercise, teaching method for mutual learning, reading from images from atlases, encyclopedias, magazines, didactic films, exercise, pyramid method, directed and spontaneous observations. *Teaching Aids*: toys, play kits, model books, various types of books, images, thematic posters, coloured pencils, markers, laptop, projector, screen, watercolours, modelling clay, water, sand, microscope. *Organisational forms*: whole class, group, individual.

Around me!	• find solutions/answers to questions, problems, or unknown situations from personal and group life: *What do clouds look like? Rain drops and snowflakes, How do people commute to work? Answer quickly and accurately! What is heavier: a kilogram of potatoes or a kilogram of wool?* • perform guided activities for environmental exploration, using appropriate methods and tools: *Does it sink or float? Wavy lines, Portraits and images, Open and close!*	*Teaching methods and approaches:* explanatory reading, games to identify similarities and differences, discussion, cube method, demonstration, problem-solving, exercises, collage, dramatisation, educational films *Teaching aids:* toys, game kits, thematic boards, coloured pencils, markers, notebooks, scissors, glue, coloured paper, miniature images, textiles, coloured cardboard, projector, tokens, pictures, natural materials (leaves, branches, straw, stones, rocks, water, sand, dyes), magnifying glass *Organisational forms*: whole class, group, individual.
Toward the Blue Horizon!	• build new experiences based on past ones: *Stories from the Polluted Forest* • activities offering children opportunities to use previously acquired knowledge: *Continue what I started! Can you do what I do? The seesaw Lever.* • Practical activity: *Create a model of the area/neighborhood where the kindergarten is located.* • Role-playing games where children use various objects for intended purposes, drawing on prior experience. • *Small group activities*: preschoolers create doll clothes for different seasons using diverse materials and techniques. • *Educational games created by children*: *Codes and treasures, The Adventures of Bulbsy in the World of Electricity, The Magic Computer!*	*Teaching methods and approaches:* educational play, discussion, brainstorming, observation, demonstration, problem-solving, exercises. *Teaching aids:* toys, game kits, thematic boards, books, coloured pencils, markers, notebooks, watercolours, modelling clay, scissors, glue, coloured paper, miniature images, textiles, natural materials, scale, stopwatch, compass, hourglass, coloured cardboard, projector. *Organisational forms*: whole class, group, individual.
1, 2, 3 are my friends!	• demonstrate familiarity with the concept of numbers and counting: *Place me in my house! The number ruler.* • show familiarity with information about shape, size, height, length, weight, and volume: *At the market, Measuring and guessing! Shopping, The scale.* • recognise and name the shapes of objects in the environment: *Build based on a model! Cheerful and colourful shapes!* • perform grouping, classifying, sequencing, and measuring objects: *Where is my place? Choose and match!* • solve problem situations by identifying, sorting, and then representing data: *The bus with passengers, Move away, Tables and models.*	*Teaching methods and approaches:* educational play, discussion, brainstorming, observation, demonstration, problem-solving, exercises *Teaching aids:* toys, game kits, thematic boards, books, coloured pencils, markers, notebooks, watercolours, modelling clay, scissors, glue, coloured paper, miniature images, textiles, natural materials, scale, stopwatch, compass, hourglass, coloured cardboard, projector *Organisational forms*: *whole class, group, individual.*

Step 3. The post-experimental evaluation (post-test) – 3th – 7th June 2024 - the developmental level of scientific inquiry skills of the children in the research sample was re-assessed.

In the approach to validate the general research hypothesis, specific teaching strategies were used in teaching - learning - assessment of the content of the Science domain, the activity of Environmental Knowledge and Mathematical Activity, middle group, level I.

4. Results

The data obtained in the pre-experimental evaluation phase (L1) and the post-experimental evaluation phase (L2) of the experimental research are presented as in Table 2.

Table 2. Comparative presentation of results obtained in L1 and L2 phases

Observational indicators	Levels of research phase	FR	R	P	D	FD
I1 Identifying and illustrating cause-effect relationships	*L1*	0	4	7	6	4
	L2	0	2	7	4	8
Evolution	*L1 to L2*	-	-2	-	-2	*+4*
I2 Applying previously acquired knowledge	*L1*	2	1	7	6	5
	L2	0	1	7	5	8
Evolution	*L1 to L2*	-2	-	-	-1	*+3*
I3 Solving problems by organising and representing data	*L1*	3	6	4	5	3
	L2	0	3	6	7	5
Evolution	*L1 to L2*	-3	-3	+2	+2	*+2*
I4 Using senses and various tools to explore the environment and gather information	*L1*	1	-3	5	9	3
	L2	0	3	5	4	9
Evolution	*L1 to L2*	-1	-	-	-5	*+6*
I5 Expressing opinions about experiences, actions, and phenomena in the immediate environment	*L1*	0	6	5	7	3
	L2	0	1	8	5	7
Evolution	*L1 to L2*	-	-5	+3	-2	*+4*

Below we comparatively present the results obtained on each observational indicator in order to highlight the evolution. The comparative results obtained for I1 are presented in Figure 2.

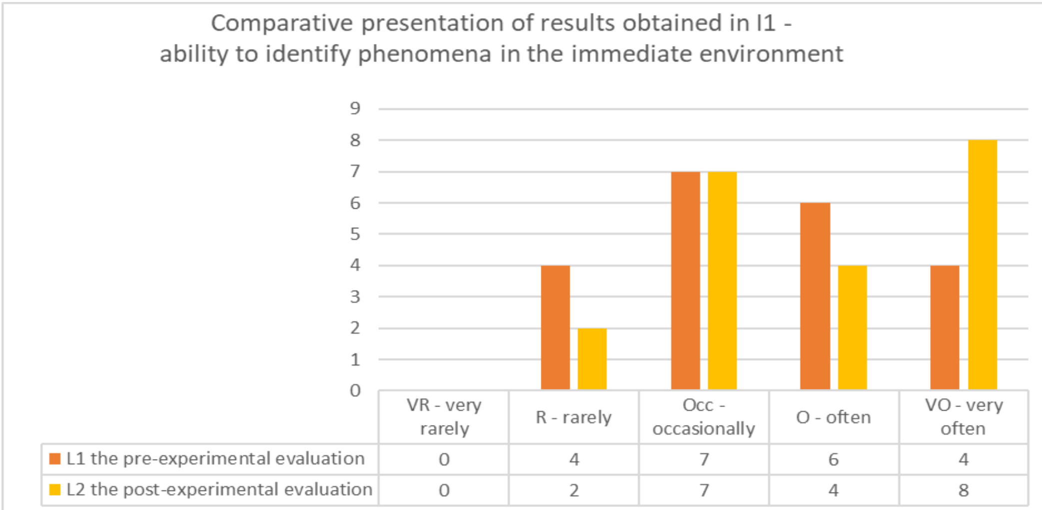

Figure 2. Graphic representationof results obtained in I1 -
ability to identify phenomena in the immediate environment

The comparative analysis of the results obtained by the pre-schoolers in I1 shows that the very rarely level remains constant (0%), the rarely level shows a decrease of 2 children (9.52%), the occasionally level remains constant (33.33%), the 'often' level shows a decrease of 2 children (9.52%), and the very often level shows a progress for 4 children (19.05%). The data show a progress in this observational indicator. The comparative results obtained for I2 are presented in Figure 3.

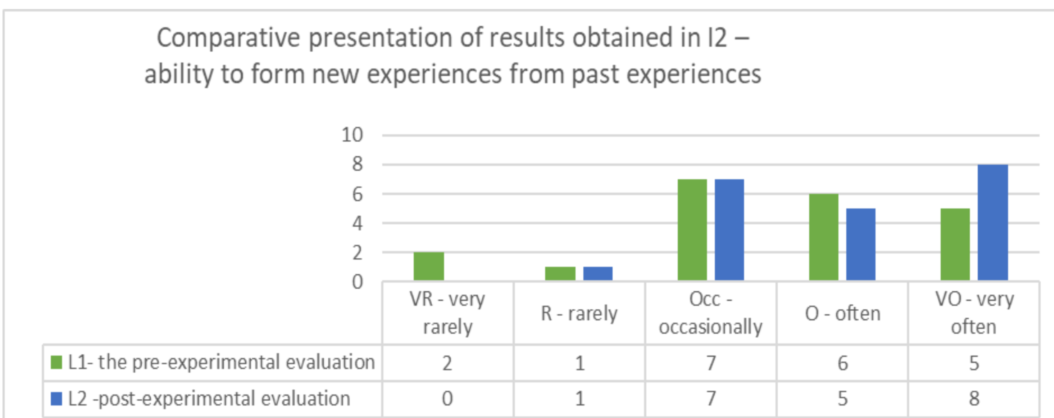

Figure 3. Graphic representationof results obtained in I2 –
ability to form new experiences from past experiences

The comparative analysis of the results obtained by pre-schoolers at I2 shows that at the *very* rarely level there is a decrease by 2 children (9.52%), at the rarely level the number of children remains constant (4.76%), at the occasionally level the number of children remains constant (33.33%), at the often level there is a decrease by 1 child (4.76%), and at the very often level there is a progress for 3 children (14.29%). The data show a progress at the level of this observational indicator.

Graphically represented, the comparative results obtained for I3 are presented in Figure 3.

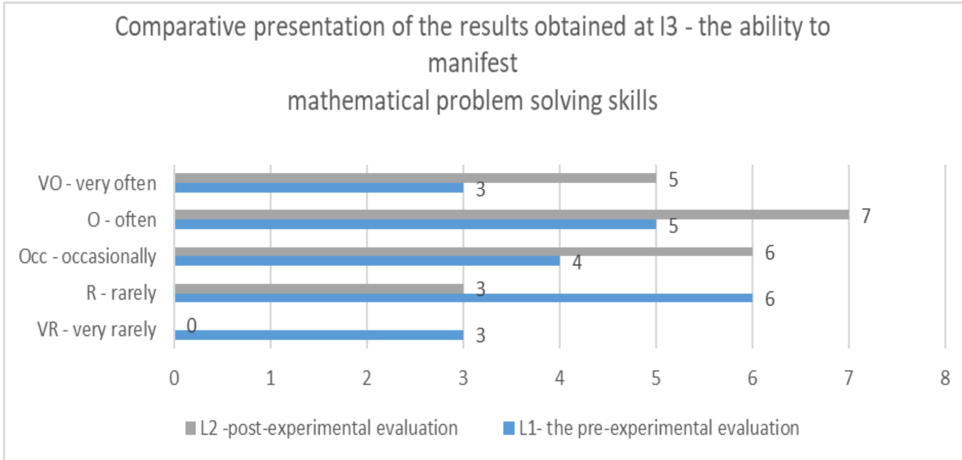

Figure 3. Graphic representationof the results obtained at I3 - the ability to manifest mathematical problem solving skills

The comparative analysis of the results obtained by the pre-schoolers at I3 shows that at the very rarely level there is a decrease of 3 children (14.29%), at the rarely level there is a decrease of 3 children (14.29%), at the occassionally level there is an increase of 2 children (9.52%), at the often level there is an increase of 2 children (9.52%) and at the very often level there is an increase of 2 children (9.52%). The data show that there is progress in this observational indicator. The comparative results obtained for I4 are presented in Figure 4.

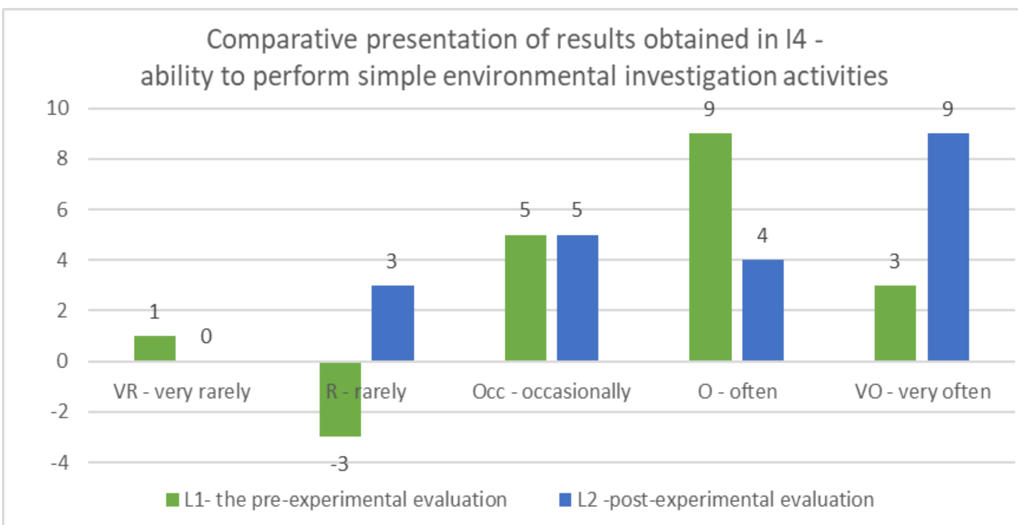

Figure 4. Graphic representationof results obtained in I4 -
ability to perform simple environmental investigation activities

The comparative analysis of the results obtained by preschoolers in I4 shows that at the very rarely level there is a decrease by 1 child (4.76%), at the rarely level the number of children remains constant (14.29%), at the occasionally level remains constant (23.81%), at the often level there is a decrease by 5 children (23.81%), and at the very often level there is a progress for 6 children (28.57%). Graphically represented, the comparative results obtained for I5 are shown in Figure 5.

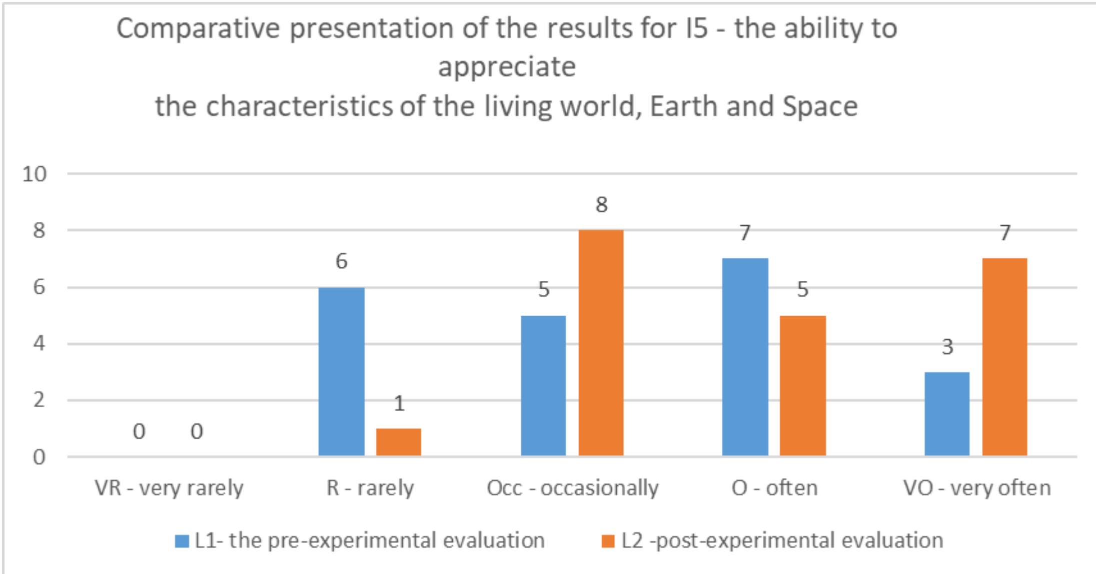

Figure 5. Graphic representationof the results for I5 - the ability to appreciate the characteristics of the living world, Earth and Space

The comparative analysis of preschoolers' results for I5 reveals the following trends: the number of children at the very rarely level remains unchanged (0%), while the rarely level shows a decrease of 5 children (23.81%). At the occasionally level, there is an improvement with 3 additional children (14.29%), while the often level sees a decrease of 2 children (9.52%). Notably, the very often level shows an increase of 4 children (19.05%). In order to highlight the overall progress in preschoolers' scientific investigation skills after the experiment, the final aggregated data are presented comparatively in Figures 6 and 7.

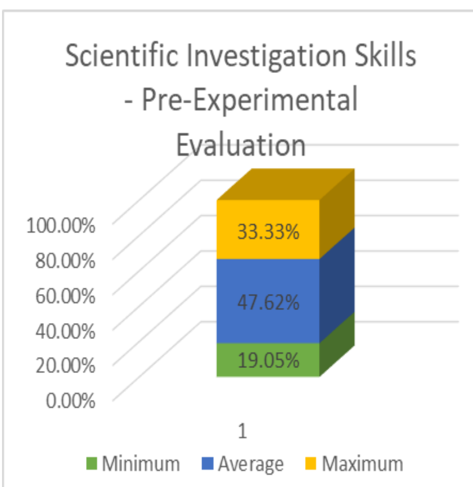

Figure 6. Scientific investigation skills - Pre-experimental test

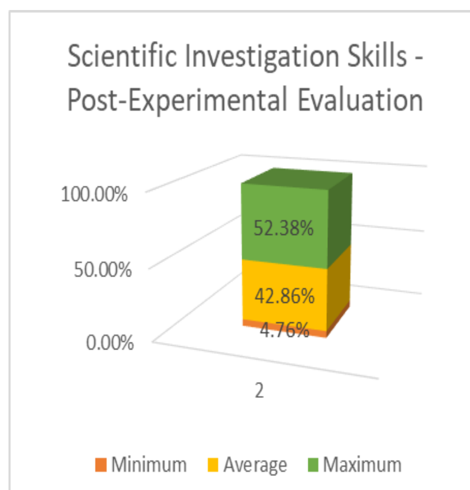

Figure 7. Scientific investigation skills - Post-experimental test

The data reveal a significant decrease in the minimum level of scientific investigation skills (from 19.05% to 4.76%, a reduction of 14.69%); a slight decrease in the average level of these skills (from 47.62% to 42.85%, a reduction of 4.77%); and a notable increase in the maximum level of scientific investigation skills (from 33.33% to 52.37%, an increase of 19.04%). These results collectively demonstrate progress in the development of scientific investigation skills among preschoolers. While the pre-experimental evaluation showed the average level as predominant, the post-experimental evaluation indicates a shift, with the maximum level becoming the most prevalent.

5. Discussions and conclusions

The data presented, analysed, and reviewed confirm the impact of the specific STEM teaching strategies employed during the experimental period on the development of preschoolers' scientific investigation skills, thereby validating the initial hypothesis of the experiment. These findings provide a basis for reflecting on the applicability of these strategies and recognising certain limitations in their use with preschool-aged children. The STEM-focused teaching strategies proved to be an effective intervention for fostering scientific inquiry skills. The activities were thoughtfully designed to ensure that learning relationships, logical operations, and inferences drawn from the children's immediate environment were meaningful and engaging. Since cognitive development and understanding of the world are intrinsically linked to other areas of child development, identifying activities that adopted a holistic approach posed a significant challenge. The effectiveness of these strategies is evidenced by a comparative analysis of pre- and post-experimental evaluation results, which show a significant improvement in the scientific inquiry skills of the preschool children in the experimental group.

The results of implementing specific teaching strategies for STEM education to develop scientific research skills in preschool children reveal several positive outcomes. Rather than acquiring information about each field of knowledge in isolation, children often make meaningful connections between disciplines, demonstrating clear links between the knowledge gained during lessons and its application in real life. They enthusiastically share their ideas and discoveries with peers, engage actively in the learning process, show perseverance in problem-solving, and develop communication skills. Children were also observed analysing and correcting their solutions, whether right or wrong, while exhibiting self-confidence, creativity, and imagination. Additionally, the teacher-student relationship improved significantly, marked by more effective communication and a notable decrease in children's dependency levels. These changes highlight important strides in their independence, decision-making abilities, self-confidence, trust in others, and capacity to manage their actions and investigative activities. Among the activities most favoured by preschoolers, which further support the development of scientific inquiry skills, are: holistic learning through play and exploration, including simple scientific experiments, construction activities, and nature exploration; hands-on, experiential projects such as recycling, gardening, and plant cultivation, as well as activities centered on environmental protection and outdoor education (Câmpan & Bocoș, 2019); collaborative projects and partnerships involving the kindergarten, families, and the community (Breiner et al., 2012; Nhil, 2021). Overall, effective STEM-specific strategies should emphasise nurturing research skills, sustaining curiosity, fostering engagement, seeking mentorship, enhancing social skills, and securing institutional support (Bouchrika, 2024).

This study has several limitations. First, the relatively short duration of the experiment restricts the findings to contextual and potential data, making them non-generalisable. Ideally, the development of preschool children's scientific investigation skills should be monitored over the entire kindergarten education span (i.e. three years). Second, the research instrument-the observation grid—was limited in robustness and lacked complementary methods or tools to enhance data validity. Third, the absence of a control group in the experiment limits the ability to compare results with an alternative baseline, which could have strengthened the validation of the findings.

Despite these limitations, we believe this action research holds value. It addresses a unique topic within preschool education, an area where such studies remain scarce (Sungur et al., 2023). Additionally, the explicit proposals for action during the formative-improvement phase contribute practical insights. Educators interested in incorporating STEM-specific strategies, particularly in kindergarten, must begin with self-reflection on their understanding and approach to STEM education (Breiner et al., 2012; Diana et al., 2021; Leung, 2023; Martín-Páez et al., 2019; Sungur et al., 2023; Wan et al., 2020). This includes evaluating their familiarity with STEM, their agreement with its principles, their willingness to implement it, their belief in its formative value, and their awareness of the challenges it entails.

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