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Unleashing Young Minds: Fostering Scientific Thinking in Early Childhood (Ages 5-9) through Experiential Learning in Kids Science Labs (STEM): Evaluation and Assessment

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ABSTRACT

Scientific thinking, characterized by purposeful knowledge-seeking and the harmonization of theory and facts, holds a crucial role in preparing young minds for an increasingly complex and technologically advanced world. This paper presents a research study aimed at fostering scientific thinking in early childhood, focusing on children aged 5 to 9 years, through experiential learning in Kids Science Labs (STEM). The study utilized a longitudinal exploration design, spanning 240 weeks from September 2018 to April 2023, to evaluate the effectiveness of the Kids Science Labs program in developing scientific thinking skills. Participants in the research comprised 72 children drawn from local schools and community organizations. Through a formative psychology-pedagogical experiment, the experimental group engaged in weekly STEM activities carefully designed to stimulate scientific thinking, while the control group participated in daily art classes for comparison. To assess the scientific thinking abilities of the participants, a registration table with evaluation criteria was developed. This table included indicators such as depth of questioning, resource utilization in research, logical reasoning in hypotheses, procedural accuracy in experiments, and reflection on research processes. The data analysis revealed dynamic fluctuations in the number of children at different levels of scientific thinking proficiency. While the development was not uniform across all participants, a main leading factor emerged, indicating that the Kids Science Labs program and formative experiment exerted a positive impact on enhancing scientific thinking skills in children within this age range. The study's findings support the hypothesis that systematic implementation of STEM activities effectively promotes and nurtures scientific thinking in children aged 5-9 years. Enriching education with a specially planned STEM program, tailoring scientific activities to children's psychological development, and implementing well-planned diagnostic and corrective measures emerged as essential pedagogical conditions

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for enhancing scientific thinking abilities in this age group. The results highlight the significant and positive impact of the systematic-activity approach in developing scientific thinking, leading to notable progress and growth in children's scientific thinking abilities over time. These findings have promising implications for educators and researchers, emphasizing the importance of incorporating STEM activities into educational curricula to foster scientific thinking from an early age. This study contributes valuable insights to the field of science education and underscores the potential of STEM-based interventions in shaping the future scientific minds of young children.

1. Introduction

In recent decades, the field of education has witnessed significant transformations driven by evolving societal needs, advancements in psychology and pedagogy, and the introduction of innovative teaching methods. Scientific thinking, a crucial cognitive skill, plays a fundamental role in children's development by laying the foundation for lifelong learning and problem-solving abilities. Early childhood is a critical period where children exhibit innate curiosity and a strong desire for knowledge. Nurturing and harnessing this curiosity through the development of scientific thinking skills is essential for their intellectual growth.

However, there remains a research gap in understanding the most effective ways to foster scientific thinking in early childhood, particularly through experiential learning approaches. This study aims to address this gap by investigating the impact of implementing a unique and innovative afterschool STEAM (Science, Technology, Engineering, Arts, and Mathematics) intervention program at Kids Science Labs on the development of scientific thinking in children aged 5-9 years.

The primary objective of this study is to evaluate and assess the components of scientific thinking in children aged 5-9, focusing on their ability to ask questions, conduct research, formulate hypotheses, design experiments, analyze data, and draw conclusions. These components are crucial for fostering scientific thinking skills and promoting critical and analytical thinking abilities in young learners.

In the present study, we propose evaluation criteria and indicators specific to each component of scientific thinking. These criteria are designed to capture the depth, relevance, difficulty, originality, and logical reasoning exhibited by children in their scientific thinking processes. To measure children's performance in each component, various assessment methods, including observation, interviews, and questionnaires, will be employed. These methods will utilize age-appropriate language and appropriate evaluation techniques to ensure the validity and reliability of the assessment process.

By evaluating and assessing the components of scientific thinking in children aged 5-9, this study aims to contribute to the understanding of their cognitive development and provide educators, researchers, and practitioners with effective tools to assess and foster scientific thinking skills. The findings of this study will inform educational practices and interventions that promote scientific thinking in young children, enabling them to become curious, analytical, and critical thinkers capable of tackling complex problems. Ultimately, this research aims to lay the groundwork for future investigations and advancements in early childhood STEM education and scientific thinking development.

2. Literature Review

Scientific thinking, characterized by purposeful knowledge-seeking and the integration of theory and facts, encompasses diverse phases and essential skills (Kuhn, 2010). At its core, scientific thinking encompasses a wide range of abilities crucial for inquiry, experimentation, evidence evaluation, and drawing inferences, all of which play a significant role in conceptual change and the pursuit of scientific understanding (Stohlmann, Moore&Roehrig, 2012; Thitima&Chaijaroen, 2012 ; Zimmerman, 2007).

Certain studies have placed significant emphasis on critical skills, such as hypothesis formulation, comprehension of the nature of science, theories, and experimental design (Mayer, Sodian, Koerber& Schwippert, 2014; Schlatter, Molenaar & Lazonder, 2021).

Despite significant psychological and pedagogical studies on scientific thinking in the past decade (Burke & Williams, 2008; Dejonckheere, Wit, Keere & Vervaet, 2016; King & Wiseman, 2001; Kuhn, 2010; Morrison, 2006), there remains a gap in formulating a general structure of scientific thinking tailored to the psychological and pedagogical development of children aged 5-9 years.

In the realm of psychological and pedagogical research, it has been established that integrated curricula and technology-enhanced learning positively impact learning outcomes (Bybee, 2010).

STEM education offers numerous benefits, including the development of problem-solving abilities, innovation, self-confidence, logical reasoning, and technology literacy (Morrison, 2006). Despite these advantages, the promotion of scientific thinking in early childhood through an interdisciplinary research environment has received limited attention in research and educational practice. However, recent evidence supports the positive impact of technology-assisted education on high school (Fikriyah, Kassymova, Novita&Retnawati, 2022). These studies are particularly relevant in the context of national initiatives to foster STEM skills and support STEM-related education (Committee on STEM Education, 2018; National Research Council, 2007, National Science Board, 2007-2010).

Integrated curricula have been recognized for providing relevant, coherent, and engaging learning experiences for students (Furner& Kumar, 2007). Previous studies have reported improvements in thinking skills, memory performance, and problem-solving abilities resulting from integrated curricula (Fllis & Fouts, 2001; King& Wiseman, 2001; Smith& Karr-Kidwell, 2000).

According to certain researchers, STEM education is gaining growing significance in equipping students for a technologically advanced society, offering them the chance to cultivate intricate problem-solving abilities, effective communication, and collaboration skills (Breiner, Harkness, Johnson & Koehler, 2012; Burke, & Williams, 2008).

In a real-world practical experiment (Dejonckheere at al., 2016) the attention and comprehension of causal events at the level of scientific thinking skills were assessed among 4-6 year-olds. The study integrated the inquiry-based didactic method for preschool science to evaluate its impact. The findings revealed that 6-year-old children engaged in the scientific thinking circle demonstrated significantly higher adherence to physical laws and a lower occurrence of actions that contradicted these laws, in comparison to the control group. However, similar effects were not observed in the other age groups.

Asmoro Seto Prio (2021) emphasized the importance of implementing learning models that provide students with opportunities to engage in scientific activities, as it can empower their scientific thinking skills. Hands-on activities and active participation in scientific processes contribute to the development of critical thinking and inquiry skills.

The urgency to improve STEM (Science, Technology, Engineering, and Mathematics) education has been acknowledged due to the accelerating pace of global innovation and the increasing competition for STEM talent (Committee on STEM Education, 2018). The National Science Board (2007 and 2010) highlighted the need for a nationwide effort aligned with the goals of STEM education and emphasized the significance of qualified and effective teachers in teaching STEM classes. However, attracting, preparing, and retaining qualified teachers in STEM fields remains a challenge that requires further attention.

In the fields of psychology and pedagogy, numerous studies are dedicated to evaluating the effectiveness of diverse STEM-educational approaches (Breiner at al, 2012; Bybee, 2010, Dejonckheere at al., 2016; Morrison, 2006). Integrated STEM education has emerged as a highly promising method to enhance learning by fostering connections and relevance across a wide range of subjects. By seamlessly integrating science, technology, engineering, and mathematics, students are exposed to interdisciplinary learning experiences that closely resemble real-world problem-solving scenarios and effectively cultivate critical thinking skills.(Stohlmann at al., 2012)

The reviewed literature highlights the importance of scientific thinking skills, the components of scientific thinking, the impact of integrated curricula and technology-assisted learning on learning outcomes, and the benefits of STEM education. The researches emphasizes the need for interdisciplinary research environments in early childhood education to foster scientific thinking. The positive effects of technology-assisted education and integrated curricula provide further support for the integration of STEM subjects and the use of innovative teaching approaches. However, further research is required to explore the most effective strategies and approaches to promote scientific thinking skills among children in the targeted age range.

Through a rigorous examination of scientific, psychological, and pedagogical literature, a research problem has emerged, shedding light on the juxtaposition between the criticality of introducing STEM education as a means to cultivate scientific thinking in children and the scarcity of empirical research in this field.

This contradiction stems from various notable disparities:

The imperative to introduce STEM education from an early age, highlighting the pressing need for programs that prioritize developmental activities through hands-on STEM experiences for students.

The insufficient progress in the development of STEM activities within preschools and primary schools and after-school programs, resulting in a significant gap in offering comprehensive and well-rounded STEM learning opportunities.

The need for the implementation of effective strategies and methodologies to foster scientific thinking skills, while lacking a precise measurement tool for accurate assessment and evaluation of these skills.

The call for the integration of STEM learning in educational institutions, juxtaposed with the existing scarcity of qualified teachers equipped with the necessary expertise and competencies in STEM education.

These contradictions emphasize the urgent and compelling demand for empirical and scientific research to address these gaps and challenges. They serve as the foundational basis for the purpose of this study: to investigate the formation and development of scientific thinking in children aged 5 to 9 years through a specially designed STEM activity. By exploring this research area, the study aims to contribute to the existing body of knowledge, provide valuable insights, and pave the way for effective strategies and interventions in promoting scientific thinking skills among young children.

Research Hypothesis: The effective development of scientific thinking in children aged 5-9 through specially organized STEM activities can be achieved by:

- Identifying the components of scientific thinking, establishing criteria, indicators, and methods for the formation and development of scientific thinking in children aged 5-9.
- Exploring the psychological and pedagogical features of STEM activities for fostering scientific thinking in children aged 5-9.
- Applying a systematic and activity-based approach to the development of scientific thinking in children aged 5-9.
- Establishing and implementing pedagogical conditions to effectively develop scientific thinking, including:
  a) Informational conditions - enriching educational programs with STEM tasks.
  b) Organizational conditions - involving children in scientific activities, considering their psychological development at this age.
  c) Diagnostic and corrective conditions - implementing diagnostic and corrective measures to facilitate the development of scientific thinking in children aged 5-9.

Aligned with the purpose and hypothesis, the study aims to accomplish the following objectives:

- Investigate and analyze the issue of developing scientific thinking in children aged 5-9 years and propose strategies for addressing it.
- Clarify and define key concepts related to the research problem, such as "scientific thinking in children aged 5-9" and "developing STEM activity."
- Determine the criteria, indicators, and assessment methods for evaluating each component of scientific thinking in children aged 5-9, taking into account their psychological characteristics at this developmental stage.
- Identify and experimentally examine the effectiveness of pedagogical conditions that contribute to the development of scientific thinking in children aged 5-9.
- Develop scientific and methodological recommendations for elementary school teachers to foster the development of scientific thinking in children aged 5-9. These recommendations will provide practical guidance for educators in implementing effective strategies and approaches.

By addressing these tasks, the study aims to contribute to the existing knowledge on the development of scientific thinking in children aged 5-9 and provide valuable insights for educators and practitioners in promoting scientific thinking skills in this age group.

3. Methodology

3.1. Registration Table and Evaluation Criteria

The development of scientific thinking in children aged 5 to 9 years was comprehensively assessed using a registration table that incorporated evaluation criteria for each indicator. This subsection outlines the process of developing the registration table, the criteria used for evaluation, an explanation of the numerical scores and corresponding levels of development of scientific thinking, and the research design of the study.

3.2. Research Design

This study employed a longitudinal exploration design, spanning a duration from September 2018 to April 2023, with a total duration of 240 weeks. The research aimed to investigate the effectiveness of the STEM education program, Kids Science Labs, in fostering the development of scientific thinking in children aged 5 to 9 years. The study adopted a formative psychology-pedagogical experiment, implementing a unique and innovative experimental intervention STEM program for the experimental group, while the control group engaged in daily art classes.

3.3. Participants

A total of 72 regular study participants were included in this research, drawn from a target population comprising children aged 5 to 9 years. The experimental group consisted of 37 participants (21 boys, 16 girls), while the control group comprised 35 participants (17 boys, 18 girls). These participants were recruited from diverse sources, including local schools and community organizations, in collaboration with the non-profit organization "House of Talents," which facilitated the implementation of the Kids Science Labs program.

3.4. Intervention Program

The experimental group participated in the Kids Science Labs STEM program, offering weekly extra-curricular activities.

Considering the age range of the children who participated in our experimental study, which included 5-9-year-olds—a stage highly sensitive to cognitive development encompassing attention, perception, thinking, memory, sensation, representation, and imagination—our STEM extracurricular program was meticulously crafted based on psychological and pedagogical principles. This approach was designed to effectively nurture children's scientific thinking.

Outlined below is a synopsis of the core psychological and pedagogical principles underpinning the extracurricular STEM program:

3.4.1. Hands-on Learning

Within the framework of STEM education, our emphasis was on experiential learning, with a focus on hands-on, exploratory activities that empowered children to independently explore and uncover scientific concepts. Specifically designed to foster scientific thinking skills in children, the activities encompassed question formulation, research, hypothesis development, experiment design, execution of experiments, data analysis, and drawing conclusions.

3.4.2. Scaffolding and Support

Throughout the process of experiential learning, we provided structured support and guidance tailored to the child's age and individual psychological development. Over time, we gradually reduced this support, delegating decision-making authority to the child or a group of children. This approach encouraged the growth of independence, self-confidence, and self-esteem. It not only facilitated the progressive development of scientific thinking skills but also ensured emotional comfort, contributing to the child's overall personality and interpersonal relationship development.

3.4.3. Game-Based Training

All our STEM sessions centered around playful, hands-on activities that fostered exploration, creativity, curiosity, imagination, and experimentation. The material was presented in a manner that encouraged children to identify cause-and-effect relationships and engage in critical thinking and reasoning.

3.4.4. Reflection and Metacognition

Within our STEM groups, we focused on nurturing reflection through the comprehensive analysis of obtained results. This approach directed attention not only to the search activity process itself but also to the changes that stemmed from it. This facilitated the development of metacognitive skills—equipping them with the ability to set personal goals, devise plans and action strategies, and effectively solve problems.

3.4.5. Inquiry-Based Approach

Our tasks were meticulously designed to stimulate children to ask questions, hypothesize, and seek answers through exploration. This approach fostered the development of critical thinking and curiosity.

3.4.6. Child-Centric Activities

Our classes were adapted to the age and catered to the interests and preferences of the children, allowing them to choose topics that captivated their attention. This customization increased engagement and motivation, promoting the development of attention stability and children's arbitrary memory. The flexibility in our program design ensured that children remained engaged and successful.

3.4.7. Collaboration and Communication

We actively encouraged collaborative activities where children worked together, exchanged ideas, and discussed their discoveries. Group activities fostered teamwork, idea exchange, and result discussions, enhancing communication skills and empathy towards diverse viewpoints.

3.4.8. Real-World Context

Our STEM activities were linked to the real-world context of children's lives. This made learning meaningful and practical, broadening their horizons and helping them view the world from multiple perspectives, encouraging the formulation of their own questions and understanding diverse viewpoints.

3.4.9. Positive Reinforcement and Encouragement

We placed particular emphasis on the emotional and volitional development of children in this age group. In this age, self-esteem, self-confidence, and autonomy were beginning to form. Consequently, assessments from both adults and peers became significant. Positive feedback and praise for their efforts, self-expression, and discoveries boosted children's confidence and motivation to engage in scientific thinking.

3.4.10. Assessment for Learning

Our evaluation approach incorporated informal assessments such as open-ended questions, observations, and discussions to gauge children's understanding and make necessary adjustments.

By integrating these psychological and pedagogical principles, our STEAM after-school program was designed to effectively nurture scientific thinking in children aged 5-9 years. This holistic approach fostered a supportive and engaging environment where children comfortably flourished, explored, inquired, and developed essential scientific thinking skills. Throughout the program, the experimental group actively engaged in age-appropriate science experiments and hands-on exploration.

Furthermore, diagnostic experiments were conducted, and feedback results were processed to identify individual strengths and areas for improvement in the children participating in the experimental group. This approach aimed to enhance each child's scientific thinking abilities, and appropriate corrective methods were selected as needed.

3.5. Data Collection

Data collection occurred at intervals of 40 weeks, allowing for a comprehensive assessment of the research process. Both quantitative and qualitative data were collected to capture various aspects of the study. The data collection methods included:

1. **Observation:** Trained researchers observed and documented the participants' engagement, interactions, and progress throughout the program.
2. **Surveys:** Participants and their parents/guardians were administered surveys to gather information about their experiences, perceptions, and changes in scientific thinking skills.
3. **Assessments:** Standardized assessments were conducted to measure the participants' scientific thinking abilities at different stages of the study.
4. **Interviews:** Selected participants were interviewed to gain further insights into their experiences, challenges, and progress within the program.

3.6. Registration Table and Evaluation Criteria

The registration table (Table 1) was meticulously designed to capture essential components of scientific thinking, providing a structured framework for evaluation. It consisted of six key components: ability to ask questions, conduct research, formulate hypotheses, design experiments, data analysis, and Conclusion. Within each component, specific indicators were identified to assess the child's proficiency in various aspects of scientific thinking.

To evaluate the child's performance in each indicator, a numerical assessment ranging from 0 to 5 was used, reflecting different levels of competency:

0: No Evidence - The child does not demonstrate any of the indicated behaviors or skills related to the specific criterion.

1: Minimal - The child shows minimal evidence of the indicated behaviors or skills but does not fully meet the expected level.

2: Emerging - The child is beginning to exhibit the indicated behaviors or skills, but there are inconsistencies or limitations in their application.

3: Developing - The child is making progress in demonstrating the indicated behaviors or skills, although there may still be room for improvement or refinement.

4: Proficient - The child consistently demonstrates the indicated behaviors or skills at an appropriate level for their age, with few errors or limitations.

5: Advanced - The child consistently and effectively demonstrates the indicated behaviors or skills at an advanced level, surpassing expectations for their age.

Table 1 (part 1).
Assessment of Scientific Thinking Components (part 1)

Component	Evaluation Criteria	Indicators	Assessment (0-5)
Ability to ask questions	1. Depth of questioning	- Asks open-ended questions	[0-5]
	2. Relevance of questions	- Asks questions related to the topic	[0-5]
	3. Complexity of questions	- Asks questions that require thinking and analysis	[0-5]
Conduct research	1. Resource utilization	- Uses age-appropriate sources for information	[0-5]
	2. Organization of research materials	- Keeps notes or records of research findings	[0-5]
	3. Understanding of the topic	- Demonstrates comprehension of researched information	[0-5]
Formulate hypotheses	1. Logical reasoning	- Provides plausible explanations or predictions	[0-5]
	2. Originality of hypotheses	- Proposes unique or creative hypotheses	[0-5]
	3. Relevance to the research question	- Links hypotheses to the topic being investigated	[0-5]

Table 1 (part 2).
Assessment of Scientific Thinking Components (part 2)

Component	Evaluation Criteria	Indicators	Assessment (0-5)
Design experiments	1. Procedural accuracy	- Planning. Follows steps of the experiment correctly	[0-5]
	2. Consideration of variables	- Identifies and controls relevant variables	[0-5]
	3. Predicted outcomes	- Anticipates possible results of the experiment	[0-5]
Data Analysis	1. Observation and recording accuracy	- Records data accurately and systematically	[0-5]
	2. Identification of patterns or trends	- Recognizes recurring patterns or trends in the data	[0-5]
	3. Ability to make basic connections	- Links data observations to hypotheses or research questions	[0-5]
Conclusion	1. Summary of findings	- Provides a concise summary of the experiment's outcomes	[0-5]
	2. Justification of conclusions	- Provides reasoning or evidence to support the conclusions	[0-5]
	3. Reflection on the research process	- Reflects on the experiment and discusses lessons learned	[0-5]

These numerical scores provide a relative measure of the child's proficiency in each indicator, allowing for a more detailed assessment of their development in scientific thinking. Based on the total numerical indicators, participants were categorized into different levels of development of scientific thinking, namely Novice Thinker, Developing Thinker, Competent Thinker, Proficient Thinker, and Expert Thinker.

3.7. Levels of Development of Scientific Thinking

Based on the total numerical indicators for all selected components, participants were classified into different levels of development of scientific thinking:

Novice Thinker: Total Numerical Range: 0-18 Description: The child is in the early stages of developing scientific thinking skills. They show minimal evidence or understanding of the components assessed. Further support and guidance are needed to foster their scientific thinking abilities.

Developing Thinkers: Total Numerical Range: 19-36 Description: The child is making progress in developing scientific thinking skills. They demonstrate emerging or developing abilities in some of the assessed components. With continued practice and guidance, their scientific thinking skills can be further enhanced.

Competent Thinker: Total Numerical Range: 37-54 Description: The child has developed a solid foundation in scientific thinking skills. They consistently demonstrate proficient abilities across most of the assessed components. They show a good understanding of scientific concepts and can apply them effectively.

Proficient Thinker: Total Numerical Range: 55-72 Description: The child is a proficient scientific thinker. They consistently demonstrate advanced abilities in the assessed components. They exhibit a high level of understanding, critical thinking, and problem-solving skills in scientific contexts. They are able to independently and effectively apply scientific principles.

Expert Thinker: Total Numerical Range: 73-90 Description: The child is an expert scientific thinker. They excel in all assessed components and consistently demonstrate exceptional abilities in scientific thinking. They display a deep understanding of scientific concepts, exceptional critical thinking skills, and the ability to conduct complex scientific investigations. They exhibit a high level of creativity, innovation, and scientific inquiry.

It is important to note that each child's development is unique, and their progress should be considered in the context of their individual abilities and experiences. The registration table and evaluation criteria served as a valuable tool in assessing the impact of the Kids Science Labs program on the development of scientific thinking in children aged 5 to 9 years.

4. Results

The Results section depicts the outcomes of a longitudinal investigation concerning the advancement of scientific thinking in children aged 5-9 years, concentrating on evaluating the impact of a systematic-activity approach in nurturing scientific thinking. The study consisted of two groups: an experimental group engaging in weekly STEM activities and a control group without any STEM involvement. The data was collected and analyzed over a span of 240 weeks, starting from September 2018 to April 2023.

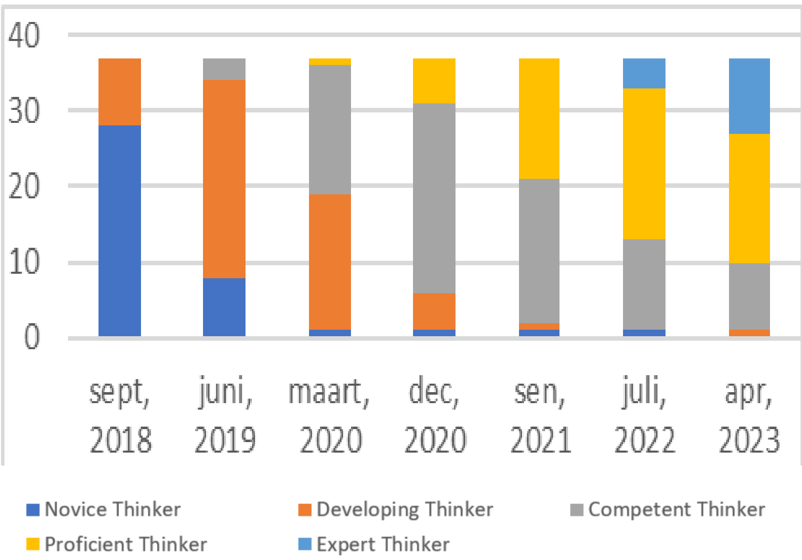

Figure 1. Development of Scientific Thinking in Children of experimental group

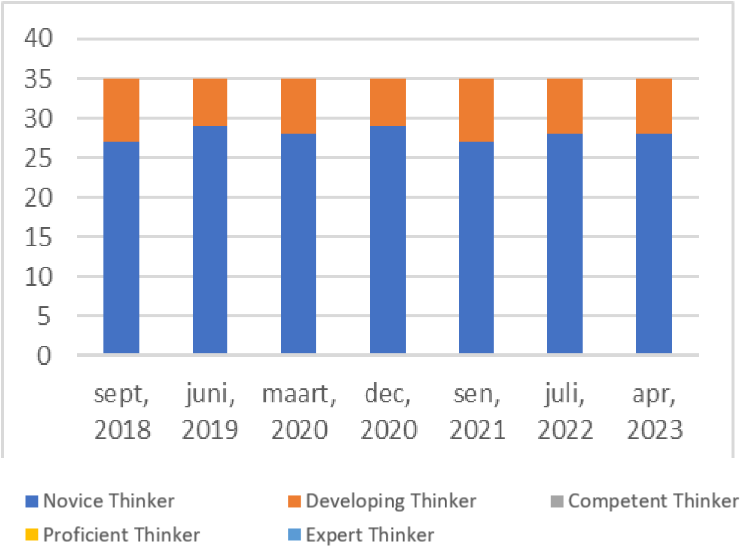

Figure 2. Development of Scientific Thinking in Children of control group

The bar graphs depict the distribution of children in each level of scientific thinking for both the control group (e.g. Figure 2) and the experimental group (e.g. Figure 1). The x-axis represents different time periods: September 2018, June 2019, March 2020, December 2020, September 2021, July 2022, and April 2023. The y-axis represents the number of children falling into each category of scientific thinking: "Novice Thinker," "Developing Thinker," "Competent Thinker," "Proficient Thinker," and "Expert Thinker."

In the experimental group, we observed significant changes in the distribution of participants across different levels of scientific thinking over the 240-week period. The number of participants classified as "Novice Thinker" decreased, while the number of participants in higher categories such as "Developing Thinker," "Competent Thinker," "Proficient Thinker," and even "Expert Thinker" consistently increased. The longitudinal analysis demonstrated that the systematic implementation of STEM activities played a pivotal role in fostering advanced scientific thinking skills, as evidenced by participants reaching the "Expert Thinker" level.

In contrast, the control group, which did not receive any STEM activities, showed minimal variation in the number of participants in different levels of scientific thinking throughout the experiment. The majority of participants remained classified as "Novice Thinker" and "Developing Thinker" at every time point, with no observable progress towards higher levels of scientific thinking.

Statistical analyses were conducted to quantify the differences and significance between the groups. At the beginning of the experiment, the t-test showed no statistically significant difference between the performance of the experimental and control groups (t-value = 0.632, df = 70, p-value > 0.05). However, at the end of the experiment, the t-test revealed a statistically significant difference between the two groups (t-value = 3.256, df = 70, p-value < 0.05), indicating a positive impact of the systematic implementation of STEM activities in fostering scientific thinking skills compared to the control group's lack of progress.

Moreover, within the experimental group, a paired t-test compared the data at the beginning and end of the 240-week experiment. The comparison revealed a significant improvement in scientific thinking skills (t-value = 7.152, df = 36, p-value < 0.05). Participants demonstrated notable progress, as reflected in the considerable increase in the number of "Proficient Thinkers" and "Expert Thinkers" by the end of the study period.

The data highlights that the development of scientific thinking skills in children aged 5-9 years is a dynamic process, with fluctuations in the number of children at different levels of proficiency. While the development may not be uniform, the presence of a main, leading factor that drives progress suggests that the efforts of the Kids Science Labs and the formative experiment have a positive impact on enhancing scientific thinking skills in children during this critical age range.

In conclusion, the findings of this study support the hypothesis that the systematic implementation of STEM activities can effectively promote and nurture scientific thinking in children aged 5-9 years. The enrichment of education with a specially planned STEM program, the involvement of children in scientific activities tailored to their psychological development, and the implementation of well-planned diagnostic and corrective measures are essential pedagogical conditions for enhancing scientific thinking abilities in this age group.

The results demonstrate that the use of a systematic-activity approach in the development of scientific thinking has a significant and positive impact, leading to notable progress and growth in children's scientific thinking abilities over time. The implications of these findings are promising for educators and researchers alike, highlighting the importance of incorporating STEM activities into educational curricula to foster scientific thinking from an early age. This study contributes valuable insights to the field of science education and underscores the potential of STEM-based interventions in shaping the future scientific minds of young children.

5. Conclusion and Significance

The results of the study support the hypothesis that a systematic-activity approach to the development of scientific thinking in children aged 5-9 is effective, provided specific pedagogical conditions are met:

a) The enrichment of education with a specially planned STEM program in the experimental group led to significant advancements in scientific thinking compared to the control group without STEM-activity. The longitudinal analysis revealed a substantial increase in the number of participants progressing from the "Novice Thinker" level to higher categories, such as "Developing Thinker," "Competent Thinker," "Proficient Thinker," and even "Expert Thinker." The systematic exposure to STEM activities facilitated the development of critical thinking, problem-solving skills, and a deeper understanding of scientific concepts, thereby nurturing the growth of scientific thinkers.

b) The involvement of children in scientific activities, tailored to their psychological development at this age, played a crucial role in enhancing their scientific thinking abilities. By engaging children in hands-on experiments and exploration, the experimental group was immersed in an environment that fostered curiosity and a sense of discovery. This active participation allowed children to make connections between theoretical concepts and real-world phenomena, encouraging them to ask questions, form hypotheses, and analyze data critically.

c) The well-planned diagnostic and corrective measures implemented in the experimental group contributed to the continuous development and improvement of scientific thinking skills in children aged 5-9 years. Periodic assessments and feedback sessions allowed educators to identify individual strengths and areas for improvement in each child's scientific thinking abilities. Targeted interventions and support were provided to address specific challenges and enhance overall scientific reasoning.

The statistical analyses conducted on the data reinforced the effectiveness of the systematic-activity approach. The comparison between the experimental and control groups at the end of the experiment showed a statistically significant difference (p-value < 0.05) in the development of scientific thinking, indicating that the implementation of weekly STEM activities had a positive impact on the experimental group's progress.

In conclusion, the findings of this study highlight the significance of incorporating a systematic-activity approach into the education of children aged 5-9 years to foster their scientific thinking skills. The combination of a specially planned STEM program, tailored scientific activities, and personalized diagnostic and corrective measures serves as a powerful framework for promoting scientific thinking in young minds. These results have valuable implications for educational practices, emphasizing the importance of creating an enriched learning environment that nurtures scientific curiosity and critical thinking from an early age. The successful implementation of STEM-based interventions paves the way for empowering the next generation of scientific thinkers and fostering a deep appreciation for the wonders of the natural world.

5.1. Theoretical Significance

This study holds considerable theoretical significance as it contributes valuable insights to the field of science education and child development. By investigating the development of scientific thinking in children aged 5-9 years, it enhances our understanding of how young minds acquire and progress in their scientific thinking abilities. The findings support the idea that a systematic-activity approach, such as incorporating STEM activities, can serve as an effective pedagogical tool to foster scientific thinking from an early age. Understanding the factors that influence the development of scientific thinking in children can inform educators and researchers in designing more effective and targeted educational interventions.

5.2. Practical Significance

The practical significance of this study lies in its potential to impact preschool and elementary school education positively. The research provides evidence-based recommendations for teachers to foster the development of scientific thinking in young children effectively. Teachers can implement the suggested strategies, such as enriching education with a structured STEM program, tailoring scientific activities to match children's psychological development, and employing well-planned diagnostic and corrective measures. By incorporating these practical guidelines into their teaching methodologies, educators can enhance the scientific thinking abilities of their students, empowering them to become curious, critical, and innovative problem solvers.

Additionally, the study's results emphasize the importance of early exposure to STEM activities in educational curricula. By introducing STEM concepts and fostering scientific thinking from a young age, educators can lay a strong foundation for children's future academic and professional pursuits. This research serves as a catalyst for promoting the integration of STEM-based interventions in elementary school curricula, preparing the next generation to thrive in a rapidly evolving and technology-driven world.

In conclusion, the theoretical and practical significance of this study lies in its contributions to the understanding of scientific thinking development in children aged 5-9 years and its practical implications for educators to foster scientific thinking effectively. By leveraging the insights gained from this research, educators and policymakers can work together to create innovative and impactful educational approaches that nurture young minds and cultivate a future generation of scientifically adept individuals.

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