



Abstract. *Developing scientific literacy and critical thinking is fundamental to contemporary science education. This study explored whether integrating guided inquiry learning with peer scaffolding could improve the scientific literacy and critical thinking of pre-service elementary school teachers. A total of 226 pre-service elementary school teachers enrolled in the Basic Concepts of Elementary Science course participated in this quasi-experimental study using a pretest-posttest control group design. Students in the experimental group engaged in guided inquiry integrated with peer scaffolding, whereas the control group received conventional teaching. Peer scaffolding was systematically incorporated throughout all phases of guided inquiry and was preceded by a pre-peer scaffolding phase involving briefing and concept reinforcement. Scientific literacy and critical thinking were assessed using validated instruments developed from the OECD/PISA framework and Ennis' critical thinking indicators (Cronbach's $\alpha = .835$). Data were examined using the Mann-Whitney U test, N-gain analysis, and effect size. The experimental group demonstrated significantly higher scientific literacy and critical thinking than the control group ($p < .001$), with N-gain scores of .676 and .773, respectively. The findings indicate that integrating peer scaffolding into guided inquiry is an effective approach for enhancing the scientific literacy and critical thinking of pre-service elementary school teachers.*

Keywords: *guided inquiry learning, peer scaffolding, scientific literacy, critical thinking, pre-service elementary school teachers, science learning*

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INTEGRATING PEER SCAFFOLDING INTO GUIDED INQUIRY LEARNING TO ENHANCE SCIENTIFIC LITERACY AND CRITICAL THINKING AMONG PRE- SERVICE ELEMENTARY SCHOOL TEACHERS

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Introduction

The rapid transformation of twenty-first-century education has positioned higher-order thinking skills as one of the key competencies that should be developed through the learning process. Fostering twenty-first-century competencies requires learning approaches that actively engage students in critical thinking, problem solving, and knowledge construction (Saavedra & Opfer, 2012). Within contemporary science education, learners are expected not only to master scientific concepts but also to understand scientific phenomena, evaluate information critically, and make decisions based on scientific evidence and logical reasoning. Therefore, scientific literacy and critical thinking are widely recognized as key competencies that enable students to respond to the demands of a knowledge-based society and continuing scientific advancement (Partnership for 21st Century Learning, 2019; OECD, 2019). Scientific literacy enables individuals to critically analyse and explain real-world phenomena, design scientific investigations, and draw evidence-based conclusions (National Research Council, 2012; OECD, 2019). In addition, the ability to think critically helps students in science class to evaluate claims, assess evidence, and reach reasonable conclusions (Ennis, 2011). Therefore, contemporary science curricula should emphasize the development of scientific literacy and critical thinking as core educational outcomes (Bybee, 2013).

Developing scientific literacy requires learners to actively engage in inquiry, analyse evidence, and solve scientific problems rather than merely acquire conceptual knowledge (Lederman et al., 2013). As a result, inquiry-based learning has become a widely recognized instructional approach for involving students in authentic scientific investigations. Inquiry-based activities allow learners to strengthen investigation skills, scientific reasoning, and reflective thinking through direct engagement with scientific problems (National Research Council, 2012). Students have the opportunity to enhance



their scientific reasoning skills through inquiry-based science education, which regularly involves observation, research, and reflection on scientific phenomena (Uum et al., 2016).

Preparing future primary school teachers requires more than disciplinary knowledge; it also demands the development of scientific literacy and critical thinking. As prospective primary school teachers, pre-service elementary education students have an important responsibility for cultivating scientific thinking from the beginning of formal education. In addition to mastering scientific concepts, they are expected to facilitate students' engagement in observation, scientific inquiry, problem solving, and evidence-informed decision making (National Research Council, 2012). Hence, pre-service elementary school teachers need to possess strong scientific literacy and critical thinking skills to create active, investigative, and meaningful learning environments. The development of these competencies is closely related to teachers' capacity to design instructional experiences that promote higher-order thinking skills (Darling-Hammond, 2017). Thus, pre-service teachers' ability to understand and apply scientific thinking plays an important role in determining the quality of science learning at the primary school level. Consistent with this perspective, previous studies have reported that inquiry-based science learning conducted through collaborative small-group activities helps pre-service teachers strengthen both their scientific reasoning and pedagogical competence (Havu-Nuutinen et al., 2019).

Research Problem

Although scientific literacy and critical thinking have become crucial demands in 21st-century education, the science learning in higher education continues to encounter several challenges. Science learning still tends to be teacher-centered (teacher-centered learning), resulting in students passively receiving information rather than actively engaging in the scientific inquiry process. As a result, investigation activities, scientific discussions, and evidence-based argumentation remain underdeveloped (Hmelo-Silver et al., 2007). In pre-service elementary teacher education, these challenges are reflected in students' limited participation in scientific investigations, difficulties in interpreting research findings, and insufficient ability to justify conclusions using logical reasoning during science learning. Scientific argumentation and inquiry skills constitute fundamental elements for developing scientific literacy and critical thinking (OECD, 2019; Osborne, 2010). These conditions indicate that students still require learning experiences capable of fostering active engagement in the processes of investigation and knowledge construction, both scientifically and collaboratively.

Guided inquiry learning has long been acknowledged as an effective instructional approach for fostering students' scientific literacy and critical thinking. Through activities such as problem orientation, problem and hypothesis formulation, investigation planning, investigation, data analysis, communication and reflection, inquiry learning actively engages students throughout the scientific learning process (Joyce et al., 2015). Through these activities, students acquire the opportunity to construct knowledge via active and reflective scientific learning experiences (Bruner, 1961; Dewey, 1938). Similarly, recent research has shown that student-centered learning approaches can improve conceptual understanding while simultaneously fostering communication, collaboration, and problem-solving skills through active learning experiences (Peiyao et al., 2021). Furthermore, guided inquiry provides structured opportunities in which students actively construct knowledge through structured scientific exploration. Previous empirical studies have reported that inquiry-based learning contributes to improvements in students' scientific literacy, science process skills, and critical thinking (Furtak et al., 2012; Lazonder & Harmsen, 2016; Nuryanti et al., 2019). Nevertheless, the success of inquiry learning is influenced not only by students' engagement in scientific investigation but also by the provision of appropriate social and cognitive support throughout the learning process.

The implementation of guided inquiry in classroom practice does not always proceed optimally. The scientific investigation process frequently causes students to experience difficulties in problem orientation, problem and hypothesis formulation, investigation planning, investigation, data analysis, communication and reflection. Such difficulties may impose a greater cognitive burden, particularly when students have limited prior knowledge and experience in conducting scientific investigations independently (Kirschner et al., 2006; Sweller, 2011). Moreover, inquiry learning without adequate instructional and peer support may cause student confusion throughout the inquiry process and hinder the development of meaningful scientific understanding (Hmelo-Silver et al., 2007). As a consequence, students may participate in inquiry activities without adequate social and cognitive support during the scientific investigation process. Within the context of pre-service elementary teacher education, this situation can hinder the development of scientific literacy and critical thinking because students still require guidance and assistance throughout the inquiry process. Therefore, the implementation of guided inquiry should be supported by instructional strategies that help students in navigating the scientific investigation process in a more directed

and meaningful manner. This need for learning support is consistent with recent evidence showing that carefully designed scaffolding questions can guide learners' conceptual understanding and scientific reasoning throughout inquiry activities (Øyehaug et al., 2024).

Research Focus

Peer scaffolding represents one form of learning support that can be systematically integrated into guided inquiry. The concept of scaffolding is grounded in socioconstructivist theory (Vygotsky, 1978), according to which people gain knowledge via interacting with others and receiving guidance from those with more experience and expertise. From the perspective of the Zone of Proximal Development (ZPD), learners are able to attain higher levels of understanding when appropriate instructional support is provided during learning. Within the context of collaborative learning, peer scaffolding enables students to receive assistance, guidance, and feedback from their peers while scientific investigation activities take place (Wood et al., 1976). Such support assists students in understanding concepts, reducing cognitive difficulties, and supporting the process of scientific argumentation during inquiry learning. Furthermore, collaborative learning environments promote reflective thinking, shared knowledge construction, and critical reasoning through meaningful social interaction among learners (Gillies, 2016; Mercer & Littleton, 2007). Moreover, collaborative inquiry allows learners to build understanding through social interaction, discussion, and the negotiation of meaning while the scientific investigation process occurs (Uiterwijk-Luijk et al., 2019).

Recent evidence has shown that collaborative inquiry environments become more effective when learners receive structured scaffolding that facilitates interaction, knowledge construction, and scientific reasoning throughout inquiry. Rather than functioning as simple group discussions, effective collaborative inquiry requires structured peer scaffolding that helps learners coordinate investigation activities, exchange scientific ideas, and collaboratively construct evidence-based explanations (Zhang et al., 2024; Hoe et al., 2024). Building upon these findings, this study positions peer scaffolding not merely as a group discussion activity but as a structured socio-cognitive support mechanism systematically integrated into every phase of guided inquiry.

In response to these research gaps, this study introduces a conceptual framework that integrates peer scaffolding into guided inquiry learning to enhance the scientific literacy and critical thinking of pre-service elementary school teachers. The proposed instructional framework is illustrated in Figure 1.

Figure 1

Preservice elementary school teachers' scientific literacy and critical thinking can be enhanced through the use of a conceptual framework that integrates guided inquiry learning with peer scaffolding

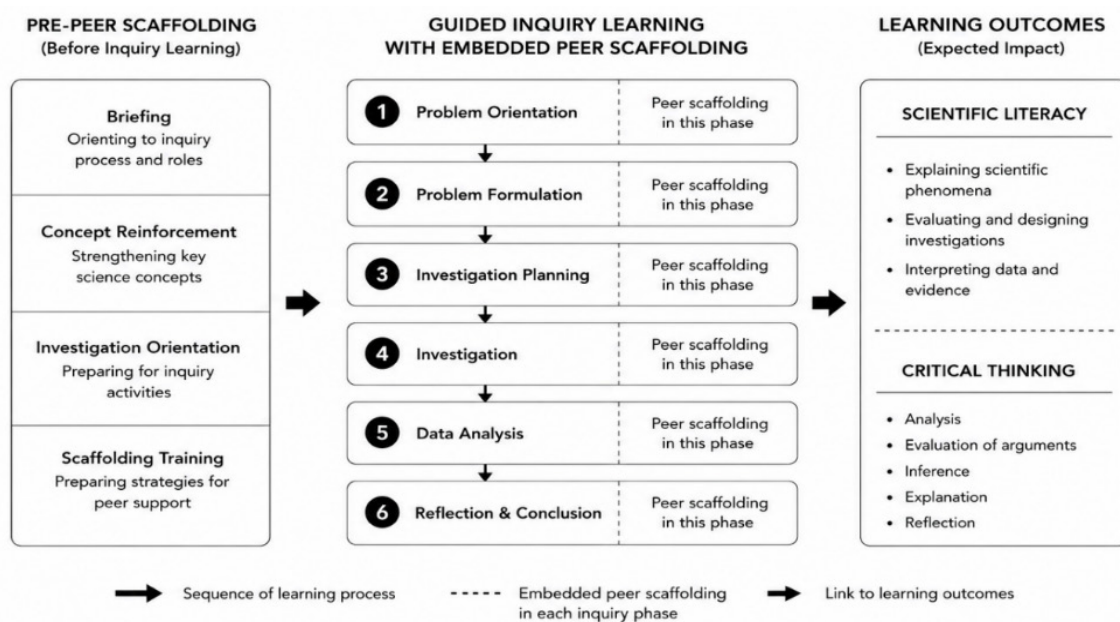


Figure 1 illustrates the proposed instructional model integrating peer scaffolding throughout the six phases of guided inquiry learning. The model incorporates a pre-peer scaffolding phase before inquiry begins and positions peer support across problem orientation, problem and hypothesis formulation, investigation planning, investigation, data analysis, and communication and reflection to facilitate scientific literacy and critical thinking.

Research Aim and Research Questions

A growing body of research has consistently demonstrated that inquiry learning supports the development of scientific literacy and critical thinking (Furtak et al., 2012; Nuryanti et al., 2019). Students' interest in and grasp of course material are both improved by collaborative learning and contact with peers, according to other studies (Georgiou & Kyza, 2023; Gillies, 2016). Nevertheless, the majority of research continues to position the inquiry process and social interaction as two learning components that operate separately. Research regarding inquiry generally focuses on scientific investigation activities, whereas collaborative learning research places greater emphasis on general group discussion activities without structured scaffolding mechanisms while the inquiry process takes place. Consequently, students frequently undergo the scientific investigation process without receiving adequate social and cognitive support at every phase of inquiry. Moreover, empirical evidence on integrating peer scaffolding into guided inquiry within pre-service elementary teacher education remains limited. As a matter of fact, primary school teacher candidates need pedagogical tools that facilitate group work in scientific inquiry and critical thinking as well as the comprehension of abstract scientific concepts. Earlier studies have shown that inquiry-oriented teacher education programs contribute to the development of pre-service teachers' scientific reasoning and pedagogical competence (Crawford, 2007).

In this study, peer scaffolding is systematically embedded throughout all phases of guided inquiry to foster scientific literacy and critical thinking among pre-service elementary school teachers. In contrast to previous studies that have generally treated inquiry and social interaction as separate instructional components, the present study conceptualizes peer scaffolding as an integral element of the scientific investigation process. Additionally, this research also implements a pre-peer scaffolding phase through briefings and concept reinforcement for peer scaffolders before instruction occurs, ensuring that social and cognitive support can operate in a more structured manner throughout the inquiry process. Consequently, this study extends the existing literature by providing additional conceptual insights into the application of social constructivist principles within inquiry-based learning for pre-service primary teacher education. More specifically, this study extends the theoretical understanding of peer scaffolding by conceptualizing it as a structured collaborative learning process that starts with the systematic preparation of peer scaffolders before inquiry and continues throughout all phases of guided inquiry.

Accordingly, this study examines the effectiveness of integrating peer scaffolding into guided inquiry learning to improve the scientific literacy and critical thinking of pre-service elementary school teachers while also exploring how peer scaffolding supports the scientific investigation process during inquiry activities.

Accordingly, the study addressed the following research questions:

1. Does peer scaffolding-assisted guided inquiry learning possess the capability to enhance the scientific literacy of pre-service elementary school teachers?
2. Does peer scaffolding-assisted guided inquiry learning possess the capability to enhance the critical thinking of pre-service elementary school teachers?
3. How does peer scaffolding support the scientific investigation process while inquiry learning takes place?

Research Methodology

General Background

This research looked at how pre-service elementary school teachers learned science using guided inquiry learning and peer scaffolding. To examine how the model's implementation affected students' scientific literacy and critical thinking, this study utilized a quasi-experimental methodology using a pretest-posttest control group design approach. In order to help pre-service elementary school teachers strengthen their scientific literacy and critical thinking skills, this study centered on the adoption of guided inquiry learning with peer scaffolding.

The instructional model implemented in this research consisted of six primary phases, namely problem orientation, problem and hypothesis formulation, investigation planning, investigation, data analysis, as well as communication and reflection. In this study, peer scaffolding was integrated into every phase of inquiry through



peer assistance while the scientific investigation process occurred. The forms of peer scaffolding were expected to vary across the inquiry phases according to the cognitive demands of students' scientific investigation activities. Furthermore, before the implementation of guided inquiry, a pre-peer scaffolding phase was conducted through briefing and concept reinforcement sessions for peer scaffolders.

Participants

Students in the Elementary School Teacher Education Study Program's Basic Concepts of Elementary Science course served as research participants. Two hundred and twenty-six students from four different courses took part in the research; 107 served as controls and 119 as experimental subjects. A method of purposive sampling based on whole classes was used to select the participants. Because this study employed a quasi-experimental design, all eligible students from the selected classes were included to preserve the natural instructional setting and provide valid comparisons between the two groups. All participants were first-year undergraduate students aged 18–19 years, and the sample was predominantly female, reflecting the demographic characteristics of elementary teacher education programs. The instructional implementation was conducted over six meetings within the Basic Concepts of Elementary Science course. The study was conducted over six consecutive weeks from November to December 2025 during the first semester of the 2025/2026 academic year. Before the instructional intervention began, students in both classes completed a pretest to measure their initial scientific literacy and critical thinking abilities. In the experimental group, peer scaffolders received briefings and concept reinforcement before the inquiry activities commenced at each meeting. After the entire instructional intervention was completed, both classes completed a posttest to measure improvements in students' scientific literacy and critical thinking.

The research obtained approval from the Elementary School Teacher Education Study Program, and all participants voluntarily participated in the study for academic purposes. All participants were briefed on the study's goals and methods before any data was collected. The data that was obtained was handled with the utmost confidentiality and was utilized only for the study.

Instrument and Procedures

Research data were collected using a model implementation observation sheet, a scientific literacy test, a critical thinking test, and students' inquiry worksheets. The OECD/PISA (2019) scientific literacy framework served as the basis for the scientific literacy instrument. This framework encompasses the abilities to explain scientific phenomena, evaluate and plan scientific research, and understand data and evidence. The critical thinking instrument was adapted from Ennis's (2011) critical thinking indicators, which include the abilities of clarification, inference, argument evaluation, and drawing logical conclusions.

Both instruments were adapted to align with the learning objectives and characteristics of pre-service elementary school teachers enrolled in the Basic Concepts of Elementary Science course. The adaptation process involved modifying the contextual scenarios and item wording while maintaining the original constructs and indicators proposed by OECD/PISA (2019) and Ennis (2011). Prior to implementation, the adapted instruments were reviewed by two science education experts and three educational evaluation experts to assess content relevance, construct representation, clarity, and suitability for the study context. Revisions were made based on the experts' recommendations before the instruments were administered.



Table 1*Summary of Research Instruments*

Instrument	Format	Scoring	Purpose
Scientific literacy test	Multiple-choice items with scientific reasoning responses	Predetermined answer keys and reasoning criteria	Measuring scientific literacy
Critical thinking test	Open-ended essay questions	Analytical scoring rubric based on Ennis's (2011) indicators	Measuring critical thinking
Model implementation observation sheet	Structured rating scale	Observation rating criteria	Observing the implementation of guided inquiry integrated with peer scaffolding
Students' worksheets	Guided inquiry worksheet	Supporting evidence for implementation analysis	Supporting the analysis of students' scientific investigation processes

Table 2 shows a sample of items that are representative of the scientific literacy and critical thinking instruments showing their qualities.

Table 2*Representative Sample Items from the Scientific Literacy and Critical Thinking Instruments*

Instrument	Representative Sample Item
Scientific literacy (multiple-choice with scientific reasoning)	In an experiment comparing eggs coated with toothpaste and uncoated eggs immersed in an acidic solution, why should the immersion time be kept constant?
Critical thinking (open-ended essay)	You are asked to teach the concept of specific heat to elementary school students. Compare lecture-based instruction and experimentation, determine which approach is more effective, and justify your answer using both scientific and pedagogical reasoning.

Table 2 illustrates representative sample items to demonstrate the response formats and cognitive demands of the scientific literacy and critical thinking instruments used in this study.

The modified instruments were subjected to content validity and internal consistency reliability evaluations after the expert review and revision procedure. Content relevance, concept representation, and measurement adequacy were all deemed adequate by the validation findings, indicating that the instruments were suitable. Analysis of internal consistency demonstrated satisfactory reliability (Cronbach's $\alpha = .835$), indicating that the instruments were reliable for measuring students' scientific literacy and critical thinking.

Quantitative data used to answer the first and second research questions were collected through pretest and posttest assessments of scientific literacy and critical thinking. To address the third research question, implementation data were collected using the model implementation observation sheet completed by two independent observers and students' inquiry worksheets (LKM). These implementation data were analyzed descriptively to identify the forms of peer scaffolding across the six inquiry phases, examine how peer scaffolders supported students' scientific investigation processes, and interpret the progression of conceptual, procedural, and metacognitive support throughout guided inquiry learning.

Data Analysis

Quantitative statistical procedures were complemented with descriptive analyses to interpret implementation findings. A qualitative descriptive analysis was employed to examine implementation evidence obtained from classroom observation sheets and students' worksheets (LKM). The analysis focused on identifying the forms of peer scaffolding implemented during each inquiry phase, describing the scientific investigation processes supported by peer scaffolders, and examining the progression of peer scaffolding support throughout the guided inquiry cycle. Findings were synthesized across both data sources to provide implementation evidence addressing the third research question.

Research Results

Scientific Literacy

Students who participated in the peer-scaffolding intervention consistently outperformed those receiving conventional instruction in scientific literacy.

Table 3 presents the differences in scientific literacy between the experimental and control groups.

Table 3

Differences in Scientific Literacy between Experimental and Control Groups

Group	Pretest Mean	Posttest Mean	Mean Rank	N-Gain	Effect Size
Experimental	73.84	91.52	155.18	0.676	Large
Control	74.28	82.81	67.14	0.331	—

Posttest performance was consistently stronger among participants receiving the intervention. In contrast to the control group, whose mean score rose from 74.28 to 82.81, the experimental group's score rose from 73.84 to 91.52 on the posttest.

There was a notable disparity in scientific literacy between the two groups, as shown by the Mann-Whitney test ($p < .001$). When compared to the control group's mean rank of 67.14, the experimental group achieved a higher value of 155.18. On top of that, the experimental group had a greater N-Gain value (.676) compared to the control group (.331).

Critical Thinking

Compared to the control group, participants whose lessons included the suggested model demonstrated much better critical thinking skills.

The critical thinking skills of the control and experimental groups are compared in Table 4.

Table 4

Differences in Critical Thinking between Experimental and Control Groups

Group	Pretest Mean	Posttest Mean	Mean Rank	N-Gain	Effect Size
Experimental	67.66	92.66	148.61	.773	Large
Control	58.05	83.05	74.45	.596	—

When comparing the two groups' posttest scores, the experimental group came out on top. From 67.66 to 92.66, the experimental group's mean score rose, whereas the control group's rose from 58.05 to 83.05.

Statistical analysis using the Mann-Whitney U test revealed a notable disparity in critical thinking abilities between the two categories ($p < .001$). The experimental group had a higher mean rank value (148.61) compared to the control group (74.45). The control group's N-Gain value was 0.596, which is considered moderate, whereas the experimental group's value was .773, which is considered high.

How Peer Scaffolding Supported the Scientific Investigation Process

Classroom implementation observations conducted by two independent observers across six guided inquiry sessions indicated that peer scaffolders provided conceptual, procedural, and reflective support throughout the guided inquiry process. The implementation findings presented in Table 5 were synthesized from the model implementation observation sheet and students' learning activities documented in the worksheets (LKM).

Table 5 summarizes the forms of peer scaffolding support observed across the six phases of guided inquiry learning.

Table 5.

Peer Scaffolding Support Across the Scientific Investigation Process During Guided Inquiry Learning

Guided inquiry phase	Peer scaffolding support	Scientific investigation process supported	Evidence source
Orientation	Clarifying scientific phenomena through guiding questions and activating prior knowledge	Identifying scientific problems and understanding the investigation context	Model implementation observation sheet
Problem formulation and hypothesis development	Facilitating collaborative discussion and guiding hypothesis construction	Formulating investigable questions and developing testable hypotheses	Observation sheet; Students' worksheets (LKM)
Investigation planning	Guiding investigation procedures, identifying variables, and organizing collaborative tasks	Designing systematic investigation procedures	Observation sheet
Investigation	Providing procedural guidance, monitoring collaborative work, and encouraging accurate observations	Collecting scientific evidence through systematic investigation	Observation sheet
Data analysis	Encouraging interpretation of findings through guiding questions and collaborative reasoning	Interpreting evidence and evaluating hypotheses using scientific reasoning	Students' worksheets (LKM)
Communication and reflection	Facilitating evidence-based discussion, providing feedback, and encouraging reflection	Constructing scientific explanations, communicating findings, and reflecting on the investigation process	Observation sheet; Students' worksheets (LKM)

Note. Model implementation observation sheets were completed by two independent observers to document peer scaffolding behaviors throughout the six phases of guided inquiry learning. Students' worksheets (LKM) provided documentary evidence of students' inquiry products, including hypothesis formulation, investigation planning, data interpretation, and evidence-based conclusions.

These implementation findings indicate that peer scaffolding functioned as an adaptive instructional mechanism, with the nature of support evolving according to the cognitive demands of each inquiry phase.

As shown in Table 5, peer scaffolding supported students' scientific investigations across all six phases of guided inquiry learning. However, the nature of the support varied according to the cognitive demands of each inquiry phase. During the orientation and problem formulation phases, peer scaffolders primarily facilitated conceptual understanding by clarifying scientific phenomena and guiding students. During these phases, peer scaffolders encouraged group members to interpret experimental findings, evaluate hypotheses using collected evidence, justify scientific explanations, and collaboratively reflect on the investigation process.

During the data analysis and communication-reflection phases, peer scaffolding increasingly emphasized evidence-based reasoning and reflective thinking. Peer scaffolders encouraged group members to interpret experimental findings, evaluate hypotheses using collected evidence, justify scientific explanations, and collaboratively reflect on the investigation process. This progression demonstrates that peer scaffolding functioned as an adaptive instructional support that evolved from conceptual guidance to procedural assistance and finally to metacognitive support, thereby facilitating students' scientific investigation throughout the guided inquiry process.

Implementation of Pre-Peer Scaffolding

The pre-peer scaffolding phase was implemented before inquiry learning through briefing activities, concept reinforcement, investigation orientation, and scaffolding strategy training for students acting as peer scaffolders.

Table 6 presents the pre-peer scaffolding activities implemented before inquiry learning.



Table 6*Pre-Peer Scaffolding Activities Implemented before Inquiry Learning*

Activity	Purpose
Briefing	Understanding inquiry syntax
Concept reinforcement	Strengthening science concepts
Investigation orientation	Preparing inquiry activities
Scaffolding training	Preparing peer support strategies

Implementation observations indicated that the pre-peer scaffolding session prepared peer scaffolders to perform their facilitative roles during guided inquiry. Following the briefing, concept reinforcement, investigation orientation, and scaffolding strategy activities, peer scaffolders demonstrated greater readiness to guide collaborative discussion, clarify scientific concepts, assist with data interpretation, and support procedural inquiry throughout classroom implementation.

Model Implementation

Table 7 presents the implementation fidelity of guided inquiry learning incorporating peer scaffolding.

Table 7*Implementation of Guided Inquiry with Integrated Peer Scaffolding*

Inquiry Phase	Percentage	Category
Problem orientation	88	Very Practical
Problem and hypothesis formulation	87	Very Practical
Investigation planning	86	Very Practical
Investigation	87	Very Practical
Data analysis	88	Very Practical
Communication and reflection	87	Very Practical

The implementation percentages ranged between 86% and 88% across all inquiry phases, encompassing problem orientation, problem and hypothesis formulation, investigation planning, investigation, data analysis, and communication and reflection.

Observation results indicated that all phases of guided inquiry integrated with peer scaffolding were implemented successfully, with implementation percentages ranging from 86% to 88%. The consistently high implementation across all inquiry phases indicates that the guided inquiry model integrated with peer scaffolding was implemented with high fidelity throughout the intervention.

Discussion

Integration of Peer Scaffolding within Guided Inquiry Learning

The findings suggest that integrating peer scaffolding into guided inquiry encouraged pre-service elementary school teachers to participate more actively in collaborative and inquiry-oriented learning. The integration of peer scaffolding throughout every inquiry phase helped students conduct scientific investigations in a more structured manner by providing social and cognitive support during learning activities.

This outcome may be attributed to the role of peer scaffolding as a structured learning support mechanism rather than merely a conventional group discussion activity. Peer scaffolding helped students build scientific understanding more reflectively. This interpretation is supported by Belland et al. (2017), who found that scaffolding

within inquiry-based and STEM learning environments enhanced students' scientific reasoning, problem-solving ability, and conceptual understanding.

One possible explanation for these findings is provided by the social constructivist perspective, which views learning as a process that develops through social interaction and the collaborative construction of knowledge (Vygotsky, 1978). Within the context of this study, students obtained the opportunity to construct understanding through assistance, concept clarification, and feedback from peers during inquiry activities. Such interaction enabled students not only to develop conceptual understanding but also to strengthen scientific argumentation, reflective thinking, and scientific reasoning through collaborative dialogue. Discussions in inquiry learning also played an important role in encouraging students to develop scientific questions, evidence-based argumentation, and critical reflection (Chin & Osborne, 2008). These findings suggest that inquiry became more meaningful when scientific investigation was supported by social interaction that enabled students to construct knowledge collectively (Gillies, 2016; Mercer & Littleton, 2007). Furthermore, social support and cognitive assistance helped students build understanding gradually through the processes of clarification, reflection, and meaning negotiation (Hogan & Pressley, 1997).

The effectiveness of peer scaffolding may be attributed to the availability of adequate social and cognitive support throughout the inquiry process. Across many inquiry-based learning settings, students frequently experience difficulties in formulating problems, interpreting data, and drawing scientific conclusions independently. In this research, peer scaffolding helped reduce these difficulties through peer assistance at every phase of inquiry. Collaborative support provided timely conceptual assistance, allowing students to conduct investigations in a more structured and reflective manner (Gijlers & De Jong, 2013). Peer interaction also provided immediate concept clarification, thereby reducing cognitive load during inquiry. These findings supported the view of Kirschner et al. (2006) and Sweller (2011) that inquiry learning without adequate support has the potential to cause cognitive overload.

Collectively, the evidence suggests the view that inquiry learning without structured social support has the potential to limit students' profound engagement in scientific reasoning. Therefore, the effectiveness of inquiry is influenced not only by the quality of investigation activities but also by the existence of social support mechanisms that help students understand the scientific thinking process. In this context, peer scaffolding functions as a bridge between inquiry activities and students' knowledge construction processes.

The observed improvement is likely associated with the systematic integration of peer scaffolding into all phases of inquiry, starting from problem orientation through problem and hypothesis formulation, investigation planning, investigation, data analysis, and communication and reflection. These findings represent an important contribution to the existing literature because the majority of previous studies still positioned inquiry and peer interaction as two separate components. In this study, peer scaffolding was positioned as an integral part of the scientific investigation process, ensuring that social support and inquiry activities operated simultaneously. Accordingly, this study extends guided inquiry implementation by incorporating a more structured social support mechanism within pre-service elementary teacher education. Collectively, these findings explain how peer scaffolding supported scientific investigation by providing conceptual clarification, procedural guidance, evidence interpretation, and reflective feedback throughout all phases of guided inquiry.

The implementation findings described how peer scaffolding supported scientific investigation throughout the inquiry process. However, future qualitative studies are still needed to explain the interaction mechanisms underlying these implementation patterns.

The Role of Pre-Peer Scaffolding

One of the major findings of this study was the introduction of a structured pre-peer scaffolding phase before inquiry instruction began. This phase consisted of briefings, science concept reinforcement, inquiry syntax orientation, and preparation of learning support strategies for students serving as peer scaffolders. The pre-peer scaffolding phase also improved students' readiness to provide support during scientific investigation activities.

These findings suggest that the effectiveness of peer scaffolding depended not only on collaborative inquiry activities but also on the readiness of students serving as peer scaffolders. Through the pre-peer scaffolding phase, students developed a better understanding of science concepts, investigation procedures, and strategies for providing learning assistance to group members. This preparation helped the inquiry proceed more smoothly and reduced the potential for confusion during investigation activities. In other words, pre-peer scaffolding assisted in building students' social and cognitive readiness before the inquiry was executed.



From a theoretical standpoint, these findings broaden the traditional concept of scaffolding, which has generally been viewed as support that emerges during learning activities. Scaffolding theory highlights the importance of purposeful instructional support in helping learners accomplish tasks beyond their current level of independent performance (Wood et al., 1976). Within the context of this study, learning support was prepared systematically before the inquiry began, allowing the social and academic assistance process to operate more effectively. Systematically designed scaffolding enabled learners to receive more structured learning support in the processes of problem-solving and scientific investigation (Spector & Merrill, 2014). These findings suggest that successful inquiry learning depends not only on well-designed investigation activities but also on the preparedness of the social support mechanisms integrated into instruction. Scaffolding support within inquiry learning helped learners organize thinking processes, understand problems, and manage complex investigation activities (Reiser, 2004). Rather than viewing scaffolding solely as assistance provided during learning activities, this study conceptualizes peer scaffolding as a structured socio-cognitive support mechanism that begins before inquiry and continues systematically throughout the inquiry process.

Furthermore, implementing pre-peer scaffolding demonstrated that social support in inquiry learning can be designed more systematically rather than relying solely on spontaneous interaction during group discussions. This condition became important because a large portion of collaborative learning research still positions peer interaction as a general discussion activity without adequate preparation. In the present study, briefings and concept reinforcement for peer scaffolders contributed to a more consistent process of learning support throughout inquiry activities. These findings support the view that the quality of social interaction is influenced by the readiness of learners to execute their collaborative roles (Gillies, 2016).

Contribution to Scientific Literacy

The results demonstrate that integrating peer scaffolding into guided inquiry learning contributed to improvements in the scientific literacy of pre-service elementary school teachers. Students in the experimental group demonstrated stronger performance in hypothesis testing, data interpretation, and evidence-based argumentation than those in the control group. Evidence-based argumentation and scientific reasoning skills become a critical part of modern science learning practice because they help learners understand how scientific knowledge is constructed through the processes of evidence evaluation and scientific reasoning (Osborne, 2014). These findings suggest that the integration of inquiry and social support helped students understand the scientific thinking process more profoundly.

The findings were in line with what is expected by the OECD/PISA scientific literacy framework, which places an emphasis on the capacity to describe and understand scientific events, as well as to analyze and understand the outcomes of scientific studies (OECD, 2019). In this study, students were not only involved in observation and experimentation activities, but they also received social assistance while the investigation process occurred. Such support enabled students to connect empirical evidence with scientific concepts more reflectively, allowing the scientific reasoning process to develop more deeply. These findings suggest that the development of scientific literacy was influenced not only by investigation activities but also by the quality of social interaction while the inquiry process took place.

Consistent with earlier research, these findings suggest that inquiry learning promotes scientific literacy by actively engaging learners in the process of scientific investigation (Furtak et al., 2012; Lazonder & Harmsen, 2016). However, this study also showed that the effectiveness of inquiry became more optimal when supported by peer scaffolding systematically integrated into every phase of inquiry. These findings indicated that inquiry learning and social support should not be positioned as two separate approaches, but rather as complementary instructional components in supporting the development of students' scientific literacy.

Furthermore, the findings indicate that students developed stronger data interpretation and scientific argumentation skills when they were provided with opportunities to discuss and evaluate evidence collaboratively during inquiry activities. This interaction enabled students to clarify understanding, revise interpretations, and construct scientific reasoning more reflectively. Scientific argumentation and discourse within inquiry learning assist learners in evaluating evidence, constructing scientific explanations, and developing scientific reasoning more profoundly (Duschl & Osborne, 2002). Therefore, scientific literacy within inquiry learning depends not only on experimental activities but also on social support that helps students interpret data and scientific evidence meaningfully.

Contribution to Critical Thinking

The results of this study demonstrate that integrating peer scaffolding into guided inquiry learning positively contributed to the development of critical thinking among pre-service elementary school teachers. Compared with the control group, students in the experimental group exhibited stronger performance in reasoning, evaluating arguments, interpreting evidence, and drawing logical conclusions. Critical thinking has become an important part of modern science learning because it helps learners analyze information, evaluate evidence, and construct decisions based on rational and reflective reasoning (Ennis, 2011; Facione, 2015). This suggests that the integration of inquiry and social support helped students develop the critical thinking process more profoundly.

The findings also indicated that social interaction during inquiry learning supported the development of students' critical reasoning through discussion, argumentation, and collaborative evaluation of evidence. In this study, students not only participated in scientific investigation activities but also had opportunities to defend their viewpoints, evaluate peer arguments, and refine their thinking based on feedback obtained during discussions. This condition demonstrated that the development of critical thinking was influenced not only by individual problem-solving activities but also by the quality of social interaction within inquiry learning.

These findings reinforce previous evidence that inquiry learning enhances critical thinking by actively engaging learners in investigation, data analysis, and the evaluation of scientific arguments (Furtak et al., 2012; Lazonder & Harmsen, 2016). However, the present findings indicate that the effectiveness of inquiry was enhanced when peer scaffolding was systematically integrated throughout every phase of guided inquiry. This suggests that inquiry learning and social support should not be positioned as two approaches, but rather as complementary pedagogical approaches in supporting the development of students' critical thinking.

Another important finding is that students showed greater improvement in argument evaluation and decision-making when they engaged in collaborative discussions and evidence evaluation. This interaction enabled students to clarify understanding, revise interpretations, and construct reasoning more reflectively. Argumentative discussions in inquiry learning assist learners in developing the abilities of evidence evaluation, logical reasoning, and critical reflection more deeply (Mercer & Littleton, 2007). Therefore, fostering critical thinking through inquiry requires not only scientific investigation but also structured social support that enables students to evaluate evidence and make well-reasoned decisions grounded in scientific argumentation.

Contribution to Teacher Education

This study also contributes to the advancement of primary teacher education. Preparing future teachers to implement active, inquiry-oriented science learning in primary schools requires the development of not only sound scientific content knowledge but also strong scientific literacy and critical thinking skills. In this context, integrating peer scaffolding into guided inquiry learning provided students with learning experiences that supported their understanding of the scientific investigation process while fostering collaborative and reflective skills.

Inquiry learning integrated with peer scaffolding provided students with learning experiences that emphasized not only conceptual understanding but also knowledge construction through scientific investigation and social interaction. Students not only learned as learners, but they also learned to provide assistance, feedback, and academic support to their peers. This pattern suggests that integrating peer scaffolding within inquiry holds important pedagogical implications for preparing pre-service elementary school teachers capable of creating science instruction that is more participatory, collaborative, and oriented toward the development of 21st-century skills. Pre-service teacher education requires learning experiences capable of connecting concept mastery, pedagogical practice, and instructional reflection in an integrated manner (Zeichner, 2010).

Furthermore, these findings suggest that pre-service teacher education should provide learning experiences that simultaneously develop scientific investigation skills and socio-collaborative competencies. This finding shows that the development of pre-service teacher competencies is related not only to the mastery of subject matter and instructional strategies but also to the ability to construct learning interactions that support the scientific thinking process of learners. Preparing future teachers to implement active, inquiry-oriented science learning in primary schools requires the development of not only sound scientific content knowledge but also strong scientific literacy and critical thinking skills. Advancing teacher education requires the development of a more reflective and context-sensitive understanding of teaching and learning (Loughran, 2006).



This study was limited to implementing peer scaffolding-assisted guided inquiry learning in science instruction for pre-service elementary school teachers. Therefore, future research can examine the implementation of the model in the contexts of different subjects and educational levels. Future studies could also investigate the effects of peer scaffolding on additional learning outcomes, such as collaborative problem-solving, communication skills, and self-regulated learning within inquiry-based learning environments.

Conclusion and Implications

This study demonstrated that integrating peer scaffolding into guided inquiry learning improved the scientific literacy and critical thinking of pre-service elementary school teachers. Compared with conventional instruction, guided inquiry integrated with peer scaffolding provided structured social and cognitive support that enabled students to engage more effectively in scientific investigations. Implementation findings further showed that peer scaffolders supported inquiry by adapting conceptual, procedural, and metacognitive assistance to the learning demands of each inquiry phase.

A distinctive contribution of this study is the implementation of a pre-peer scaffolding preparation phase before inquiry learning, which prepared peer scaffolders to provide more effective support throughout collaborative scientific investigations. Conceptually, these findings extend the understanding of guided inquiry learning by positioning peer scaffolding as a structured socio-cognitive mechanism that begins before inquiry and continues systematically across all phases of guided inquiry.

The findings suggest that combining guided inquiry learning with peer scaffolding provides meaningful opportunities to strengthen the scientific literacy and critical thinking of pre-service elementary school teachers. More broadly, these findings highlight the complementary roles of scientific inquiry and structured peer support in fostering evidence-based reasoning, collaborative learning, and twenty-first-century competencies.

Study Limitation and Future Research

This study was limited to the implementation of peer scaffolding-assisted guided inquiry learning in science education for pre-service elementary school teachers; therefore, the findings should be generalized with caution. In addition, this research has not yet examined the dynamics of individual interactions among students during the peer scaffolding process in depth. Therefore, future research can explore social interaction, collaborative problem solving, and the implementation of peer scaffolding across contexts of different subjects and educational levels.

This research adopted a quantitative quasi-experimental design to evaluate the effectiveness of guided inquiry learning integrated with peer scaffolding. As a result, qualitative evidence, including detailed observations of peer interactions, interviews, and discourse analysis, was not collected to examine more comprehensively how peer scaffolders supported scientific investigations. Although implementation observations documented the integration of peer scaffolding across the inquiry process, future studies should employ qualitative methods to provide a deeper understanding of the interaction mechanisms through which peer scaffolding supports scientific inquiry.

Acknowledgements

The authors would like to express their sincere appreciation to all pre-service elementary school teachers who participated in this study. The authors also gratefully acknowledge the financial support provided by the Elementary School Teacher Education Study Program.

Declaration of Interests

The author(s) declared no conflicts of interests.

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Received: May 29, 2026

Revised: July 08, 2026

Accepted: August 05, 2026

Cite as: Putri, K. E., Setyosari, P., & Ekawati, R. (2026). Integrating peer scaffolding into guided inquiry learning to enhance scientific literacy and critical thinking among pre-service elementary school teachers. *Journal of Baltic Science Education*, 25(4), 695–709. <https://doi.org/10.33225/jbse/26.25.695>



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