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INQUIRY-BASED SCIENCE APPROACH IN KINDERGARTEN: A SYSTEMATIC REVIEW

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Abstract

Inquiry-based learning is a pedagogical approach that empowers learners to actively construct knowledge by engaging in problem-solving, critical thinking, questioning, and hands-on experiences. The inquiry-based approach in science emphasizes learners' active role in creating their understanding of the natural world. This review critically examines the application and impact of inquiry-based science approaches in kindergarten education. Through a thorough analysis of 16 research articles, the study shed light on different aspects of inquiry-based learning, including subject areas, participants, methodologies, types of inquiry-based approaches, theoretical frameworks, and impacts on learning outcomes. Findings show a predominant focus on early years' science, with kindergarten children being the primary participants. The use of qualitative research methods shows a trend toward a comprehensive understanding of the issue. The study underscore the significance of using inquiry-based learning approach in kindergarten education and offers helpful information for teachers, decision-makers, and researchers. It also emphasizes the need for further empirical studies, particularly those addressing instructional models, challenges faced in the classroom to execute inquiry-based learning, and longitudinal studies to evaluate the long-term impacts of inquiry-based science education on kindergarten children performance.

Keywords: inquiry-based, kindergarten, science

INTRODUCTION

Recent years have seen an increase in awareness of the value of early science education and its benefits for children's cognitive growth and future academic success (Junge et al., 2021). Kindergarten is crucial for promoting children's natural curiosity, inquiry, and comprehension of the natural world because it is the early years of formal education. The inquiry-based approach, which strongly emphasizes inquiry, active learning, and hands-on experiences, has attracted much interest in science education. Scientific instruction that uses inquiry-based approaches has many advantages for learners. Inquiry-based science instruction in kindergarten increases children's enthusiasm to learn while improving their comprehension of scientific ideas. Children can actively develop their knowledge using this approach by

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observing their surroundings, conducting experiments, and working with peers (Eti & Sığırmaç, 2021).

The inquiry-based approach in science emphasizes learners' active role in creating their understanding of the natural world. Jerrim et al. (2022) and Öztürk et al. (2022) discovered that, compared to students who received traditional didactic training. Also, Hala and Xhomara (2022) pointed out that students who participated in inquiry-based science learning showed superior conceptual knowledge and problem-solving abilities. Despite the apparent advantages, a thorough literature study is required to assess the use and efficacy of inquiry-based techniques in science learning, particularly in kindergarten. By combining existing studies and offering insights into the application and effects of inquiry-based science instruction in kindergartens, this systematic review seeks to fill this knowledge vacuum. The conclusions will guide future studies in this area and help to establish evidence-based approaches. Ultimately, the research hopes to improve the early years of science education by giving young students a solid foundation in scientific thinking and inquiry techniques. Thus, the following research questions guide the review:

1. What are the subject areas, participants, and methodologies used in teaching science with IBL in kindergarten education?
2. What are the types of inquiry-based approaches and theoretical frameworks employed for science instruction in kindergarten classrooms?
3. How does an inquiry-based approach impact learning outcomes in kindergarten children?

Inquiry-based science education in kindergarten

Across the globe, there has been an increasing emphasis on science education reform due to pressing global challenges (National Research Council, 2000). The vision of science education goes beyond students' acquisition of scientific knowledge; it emphasizes developing skills for reasoning, problem-solving, and decision-making related to these challenges. Science education has consistently researched and examined the nature of science teaching and learning. One crucial focus of this discourse has been allowing students to actively engage in scientific processes and practices, commonly called scientific inquiry (Forbes et al., 2020). Inquiry is a pedagogical approach that entails exploring the natural or physical world, which prompts the formulation of questions, the acquisition of new knowledge, and the testing of found knowledge, all in pursuit of gaining new insights and understanding (Poekert, 2011). The inquiry-based approach is a student-centered method where students actively explore their immediate surroundings, build solid reasoning about the natural and physical world through sound justifications, develop an understanding of the importance of science, and construct knowledge related to actions, life and thinking (Aktamiş et al., 2016). Inquiry-based learning (IBL) emphasizes active learning rather than relying solely on teacher-directed instruction. IBL is a pedagogical approach that empowers learners to actively construct knowledge by engaging in problem-solving, critical thinking, questioning, and hands-on experiences (Dostál, 2015; Lau et al., 2017). In the context of IBL, learners actively engage in hands-on exploration, interact with materials, formulate questions, collect evidence, exchange ideas, and reach conclusions (Rikmanis et al., 2012).

Studies investigating inquiry-based science education (IBSE) implementation in teaching and learning have consistently shown its positive impacts across multiple domains. These include improvements in conceptual comprehension, problem-solving abilities, critical thinking skills, motivation, intellectual and scientific competencies, interest, and the promotion of good mindsets about science (Haatainen & Aksela, 2021; Laksana et al., 2019; Lederman et al., 2019; Škoda et al., 2015). IBSE promotes the growth of scientific literacy and allows for a deeper understanding of scientific processes. It is inclusive and appropriate for students with a range of academic abilities, including both talented students and those with low academic performance, and it may be used by both sexes and students of different ages, including kindergarten (Marshall & Alston, 2014; Sotáková et al., 2020; Trna et al., 2012).

Initiating inquiry-based science learning involves framing and examining a comprehensive problem by breaking it down into smaller components. In this approach, teachers relinquish the role of knowledge providers and instead position their students as active participants and drivers of their learning (Johnson et al., 2019). Integrating inquiry-based learning into science education in the early years of schooling can engage young children, foster scientific thinking, and facilitate the development of conceptual understanding (Ramanathan et al., 2022; Saçkes, 2015). Kindergarten classrooms have historically neglected science teaching and learning, but there is growing recognition and emphasis on its importance. Previously, the preschool curriculum treated science as an optional rather than a fundamental element (Pendergast et al., 2017), often placing it in the shadow of other curricular priorities and demands. By encouraging young children to participate in scientific inquiry actively, adults create suitable environments that align with their daily experiences before entering formal schooling. The existing inquiry skills possessed by children serve as a valuable foundation for nurturing their scientific reasoning abilities. The performance expectations for K–12 students are defined by the interconnected dimensions of Disciplinary Core Ideas, Science and Engineering Practices, and crosscutting concepts outlined in The Next Generation Science Standards (Next Generation Science Standards, 2013). However, implementing inquiry-based science education (IBSE) in the kindergarten classroom can create opportunities for preschool children to engage with the Science and Engineering Practices within these interconnected dimensions.

Existing reviews on inquiry-based science education

Previous reviews have presented various justifications for implementing inquiry-based science education (IBSE) in the classroom. A recent review conducted by Strat et al. (2023) aimed to explore the usage of IBSE in preservice teacher (PST) education and its resulting outcomes. The review findings suggest that IBSE is employed in PST education to support the acquisition of science concepts and processes and foster the development of teaching skills through inquiry. Also, the review reported positive outcomes concerning IBSE in PST education, particularly in terms of enhancing science knowledge, teaching proficiency, and improving attitudes and self-efficacy among PSTs.

Moreover, Liu et al. (2020) conducted a study examining research on the use of mobile technology-supported inquiry-based learning (mIBL) in secondary science education. The systematic review revealed that mIBL primarily encompasses guided and open inquiry approaches, with relatively little emphasis on teacher-controlled confirmation and structured inquiry methods. The study introduced a new synthesis that categorized different types of mIBL, including authentic, collaborative, collective whole-class, abductive, and inquiry, incorporating a game component. The review utilized the M3 evaluation framework to assess the advantages and limitations of mobile technology-supported inquiry-based learning (mIBL) across three primary levels: micro, meso, and macro. Various themes were identified within each level. At the micro level, themes encompass efficiency, effectiveness, perceived usefulness, learnability, and cognitive load. The meso-level themes focused on attitude, motivation, group work, learning performance, attention, and cognitive processes. The only overarching theme at the macro level revolved around motivation.

Furthermore, Urdanivia Alarcon et al. (2023) conducted a systematic review exploring the instructional models, subject areas, and developmental areas utilized by secondary school science teachers. The review revealed that implementing the inquiry-based instructional approach makes it easier for students to build their research abilities and create scientific knowledge. Combining this approach with effective teaching strategies allows for representing real-world laws and theories, making science more accessible to students. The findings suggest that teaching science tends to prioritize learning through scientific reasoning, with a firm reliance on evidence and a preference for constructivist instructional models. The review emphasizes the value of constant teacher development to improve educators' comprehension of scientific concepts and help them acquire techniques for successfully conducting open inquiry. It concludes that the use of inquiry-based learning encourages novel approaches to conducting science and places an emphasis on the cyclical application of techniques. Along with a rising focus on the development of STEM approaches, there is also a discernible trend towards integrating technology-based serious games, such as audio, video, and digital stands, in today's education.

The existing systematic reviews have delved so much into IBL and IBSE at the secondary and tertiary levels, preservice teachers, and in-service teachers. However, few studies have been conducted on the IBL approach at the kindergarten level.

METHODS

Search strategy

The study employed a systematic review research methodology, utilizing the databases Web of Science, EBSCOhost, and Scopus for an extensive article search. The search for relevant studies was conducted between June 14 and June 22, 2023, following a predefined set of keywords: "inquiry-based," "science," and "preschool OR kindergarten." Articles were procured from the databases based on their titles, abstracts, and keywords. The preliminary search yielded 121 articles without specific data parameters. Nonetheless, 48 documents, including book chapters, lecture notes, conference papers, dissertations, magazines, editorials, errata,

and reports, were excluded from the search. Consequently, 73 documents that met the criteria and included 'peer-reviewed' academic journal articles and review articles published in English and published between 2014 and May 2023 were retained for further analysis.

Selection Criteria

These articles were then organized into a matrix, wherein predetermined inclusion and exclusion criteria were meticulously applied. Upon selecting 16 pertinent articles, the researcher proceeded to a comprehensive reading phase to identify various aspects, including the types of inquiry-based methodologies, instructional models, framework utilization, subjects involved, contextual considerations, and methodological approaches associated with science education for kindergarten children.

Quality assessment

To maintain the quality of the review, the study used an iterative method to refine the initial pool of studies. This involved removing duplicate records identified in the three databases. This process resulted in a reduced collection of 12 articles. Also, the titles of these articles were reviewed, leading to the exclusion of 31 papers unrelated to the focus of the study. A more comprehensive assessment was then conducted, covering both titles and abstracts. This two-step evaluation aimed to rigorously analyze and refine the selection of articles, ensuring their academic quality and relevance to the goals of the review. Each research paper underwent a thorough evaluation, excluding an additional 14 papers. Based on these stringent criteria, the final systematic review included 16 articles related explicitly to inquiry-based science learning in kindergarten settings. The entire process is concisely illustrated using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework in Figure 1 (Moher et al., 2009). This rigorous approach aimed to uphold the comprehensiveness and rigor of the systematic review.

Data extraction/analysis

In this study, the selected articles were inputted into an Excel spreadsheet designed according to predefined inclusion and exclusion criteria. The relevant information was systematically extracted in response to the raised research questions. While the selected papers encompassed a variety of quantitative, qualitative, and mixed-method research approaches, many of the articles mainly offered qualitative explanations for their findings. The diverse array of instructional models and frameworks employed across the examined literature offers a unique opportunity to identify approaches tailored explicitly for integrating inquiry-based learning within science classrooms. These models and frameworks assess the effectiveness of various strategies employed to integrate inquiry-based practices into science education and offer comprehensive explanations rooted in empirical studies, which contribute valuable insights to theoretical understanding and practical application. This analytical approach subsequently served as the foundation for formulating conclusions and recommendations drawn from the analyzed studies based on empirical evidence. All data was then systematically accumulated and analyzed using an Excel spreadsheet. A comprehensive depiction of the emerging trends derived from the reviewed studies, which supported the three research questions, was provided, supplemented with illustrative examples for each identified trend.

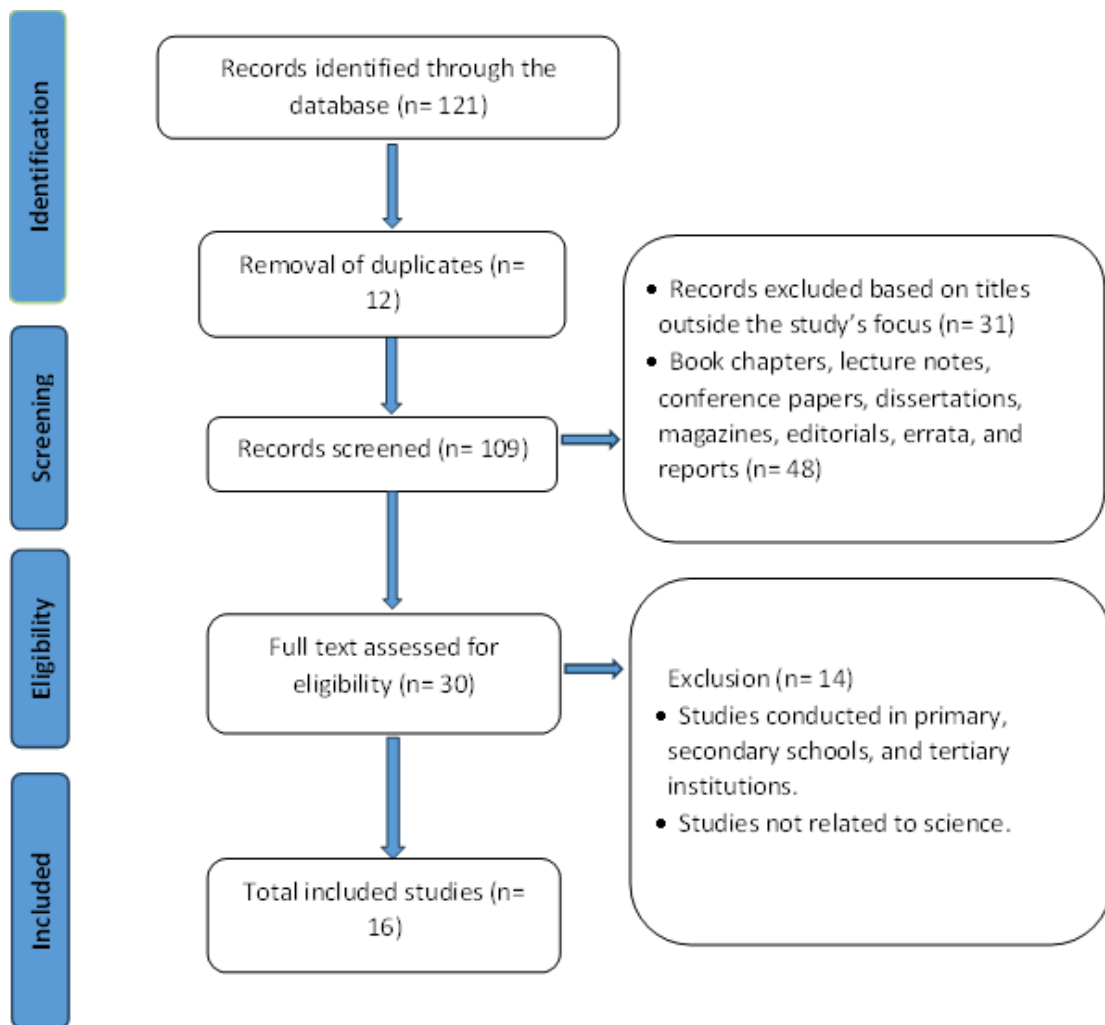


Fig.1 Study selection chart (Adapted from Page et al., 2021) PRISMA 2020 Statement

Table 1. Lists of 16 selected articles were reviewed in the study.

S/N	Author(s) and year	Title	Participants	Subject
1	Hollingsworth and Vandermaas-Peeler (2017)	Almost everything we do includes inquiry': fostering inquiry-based teaching and learning with preschool teachers	Preschool teachers	Science
2	Desouza (2017)	Conceptual play and science inquiry: using the 5E instructional model	Preschool pupils	Science

3	Kallery et al. (2022)	Cognitive style, motivation and learning in inquiry-based early-years science activities	Preschool children	
4	Furman et al. (2019)	From inception to implementation: an Argentine case study of teachers enacting early years inquiry-based science	Preschool pupils and Teachers	Science
5	Zudaire et al. (2022)	Mars Explorers: A Science Inquiry-Based Learning Project in Preschool	Preschool students	Science
6	Ünver et al. (2016)	Experiencing Inquiry with Kindergarten: Science for Kids	Preschool students	Science
7	Harris et al. (2017)	Teacher discourse strategies used in kindergarten inquiry-based science learning	Kindergarten teachers	Science
8	Macias et al (2022)	“They Were Teaching Me!”: Reimagining Collaborative Inquiry with Elementary Students in Science Teacher Education	Preservice teachers	Science
9	Lee and Bailie (2019)	Nature-based education: using nature trails as a tool to promote inquiry-based science and math learning in young children	Preservice early childhood teachers	Science and Mathematics
10	van Uum et al. (2016)	Inquiry-based science education: towards a pedagogical framework for primary school teachers	Teachers	Science
11	Kewalramani and Veresov (2021)	Multimodal Creative Inquiry: Theorising a New Approach for Children's Science Meaning-Making in Early Childhood Education	Preschool children	Science

12	Philippou et al. (2014)	The exchange of ideas was mutual, I have to say’: negotiating researcher and teacher ‘roles’ in an early years educators’ professional development programme on inquiry-based mathematics and science learning	Early childhood educators	Mathematics and Science
13	Lin et al. (2021)	Using an Inquiry-Based Science and Engineering Program to Promote Science Knowledge, Problem-Solving Skills and Approaches to Learning in Preschool Children	Preschool children	Science and Engineering
14	Eckhoff (2017)	Partners in Inquiry: A Collaborative Life Science Investigation with Preservice Teachers and Kindergarten Students	Preservice teachers and Kindergarten children	Science
15	Ghafouri (2014)	Close encounters with nature in an urban kindergarten: a study of learners' inquiry and experience	Kindergarten children	Nature
16	Karademir and Akman (2019)	Effect of Inquiry-Based Mathematics Activities on Preschoolers’ Math Skills	Kindergarten	Mathematics

RESULTS

The demographic variables of the study are assessed.

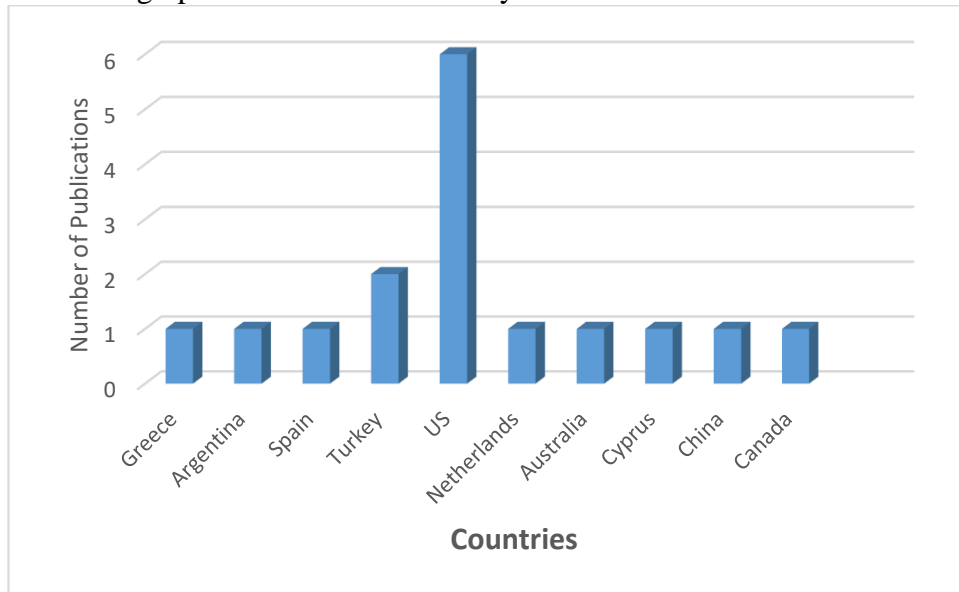


Fig. 2 Publications by Country

Figure 2 illustrates the distribution of these studies based on their respective countries. Notably, the research was conducted across various nations, encompassing ten countries. Despite the relatively small sample size, the United States emerged as the leader with the highest publication count, comprising six articles. Following closely, Turkey contributed two articles, while several other countries, such as Greece, Spain, Argentina, Cyprus, the Netherlands, China, Australia, and Canada, each presented one article.

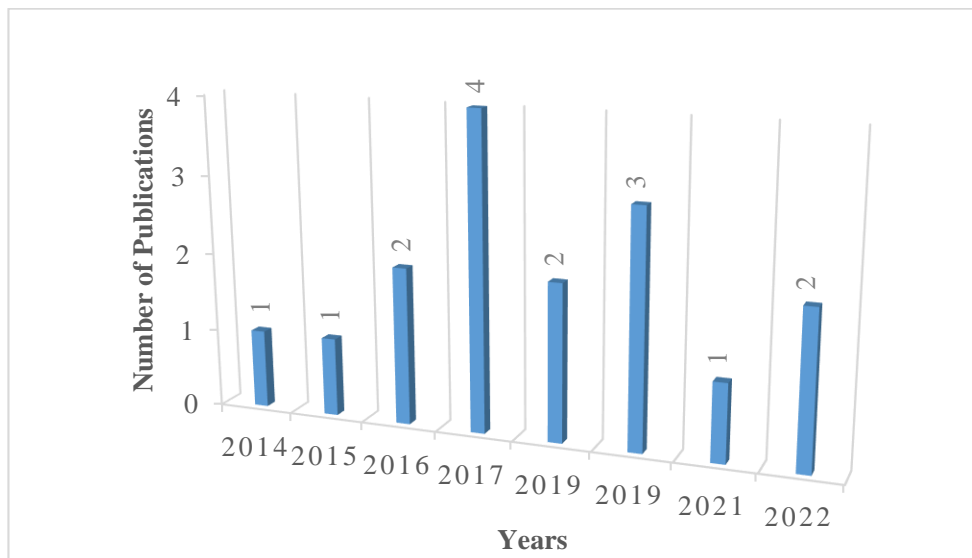


Fig. 3 Year of Publications

In terms of publication dates, the sample spans from 2014 to 2022. Notably, the year with the highest volume of publications was 2017, accounting for four

articles. Following this, 2019 witnessed the publication of three articles, while 2016, 2019, and 2022 each contributed two articles. Lastly, 2014, 2015, and 2021 had one article published. The distribution of articles across the years is presented in Figure 3.

Research Question 1: What are the subject areas, participants, and methodologies used in teaching science with IBL in kindergarten education?

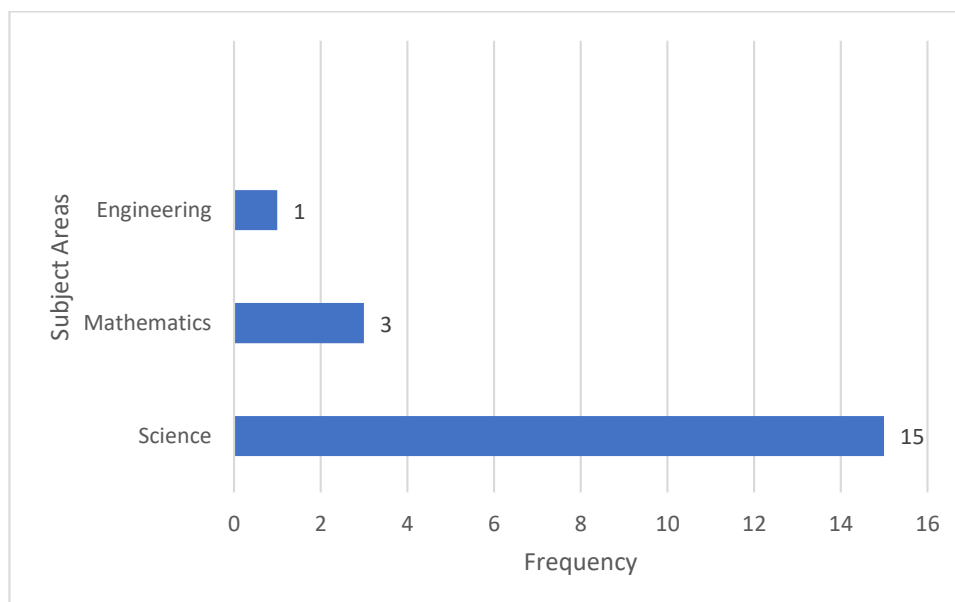


Figure 4. Subject Areas

Figure 4 outlines the subject areas that were integrated with inquiry-based learning within the kindergarten context. The data reveals that early years' science constitutes the predominant subject, being featured in 15 articles (79%). Subsequently, Mathematics is represented in 3 articles (16%), followed by nature and Engineering, each featured in 1 article (5%). Certain studies adopted a combined approach, such as the case of Lee and Bailie (2019) and Philippou et al. (2015), who combined science and mathematics in their instruction. Similarly, Lin et al. (2021) integrated science and engineering in their study.

Table 2. Descriptive statistics of participants involved.

Participants	Frequency	Percentage %
Teachers	5	27.8
Preschool/kindergarten children	10	55.5
Preservice teacher	3	16.7

Table 2 presents the descriptive statistics concerning the participants involved in the reviewed studies. The review encompasses studies conducted with diverse participant categories: teachers, totaling five studies (27.8%); preschool/kindergarten children, amounting to 10 studies (55.5%); and preservice teachers, comprising three studies (16.7%). Specifically, four studies concentrated

solely on research involving kindergarten teachers. These studies, namely Harris et al. (2017), Hollingsworth & Vandermaas-Peeler (2017), Philippou et al. (2015), and van Uum et al. (2016), predominantly explored aspects like teachers' efficacy, discourse strategies, and motivation pertaining to the utilization of inquiry-based approaches in science teaching and learning. Furthermore, eight studies were primarily focused on kindergarten children. These studies, involving Desouza (2017), Ghafouri (2014), Kallery et al. (2022), Karademir and Akman (2019), Kewalramani and Veresov (2022), Lin et al. (2021), Ünver et al. (2016), and Zudaire et al. (2022), employed the inquiry-based approach to teach science concepts to kindergarten children.

In addition, two studies exclusively concentrated on preservice teachers employing inquiry-based science instruction for teaching at the kindergarten level. These studies include Macias et al. (2022) and Lee and Bailie (2019). Moreover, two studies encompassed both teachers/preservice teachers and kindergarten children. These studies, involving Eckhoff (2017) and Furman et al. (2019), investigated the integration of preservice teachers' development of inquiry-based learning experiences alongside kindergarten students within a science methods course.

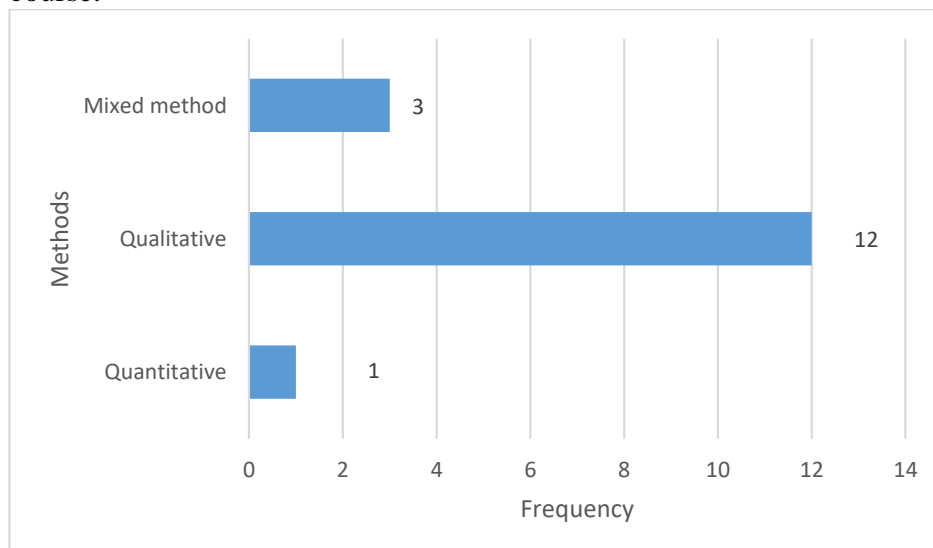


Figure 5. The method used by articles.

Figure 5 examines the research methods employed in the studies under review. The prevailing research approach was identified as a qualitative research design utilized in 12 studies. This method emphasizes capturing unstructured and non-numerical information to comprehensively explore the application of inquiry-based practices within kindergarten science education, constituting 75% of the total reviewed studies. The subsequent widely adopted methodology was a mixed-method research design observed in three studies. This approach combines both quantitative and qualitative research elements in a single project, offering a holistic understanding of the research problem. Lastly, one study used a quantitative research design, which interpret the

utilization of inquiry-based science in kindergarten classrooms through the analysis of numerical data.

Research Question 2: What are the types of inquiry-based approaches and theoretical frameworks employed for science instruction in kindergarten classrooms?

Table 3. Descriptive variables on the types of inquiry

Types of Inquiry	Frequency	Percentage %
Guided-inquiry	7	43.75
Open inquiry	4	25
Structured inquiry	2	12.5
Creative inquiry	1	6.25
Collaborative inquiry	2	12.5
Total	16	100

Table 3 illustrates the varieties of inquiry approaches employed in the studies under review. The data reveals that guided inquiry was the most frequently utilized, featured in seven studies, accounting for 43.75%. Following this, open-ended inquiry was adopted in four studies, constituting 25%. Collaborative and structured inquiry were each applied in two studies, accounting for 12.5% each. The least employed approach was creative inquiry, appearing in one study, which represents 6.25%. Moreover, after reviewing the studies, it was observed that 14 of them implemented inquiry-based learning based on the constructivism theory, whereas the remaining two studies adopted the socio-constructivism theory.

Research Question 3: How does an inquiry-based approach impact learning outcomes in kindergarten children?

The studies examined offer valuable insights into the influence of inquiry-based approaches on learning outcomes in kindergarten. For instance, a study conducted by Ünver et al. (2016) observed that adopting inquiry-based learning for teaching science concepts in kindergarten progressively enhanced children's ability to represent their outcomes using various techniques and improved their patterns of reasoning. The study also revealed that, over time, these activities facilitated a deeper understanding of nurturing curiosity about everyday queries critically. Moreover, the approach sparked an interest in science, encouraged validating explanations or predictions through results, and promoted the articulation of ideas regarding their experiences. In the study conducted by Desouza (2017), it was established that the child-centered pedagogy inherent in the 5E instructional model fosters increased interaction among teachers, children, the environment, and the social context. This model provides meaningful learning opportunities that promote acquiring science concepts through playful engagement. Also, Kallery et al. (2022) concluded that the inquiry-based activities of the early-year science program, with its specific characteristics and approach, can lead to high levels of engagement and similar learning outcomes regardless of students' cognitive styles in the early years.

Furthermore, Kewalramani and Veresov (2021) highlighted how inquiry-based learning encourages active participation and discussions among children, particularly concerning various elements of scientific concepts. This approach enables children to

comprehend science concepts while also becoming creators of diverse multimodal representations driven by their interests and curiosity. The utilization of semiotic resources facilitated by technologies like apps creates a platform for innovative inquiry, establishing spaces for communication and multimodal meaning-making encompassing visual, haptic digital touch, and textual dimensions, all centered around everyday scientific phenomena. A separate comparative study conducted by Lin et al. (2021) revealed that children instructed through Inquiry-Based Science Education (IBSE) exhibited higher scores in science-relevant problem-solving skills initially. Furthermore, this group demonstrated notably enhanced progress in engineering problem-solving skills compared to the control group. Likewise, in a study undertaken by Karademir and Akman (2019), they reported that the Inquiry-Based Mathematics Activities Module (IBMAM) yielded a positive and enduring effect on preschoolers' competency in numbers and operations. IBMAM facilitated the experimental group's engagement in small-group activities, fostering mathematical experiences and encouraging exploration.

Also, Hollingsworth and Vandermaas-Peeler (2017) conducted research involving preschool teachers and revealed that most teachers acknowledged implementing initial stages of inquiry, such as observation and questioning, within activities. However, these teachers should have reported progressing to subsequent phases like making predictions and assessing evidence. In contrast, the study conducted by Macias et al. (2022) centered on preservice teachers. This research unveiled that preservice teachers harnessed collaborative inquiry to identify challenges and opportunities in science education. They also emerged as active agents of change alongside elementary students, assuming the role of science educators. The study further delved into the transformative role of collaborative inquiry within teacher preparation programs, positioning it as a potent pedagogical instrument.

DISCUSSION

The first research question of this study was to identify the specific subject areas, participants, and methodologies employed in implementing inquiry-based learning (IBL) for science education in kindergarten. Among the 16 studies subjected to review, early years' science emerged as the predominant subject area where IBL was employed. Within this context, five studies focused on employing IBL to teach topics related to the natural environment or nature in kindergarten settings. Additionally, two studies specifically addressed the teaching of life cycles using IBL, while the remaining studies encompassed various other science topics. It has been demonstrated that employing IBL as an educational approach across all educational levels contributes to an enhanced overall learning experience and performance, a finding congruent with the outcomes of studies conducted by (Llewellyn, 2014; Marshall & Alston, 2014; Suduc et al., 2015).

The review also addresses the participants involved in the studies under examination. These studies encompassed kindergarten children, teachers, and preservice teachers as their participants. Moreover, the inquiry-based science approach's prevalent methodologies used in kindergarten teaching were also explored. Most reviewed studies predominantly employed qualitative research designs to investigate the utilization of inquiry-based science approaches in

kindergarten education. Within this review, 12 of the examined studies adopted qualitative methods, with nine utilizing observation and interviews for data collection. This practice indicates that employing multiple assessment methods offers various viewpoints on the research subject, leading to a more comprehensive comprehension of the phenomenon being studied. Additionally, it aids in producing diverse, robust data that can offer profound insights and a broader perspective on the research issue. This observation aligns with the findings of Liu et al. (2020) review.

The investigation into the types of inquiry-based methods and theoretical frameworks employed within kindergarten classrooms in this study reveals that seven of the studies opted for guided inquiry, with four studies utilizing open inquiry. The prevalence of guided inquiry indicates that educators recognize the learner as the central figure in the learning process, guided by the teacher. This perspective aligns with the insights from examining science and inquiry-based teaching and learning, as discussed by Urdanivia Alarcon et al. (2023)(Urdanivia Alarcon et al., 2023). Similarly, the adoption of open inquiry underscores the authenticity of the scientific approach, fostering active engagement among students and leading to effective implementation, a notion consistent with the findings of Rahmat and Chanunan (2018).

In this study, the utilization of Inquiry-Based Learning (IBL) centered on the constructivist theory has been a significant focus. The constructivist theory emphasizes that learners actively construct their own knowledge through interactions with the environment and experiences, aligning well with the principles of IBL, where learners engage in active exploration and discovery. This approach resonates with the idea that learners are not passive recipients of information but are actively involved in shaping their understanding. As advocated by Vygotsky (1978), the constructivist perspective highlights that learners construct knowledge by assimilating new information into their existing cognitive structures. The alignment of science teaching and learning with constructivism is underscored by studies such as those conducted by Ayaz and Şekerci (2015) and Shumba et al. (2012).

Additionally, the inquiry-based approach in kindergarten education has significantly impacted learning outcomes among young children. This approach places learners at the center of their learning, fostering active engagement, critical thinking, and a deeper understanding of scientific concepts. It also allows children to actively construct their knowledge by exploring their surroundings, conducting experiments, and collaborating with peers. The result aligns with earlier studies. Abdi (2014) and Buckner and Kim (2014) indicated that inquiry-based science instruction enhances students' knowledge of scientific concepts and promotes their engagement and motivation to learn. Furthermore, Abdelraheem (2006) and Lau et al. (2017) found that students who engage in inquiry-based science learning demonstrate higher levels of conceptual understanding and problem-solving skills than those exposed to traditional didactic instruction. This finding underscores the impact of inquiry-based approaches on cognitive development.

IMPLICATIONS

The examination of inclusion criteria yielded 16 studies that offered conceptualizations of how inquiry-based approaches are employed in teaching and learning science concepts within kindergartens. The outcomes of this systematic review bring to light a pressing need for empirical substantiation in this domain, addressing concerns regarding its limited availability. However, this study has effectively elucidated various facets, encompassing subject areas, participant demographics, research methodologies, types of inquiry-based approaches, underlying theoretical frameworks, and the measurable impact of inquiry-based science approaches in kindergarten education. Early years' science emerged as the prevailing subject area taught using this approach. Predominantly, kindergarten children constituted the majority of participants, although some studies also accentuated teacher development.

Moreover, the findings underscore the importance of embracing inquiry-based science approaches for child-centric learning, fostering proactive engagement, honing critical thinking skills, and cultivating a more profound grasp of scientific concepts. This approach inherently empowers children to actively shape their understanding by exploring their surroundings, conducting hands-on experiments, and collaborating with their peers.

LIMITATIONS OF THE STUDY

An inherent limitation of this study lies in its search scope, which was primarily confined to three educational repositories. The selected studies comprised peer-reviewed journal articles on the inquiry-based science approach in kindergarten published from 2014 to May 2023. The incorporated articles and reviews did not encompass studies published across diverse publication types, such as conference papers, editorials, books, or materials from the grey literature. Nevertheless, it is important to note that a substantial portion of the studies reviewed were conducted as intervention programs at the classroom level, focusing on delineating types, frameworks, or innovative approaches for science instruction within kindergartens. Additionally, papers addressing the nexus of inquiry-based with secondary and university-level education were deliberately excluded, given the research-specific quest for pivotal contributions concerning the inquiry-based science approach in kindergarten classrooms.

CONCLUSION AND RECOMMENDATIONS

In conclusion, this systematic review offers a qualitative synthesis of findings from 16 research studies centered on the inquiry-based science approach in kindergarten education. The examination encompasses critical aspects such as subject areas, participant demographics, research methodologies, categories of inquiry-based approaches, theoretical frameworks, and observed impacts. Despite the diverse array of inquiry-based approaches, the results highlight the pivotal role of the inquiry-based science approach in kindergarten, fostering child-centered learning, cultivating critical thinking, motivating learners, enhancing active engagement, and facilitating a deep understanding of scientific skills and literacy. Nonetheless, there remains a need for further empirical research that delves into specifics such as the instructional

models employed, classroom challenges encountered, and longitudinal studies exploring the sustained effects of inquiry-based science education on the overall performance of kindergarten children.

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