Authentic science learning through greenhouse visits: Advancing scientific reasoning with contextual teaching and learning

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Abstract
Elementary school students' scientific reasoning skills in Integrated Science and Social Studies (IPAS) learning remain relatively low because classroom instruction is still predominantly teacher-centered and insufficiently connects learning materials with students' real-life experiences. As a result, students often encounter difficulties in understanding abstract scientific concepts, including the greenhouse effect. This study aimed to examine the effect of a greenhouse visit-based Contextual Teaching and Learning (CTL) approach on elementary school students' scientific reasoning skills in learning the greenhouse effect. The study employed a quantitative approach using a quasi-experimental pretest–posttest control group design. The participants consisted of 58 fourth-grade students, including 25 students in the experimental group and 33 students in the control group. The experimental group participated in CTL instruction through educational visits to the Greenhouse of the Faculty of Agriculture, Pattimura University, while the control group received conventional instruction. Data were collected through a scientific reasoning test, classroom observations, and documentation. The data were analyzed using normality and homogeneity tests, an independent-samples t-test, and normalized gain (N-Gain) analysis. The findings revealed that the greenhouse visit-based CTL approach had a statistically significant effect on students' scientific reasoning skills ($p < .001$). Furthermore, the experimental group achieved a mean N-Gain score of 0.5763 (moderate category), which was higher than that of the control group (0.3269). These findings indicate that integrating contextual learning with authentic field experiences effectively enhances students' scientific reasoning by engaging them in observation, inquiry, data analysis, and evidence-based reasoning. This study provides practical implications for teachers in implementing contextual learning strategies and offers a reference for future research involving different science topics and educational levels.

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1. Introduction

In the twenty-first century, education is no longer solely focused on the acquisition of knowledge but also on developing the competencies required to address rapid technological advances and increasingly complex global challenges. One of the essential competency frameworks is scientific creativity, critical thinking, digital literacy, and sustainability (SCDS), which encompasses creativity, critical thinking, digital literacy, and environmental sustainability awareness (Thornhill-Miller et al., 2023). These competencies provide a crucial foundation for preparing students to think creatively and critically while fostering a strong sense of responsibility toward sustainability issues in contemporary society (Rohman et al., 2024; Rahman et al., 2026). The development of these competencies is closely supported by students' scientific reasoning, which refers to the ability to use evidence and logical reasoning to understand scientific phenomena and make informed decisions. As one of the key twenty-first-century competencies, scientific reasoning enables students to interpret evidence, formulate predictions, and draw logical conclusions based on empirical observations (Lazonder & Harmsen, 2016). In science education, scientific reasoning plays a fundamental role in helping students construct knowledge through observation, inquiry, and data analysis. Research by Osterhaus et al. (2023) demonstrated that fostering scientific reasoning from the elementary school level contributes significantly to students' science competence and their readiness to meet the demands of the twenty-first century. Scientific reasoning begins to emerge in children as early as four years of age, primarily through exploratory play and observation of others' behaviors (Buchsbaum et al., 2011; Cook et al., 2011). This ability continues to develop throughout elementary education and beyond, as direct learning experiences and inquiry-based instructional approaches provide meaningful opportunities for students to strengthen their scientific reasoning skills (Sandoval et al., 2014; Fernatubun et al., 2026).

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Scientific reasoning is a fundamental competency in science education because it enables students to understand natural phenomena through logical and systematic thinking. As a core scientific skill, scientific reasoning is essential for promoting effective science learning (Bhaw et al., 2023). It encompasses the ability to identify problems, formulate hypotheses, generate and evaluate evidence, and draw conclusions based on empirical data (Krell et al., 2022). Through scientific reasoning, students not only acquire factual knowledge but also develop a deeper conceptual understanding and the ability to explain causal relationships underlying scientific phenomena. In addition to strengthening conceptual understanding, scientific reasoning supports the development of critical thinking, problem-solving, and decision-making skills. It enables students to critically examine information and construct meaningful scientific understanding (Varma, 2014). Vo & Csapó (2023) reported a positive correlation between scientific reasoning and students' achievement in STEM disciplines, demonstrating that learners who effectively apply empirical evidence and logical reasoning are better able to understand scientific concepts and solve complex problems. Furthermore, scientific reasoning has been recognized as a fundamental component of scientific thinking and a key contributor to the development of critical thinking skills (Bao et al., 2022). Nevertheless, not all students who demonstrate consistent patterns of reasoning employ a scientific reasoning framework in their thinking processes (Lemmer et al., 2018). Students who have not yet developed scientific reasoning skills, often referred to as naïve reasoners, tend to rely on context-dependent reasoning and fail to apply consistent reasoning processes when constructing new knowledge (Magana & Boutin, 2019). When solving problems, these students are more likely to be influenced by situational contexts and may adopt different strategies to solve conceptually identical problems presented in different contexts, commonly known as isomorphic problems (Ferreira et al., 2017). Therefore, assessing scientific reasoning skills is essential for distinguishing students whose reasoning is influenced by persistent misconceptions or contextual factors from those who consistently employ scientific reasoning in their cognitive processes (Lin & Singh, 2011).

Although scientific reasoning is a fundamental competency in science education, its development among elementary school students remains suboptimal. A similar trend has also been observed among lower secondary school students. Boğar (2019) reported that seventh-grade students demonstrated extremely low levels of scientific reasoning, with their performance on the first five two-tier assessment items classified as Level 0. Many students are still unable to relate observational findings to scientific concepts, explain phenomena using empirical evidence, or draw logical conclusions. This situation indicates that science instruction continues to emphasize content acquisition rather than the development of scientific thinking, causing students to become passive recipients of knowledge instead of active participants in the learning process. In contrast, scientific reasoning develops through students' active engagement in observation, experimentation, discussion, and data analysis. Previous studies have consistently shown that elementary school students generally exhibit low to moderate levels of scientific reasoning, particularly in explaining scientific phenomena and drawing conclusions from observational evidence (Lawson, 2002). Consequently, many countries in Sub-Saharan Africa have begun reforming their elementary science and mathematics education systems by adopting more integrated science curricula that explicitly incorporate scientific reasoning and real-world problem-solving skills. These reforms aim to prepare students for increasingly complex and rapidly changing societies that require critical judgment and informed decision-making based on evidence (Abate et al., 2020). Accordingly, reasoning skills are widely recognized as essential for success in both academic learning and everyday life (Zeineddin & Abd-el-khalick, 2010). Furthermore, Luo et al. (2021) found that scientific reasoning develops progressively with increasing grade level and science achievement. Ninth-grade students demonstrated significantly higher scientific reasoning abilities than students in Grades 7 and 8, while eighth-grade students also outperformed seventh-grade students. Students with higher levels of science achievement consistently exhibited stronger scientific reasoning skills than those with moderate or lower academic performance. The study further revealed that scientific reasoning improves as students advance through school and achieve higher levels of science performance. Male students generally obtained slightly higher scientific reasoning scores than female students, and science achievement was identified as an important factor influencing the relationship between gender, grade level, and scientific reasoning ability. Similarly, Koerber et al. (2015) reported that elementary school children's scientific reasoning is still developing and is generally situated at the concrete-to-transitional level, particularly with respect to evidence-based reasoning.

One of the science topics that requires scientific reasoning is the greenhouse effect. In learning this topic, students are expected not only to understand the underlying concepts but also to explain how the greenhouse effect occurs, describe the relationship between human activities and the increase in greenhouse gas emissions, and analyze its impact on climate change. Such understanding requires the ability to interpret scientific information, analyze cause-and-effect relationships, and construct evidence-based explanations. However, the greenhouse effect is often difficult for students to understand because it involves processes that cannot be directly observed and integrates multiple interconnected scientific concepts. Research has shown that many students fail to understand the causal relationships among greenhouse gases, infrared radiation, global warming, and climate change. Students frequently confuse the greenhouse effect with ozone depletion and air pollution (Shepardson et al., 2011). In addition, students often hold persistent misconceptions about the mechanisms of the greenhouse effect and how infrared radiation is trapped in the atmosphere. Instruction that explicitly addresses these misconceptions has been shown to improve students' conceptual understanding

(McCuin et al., 2018). Similarly, Gul (2011) found that both elementary and secondary school students exhibited high levels of misconceptions regarding the causes of the greenhouse effect, the role of greenhouse gases, and their relationship to climate change. A recent systematic review further confirmed that understanding the greenhouse effect and the causal links between greenhouse gas emissions and climate change remains a major challenge in science education. Therefore, science instruction should be designed to help students integrate observational evidence, scientific data, and conceptual knowledge in order to develop a more accurate and scientifically grounded understanding.

Understanding abstract concepts such as the greenhouse effect requires instructional approaches that connect scientific content with students' everyday experiences. One such approach is Contextual Teaching and Learning (CTL), which links academic concepts to authentic real-world contexts, thereby promoting more meaningful learning. Through CTL, students actively engage in observing, questioning, investigating, discussing, and reflecting on their learning experiences. This approach is particularly appropriate for elementary school students, who tend to understand scientific concepts more effectively through concrete experiences. CTL promotes meaningful learning by incorporating the principles of constructivism, inquiry, questioning, learning communities, reflection, and authentic assessment, all of which encourage students to actively construct their own understanding (Prince, 2004). Furthermore, CTL enhances conceptual understanding and critical thinking by providing contextualized learning experiences. CTL is grounded in constructivist learning theory, which posits that learners construct knowledge by connecting new information with their prior experiences, personal needs, and real-life contexts. Contextualized instruction makes learning more meaningful, thereby increasing students' motivation, engagement, and likelihood of academic success (Ambrose et al., 2013). Contemporary education emphasizes not only learning outcomes but also the learning processes through which students develop understanding. Within this framework, teachers facilitate learning by connecting instructional content with authentic situations, enabling students to relate newly acquired knowledge to their daily experiences. To promote meaningful learning, students should be provided with opportunities to actively participate through hands-on exploration, experimentation, and direct experience rather than passively receiving information from the teacher. By adopting a contextual learning approach, students are better able to understand scientific phenomena and apply their knowledge to solve problems encountered in everyday life (Lotulung et al., 2018). Taken together, these perspectives provide a coherent theoretical pathway for the present study. The SCDS framework establishes the broader competency goal by positioning creativity, critical thinking, digital literacy, and sustainability awareness as essential outcomes of contemporary education, while scientific reasoning provides the cognitive mechanism through which students interpret evidence, explain phenomena, and make evidence-based judgments. Constructivism explains how these competencies can be developed through active meaning-making, whereas Piaget's developmental perspective provides a rationale for emphasizing concrete and observable experiences when teaching elementary school students. CTL brings these perspectives together pedagogically by connecting prior knowledge and real-life contexts with observation, inquiry, questioning, collaboration, reflection, and authentic assessment. Thus, a greenhouse visit is not merely an enrichment activity but a theoretically grounded learning context in which students can construct scientific understanding from direct experience and progressively mobilize scientific reasoning to interpret evidence and explain the greenhouse effect.

Building on this integrated theoretical framework, the greenhouse visit provides an authentic context in which these theoretical principles can be enacted in practice. In the present study, students directly observed the greenhouse effect at the greenhouse facility of the Faculty of Agriculture, Pattimura University, allowing the concepts being studied to become more concrete and meaningful. This finding is consistent with Makransky & Mayer (2022), who reported that field trip–based learning can enhance students' critical thinking skills. These findings suggest that CTL is an effective approach for fostering the development of twenty-first-century competencies. Although numerous studies have demonstrated that Contextual Teaching and Learning (CTL) effectively improves students' higher-order thinking skills and conceptual understanding, research examining its impact on elementary school students' scientific reasoning regarding the greenhouse effect remains limited, particularly studies that utilize greenhouse visits as a contextual learning resource. Based on the theoretical framework and the research gap identified above, the following hypotheses were formulated. H0: The greenhouse visit–based Contextual Teaching and Learning (CTL) approach does not have a statistically significant effect on elementary school students' scientific reasoning skills in learning the greenhouse effect. H1: The greenhouse visit–based Contextual Teaching and Learning (CTL) approach has a statistically significant effect on elementary school students' scientific reasoning skills in learning the greenhouse effect. Therefore, the present study aims to investigate the effect of a greenhouse visit–based CTL approach on elementary school students' scientific reasoning skills.

2. Method

2.1. Research Design

This study employed a quantitative approach using a quasi-experimental pretest–posttest control group design to examine the effect of a greenhouse visit–based Contextual Teaching and Learning (CTL) approach on

elementary school students' scientific reasoning skills. The design involved intact classes and did not include individual-level random assignment to the experimental and control groups (Table 1). This design was selected because the study was conducted in naturally existing classroom settings, making random assignment of individual students impractical. Pretest and posttest measurements were administered to both groups to examine changes in scientific reasoning skills following the intervention.

Table 1. Research Design

Group	Pretest (O_1)	Treatment (X)	Posttest (O_2)
Experimental Group	O_1	X (Contextual Teaching and Learning Approach)	O_2
Control Group	O_3	Conventional Instruction	O_4

Sources: Adapted from Zajić & Maksimović (2022)

2.2. Participants

The study used cluster random sampling to select intact fourth-grade classes from the available classes. Sampling was conducted at the class level rather than at the individual-student level because students were already organized into established classroom groups (Dreyhaupt et al., 2017). One selected class from State Elementary School 72 Ambon, consisting of 25 students, served as the experimental group, while one selected class from State Elementary School 1 Latihan SPG Ambon, consisting of 33 students, served as the control group. Because the two selected classes were drawn from different schools, the study did not involve random assignment of participants to experimental conditions. Accordingly, the findings should be interpreted as evidence of an association between the CTL intervention and students' scientific reasoning outcomes within the study setting rather than as evidence based on a fully randomized experiment. The independent variable was the greenhouse visit–based CTL approach, and the dependent variable was students' scientific reasoning skills.

2.3. Data Collection

Data were collected using three techniques: (1) scientific reasoning tests administered as pretests and posttests, (2) classroom observations conducted throughout the instructional process, and (3) documentation to provide supporting research data. The pretest and posttest were administered to measure students' scientific reasoning skills before and after the intervention. Classroom observations were conducted to document the implementation of the instructional process and students' learning activities, while documentation provided supplementary evidence of the research implementation. The scientific reasoning test was developed with reference to Lawson (2004) scientific reasoning framework, which emphasizes the use of evidence to explain phenomena, draw logical conclusions, and engage in scientific reasoning. However, the present manuscript does not report separate evidence of content validity or an internal-consistency reliability coefficient for the test; this limitation is acknowledged when interpreting the findings.

2.4. Data Analysis

The data were analyzed using descriptive and inferential statistics with IBM SPSS Statistics version 26.0. Descriptive statistics were used to summarize students' scientific reasoning scores using the mean, standard deviation, minimum score, and maximum score. The Shapiro–Wilk test was used to assess normality, and Levene's test was used to assess homogeneity of variances. Because the study did not include a separate inferential test of baseline equivalence, no statistical claim of pretest equivalence between the experimental and control groups was made. After the assumptions of normality and homogeneity were assessed, an independent-samples t-test was conducted at a significance level of 0.05 to examine whether the posttest scientific reasoning scores differed significantly between the experimental and control groups. In addition, normalized gain (N-gain) scores were calculated to describe the improvement in students' scientific reasoning skills from pretest to posttest. Methodological reporting of normality assessment follows established guidance for checking assumptions before parametric analyses (Ghasemi & Zahediasl, 2012), while the reporting of standardized effect sizes for independent-group comparisons follows recommendations by Lakens (2013).

3. Results and Discussion

Students' scientific reasoning skills were assessed using pretest and posttest instruments administered to both the experimental and control groups. The experimental group received instruction through a Contextual Teaching and Learning (CTL) approach incorporating a visit to the greenhouse of the Faculty of Agriculture, Pattimura University, whereas the control group received conventional instruction on the greenhouse effect. The pretest and posttest results indicated that both groups demonstrated improvements in scientific reasoning skills following the instructional intervention. However, the improvement observed in the experimental group was substantially greater than that of the control group. The mean score of the experimental group increased from 40.12 on the pretest to 74.72 on the posttest, whereas the mean score of the control group increased from 38.36 to 60.03. As shown in Table 2, the improvement in pretest and posttest scores was greater in the experimental group than in the control group.

Table 2. Comparison of Pretest and Posttest Scores Between the Experimental and Control Groups

Group	Pretest	Posttest	Score Improvement
Experimental Group	40.12	74.72	34.60
Control Group	38.36	60.03	21.67

This finding indicates that the greenhouse visit–based Contextual Teaching and Learning (CTL) approach was more effective than conventional instruction in improving students' scientific reasoning skills. By connecting scientific concepts with authentic learning experiences, the CTL approach provides students with opportunities to directly observe phenomena, formulate questions, analyze observational data, and construct evidence-based explanations. This process promotes more meaningful learning because students acquire knowledge through firsthand experience rather than merely receiving information from the teacher. The findings of this study are consistent with those of Maryani et al. (2024) , who reported that STEM–Contextual Teaching and Learning (STEM-CTL) significantly enhanced elementary school students' critical thinking skills and learning engagement. Their study demonstrated that when instruction is connected to real-world contexts and exploratory learning activities, students become more actively involved in constructing knowledge, analyzing information, and solving problems. The present findings also support those of Yonanda et al. (2025), who found that elementary school students taught using the CTL model achieved significantly higher critical thinking skills than those who received direct instruction. Their study concluded that CTL encourages students to relate learning materials to their everyday experiences, enabling them to understand concepts more effectively, strengthen their analytical abilities, and develop appropriate solutions to the problems they encounter.

Furthermore, Saputri et al (2025) reported that the CTL approach had a significant positive effect on improving elementary school students' critical thinking skills because instruction was centered on inquiry, discussion, and problem-solving activities situated in real-life contexts. Such an approach creates an active learning environment in which students not only develop conceptual understanding but also apply their knowledge to explain observed phenomena. The findings of the present study are further supported by Martasari et al. (2025), whose research on outdoor learning concluded that direct learning experiences in authentic environments enhance students' critical and analytical thinking skills more effectively than conventional classroom instruction. Direct interaction with real objects and phenomena provides students with opportunities to make observations, interpret data, and draw conclusions based on evidence gathered throughout the learning process. Taken together, these findings suggest that contextual learning experiences situated in authentic environments, such as greenhouse visits, not only enhance students' understanding of the greenhouse effect but also foster the development of scientific reasoning skills through systematic observation, data analysis, evidence evaluation, and evidence-based scientific conclusion drawing. To further examine the magnitude of students' improvement, N-gain analysis was conducted to describe changes in scientific reasoning skills from pretest to posttest. The N-gain scores were used solely for descriptive comparison of the improvement between the experimental and control groups and were not treated as the dependent variable in the independent-samples t-test.

Nevertheless, the present findings should not be interpreted as evidence that CTL or field-trip learning is universally more effective than classroom-based instruction. The effectiveness of authentic learning experiences may depend on how strongly the activity is connected to curricular objectives, how well students are prepared before the visit, the pedagogical guidance provided during the activity, and the opportunities provided for students to connect observations with classroom concepts. Alon & Ta (2015), for example, found that learning outcomes across field trips were associated with pedagogical characteristics such as storytelling, physical activity, and connections to everyday life, indicating that simply moving instruction outside the classroom does not guarantee equivalent learning benefits. More recent evidence also cautions against treating field trips as inherently superior to classroom or virtual learning, emphasizing that outcomes vary according to the design, context, participants, and evaluation approach (Dobečková & Maršálek, 2026). Accordingly, the stronger improvement observed in the present experimental group may reflect not only the greenhouse setting itself but also the combination of CTL principles, guided inquiry, teacher facilitation, and opportunities to connect firsthand observations with the greenhouse-effect concept. This interpretation also suggests that poorly structured visits, insufficient preparation, limited instructional guidance, or weak integration with the curriculum may reduce the potential effectiveness of field-trip-based learning. As shown in Figure 1, the experimental group demonstrated a greater improvement in scientific reasoning skills than the control group.

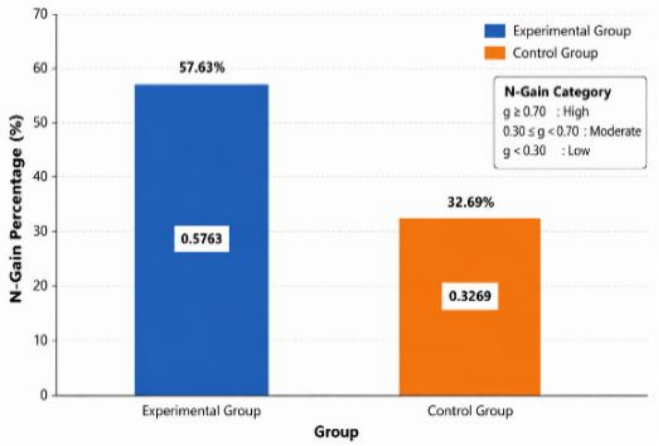

Figure 1. Comparison of the N-gain Scores of Scientific Reasoning Skills Between the Experimental and Control Groups

The experimental group achieved an N-gain score of 0.5763 (57.63%), which falls within the moderate category, whereas the control group obtained an N-gain score of 0.3269 (32.69%), also categorized as moderate but indicating a substantially lower level of improvement. These findings suggest that the greenhouse visit–based Contextual Teaching and Learning (CTL) approach was more effective than conventional instruction in enhancing students' scientific reasoning skills on the topic of the greenhouse effect. The observed improvement indicates that direct learning experiences through authentic observation enabled students to establish meaningful connections between scientific concepts and the real-world phenomena they encountered, thereby making the learning process more meaningful. The effectiveness of the CTL approach in this study was reflected in students' active participation throughout each stage of the learning process, including observing conditions inside the greenhouse, identifying problems, formulating questions, discussing observational findings, and drawing evidence-based conclusions. These activities provided students with opportunities to develop scientific thinking through firsthand inquiry rather than merely receiving information from the teacher. Such authentic learning experiences enabled students to understand the causal relationship between the increase in temperature inside the greenhouse and the greenhouse effect studied in the classroom, thereby promoting the development of scientific reasoning skills.

These findings are consistent with Morris (2025), who reported that experience-based science learning significantly improves students' scientific reasoning by providing opportunities to observe phenomena, evaluate evidence, and construct scientific explanations based on empirical data. The study emphasized that students' active engagement in the inquiry process is a key factor in the development of scientific reasoning. Similarly, Kind & Osborne, (2016) argued that scientific reasoning develops most effectively when students are actively involved in interpreting evidence, constructing scientific arguments, and connecting observational findings with scientific concepts through student-centered learning. The present findings are also supported by Krell et al. (2022), who demonstrated that instructional approaches integrating observation, inquiry, discussion, and reflection enhance scientific reasoning more effectively than instruction focused primarily on information delivery. According to these authors, scientific reasoning is developed not through memorization of concepts but through opportunities to use evidence to explain phenomena and make logical decisions. This was evident in the experimental group, where students' direct experiences during the greenhouse visit enabled them to relate their observations to the greenhouse effect in a more systematic and scientifically meaningful manner. Table 3 shown a test blueprint based on scientific reasoning indicators.

Table 3. Test Blueprint Based on Scientific Reasoning Indicators

Test Indicator	Scientific Reasoning Component
Analyzing facts related to increasing environmental temperatures based on everyday events	Evaluating evidence
Evaluating the impact of increasing numbers of motor vehicles on the greenhouse effect	Making predictions/hypotheses
Identifying the independent variable in a greenhouse effect experiment	Identifying variables
Selecting appropriate instruments to measure the results of a greenhouse effect experiment	Designing experiments
Identifying data collection activities in an experiment	Collecting data
Analyzing the relationship between temperature data and the occurrence of the greenhouse effect	Analyzing data
Drawing conclusions based on the results of a greenhouse effect experiment	Drawing conclusions

Subsequently, the assumptions for the independent-samples t-test were assessed. Normality was examined using the Shapiro–Wilk test, while homogeneity of variances was assessed using Levene's test. The Shapiro–Wilk test was conducted for both groups; however, the corresponding W statistics and p-values were not included in the statistical output available in the current manuscript. Therefore, no numerical Shapiro–Wilk values are added here without the original SPSS output. Levene's test indicated homogeneous variances ($p = .071$). The independent-samples t-test was then conducted specifically on the posttest scientific reasoning scores of the experimental and control groups, rather than on the N-gain scores. Result of the hypothesis test can be seen in Table 4.

Table 4. Results of the Hypothesis Test

Statistical Test	Value
Levene's Test (p)	0.071
Independent-samples t-test	t (56) = -4.284
p-value (two-tailed)	< .001
Mean Difference	14.690
Cohen's d	≈ 1.14 (large effect)

Furthermore, the independent-samples t-test showed a statistically significant difference in posttest scientific reasoning scores between the experimental and control groups, $t(56) = -4.284$, $p < .001$, with a mean difference of 14.690. The corresponding Cohen (1988) d was approximately 1.14, indicating a large effect. Thus, H_0 was rejected and H_1 was supported. These results indicate that students who received the greenhouse visit–based Contextual Teaching and Learning (CTL) approach achieved significantly different posttest scientific reasoning scores from those who received conventional instruction. The N-gain analysis was interpreted separately as an indicator of improvement from pretest to posttest and was not the basis of the independent-samples t-test. The reporting of Cohen's d is included to provide a standardized estimate of the magnitude of the observed between-group difference, consistent with recommendations for effect-size reporting (Lakens, 2013). The statistical reporting was strengthened by explicitly identifying the outcome tested (posttest scores), reporting the assumption checks that were available, and including a standardized effect-size estimate. These additions complement the existing methodological references on quasi-experimental and cluster-based designs (Dreyhaupt et al., 2017; Zajić & Maksimović, 2022) rather than replacing them. Table 5 shown a implementation of CTL components in the learning process.

Table 5. Implementation of CTL Components in the Learning Process

CTL Component	Implementation in Instruction
Constructivism	Students constructed conceptual understanding based on their prior knowledge and observations of the surrounding environment and the Pattimura University greenhouse.
Inquiry	Students conducted direct observations to investigate the processes underlying the greenhouse effect.
Questioning	Students formulated questions regarding the phenomenon of increasing temperatures inside the greenhouse.
Learning Community	Students collaborated in groups during observation and data analysis activities.
Modeling	The teacher demonstrated how to develop scientific explanations based on the observed phenomena.
Reflection	Students reflected on their observations and related them to the underlying scientific concepts.
Authentic Assessment	Students were assessed through classroom observations, group discussions, and evaluations of their scientific reasoning skills.

The implementation of the CTL components created an active, collaborative, and experiential learning environment in which students not only received information but also actively constructed their knowledge through observation, discussion, and evidence-based conclusion drawing. This finding is consistent with Sabudu (2025), who reported that the structured implementation of Contextual Teaching and Learning (CTL) significantly enhances students' engagement across behavioral, cognitive, and emotional dimensions. By connecting learning materials with authentic real-life contexts, CTL encourages students to participate more actively in discussions, engage in problem-solving activities, and demonstrate higher levels of learning motivation. The results of the present study indicate that implementing the CTL approach through a field visit to the greenhouse of the Faculty of Agriculture, Pattimura University significantly improved students' scientific reasoning skills. This improvement can be attributed to the fact that the learning process extended beyond theoretical instruction by providing students with authentic, firsthand experiences through direct observation in a real-world environment. The effectiveness of the intervention is reflected in the improvement in students' pretest and posttest scores, as illustrated in Figure 2.

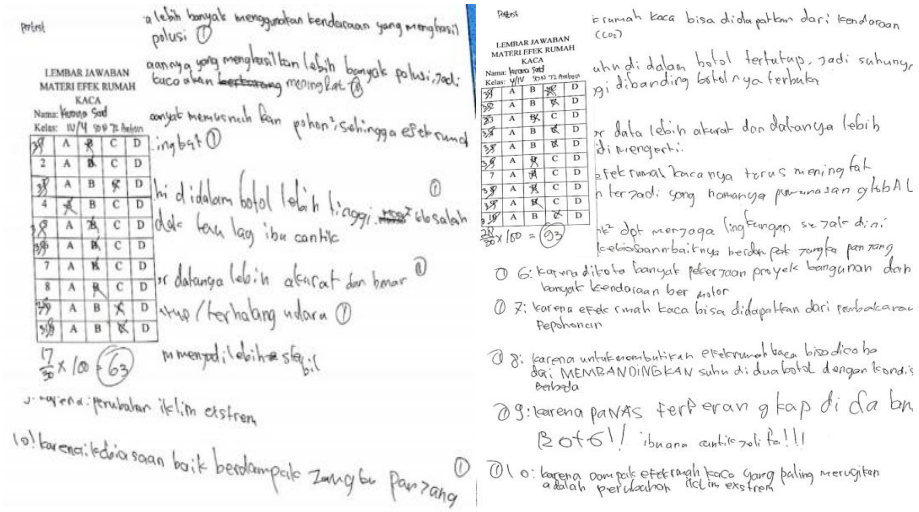

Figure 2. Pretest and Posttest Results

From a theoretical perspective, the effectiveness of the CTL approach observed in this study can be explained by constructivist learning theory, which views knowledge as being actively constructed by learners through meaningful learning experiences. Rather than passively receiving information, students develop their understanding by interacting with their learning environment. Direct observation in the greenhouse provided students with authentic, concrete experiences, enabling abstract concepts to become more comprehensible and meaningful. Scientific reasoning refers to the ability to think systematically by analyzing information, evaluating empirical evidence, examining relationships among variables, and drawing conclusions based on available data (Zimmerman, 2007). It also encompasses the use of logical reasoning and evidence-based argumentation to solve scientific problems (Bao et al., 2009; Kuhn, 2010). The findings of the present study can also be interpreted through Piaget's theory of cognitive development, which suggests that elementary school students are predominantly in the concrete operational stage. At this developmental stage, students understand scientific concepts more effectively when learning is supported by tangible objects and observable phenomena. In the present study, the greenhouse served as an authentic learning environment that enabled students to directly observe the cause-and-effect relationships underlying the greenhouse effect. Such firsthand experiences facilitated the development of students' logical thinking and scientific reasoning skills more effectively than conventional classroom instruction. Figure 3 shown a students' visit to the greenhouse of the faculty of agriculture, pattimura university.



Figure 3. Students' Visit to the Greenhouse of the Faculty of Agriculture, Pattimura University

The CTL approach supports the development of scientific reasoning through inquiry-based learning activities, including observing, questioning, analyzing data, engaging in discussions, and drawing conclusions based on empirical evidence. These activities encourage students to think logically, systematically, and critically when interpreting scientific phenomena. Scientific reasoning encompasses the ability to analyze information, evaluate evidence, construct scientific arguments, and draw conclusions grounded in empirical data (Fischer et al., 2014). Furthermore, contextual learning, which connects instructional content with authentic experiences, provides meaningful learning opportunities that enhance students' engagement, conceptual understanding, and learning motivation (Lazonder & Harmsen, 2016; Abu-rasheed et al., 2023). During the visit to the greenhouse

of the Faculty of Agriculture, Pattimura University, students demonstrated greater enthusiasm by actively asking questions and participating in group discussions. These firsthand learning experiences promoted the development of scientific reasoning, as reflected in students' ability to make careful observations, process information, and formulate evidence-based conclusions.

These findings suggest that contextual learning creates a more interactive, engaging, and meaningful learning environment than conventional teacher-centered instruction. Direct observations in the greenhouse enabled students to develop a concrete understanding of how solar heat becomes trapped within an enclosed space, leading to increased temperatures, while simultaneously relating this phenomenon to the scientific concept of the greenhouse effect encountered in everyday life. Such authentic experiential learning strengthened students' conceptual understanding, further demonstrating that the CTL approach can produce meaningful improvements in learning outcomes. In addition, learning in authentic environments contributes to the development of students' scientific literacy by providing direct interaction with natural phenomena. Overall, the findings of this study demonstrate that implementing a Contextual Teaching and Learning (CTL) approach through greenhouse visits is effective in enhancing elementary school students' scientific reasoning skills in learning about the greenhouse effect. By connecting scientific concepts with authentic learning experiences, the CTL approach enables students to develop a deeper, more logical, and more meaningful understanding than that achieved through conventional instruction.

4. Conclusion

This study demonstrated that implementing a greenhouse visit-based Contextual Teaching and Learning (CTL) approach at the Greenhouse of the Faculty of Agriculture, Universitas Pattimura had a positive and statistically significant effect on elementary school students' scientific reasoning skills in learning the greenhouse effect. By connecting scientific concepts with authentic real-world experiences, the learning process actively engaged students in observing phenomena, identifying problems, asking questions, collecting and analyzing data, and drawing conclusions based on empirical evidence. These learning experiences enabled students to construct knowledge through direct interaction with real-life contexts, making abstract scientific concepts more meaningful and easier to understand. Compared with conventional instruction, the greenhouse visit-based CTL approach proved to be more effective in enhancing students' scientific reasoning because it fostered an active, collaborative, and student-centered learning environment. In addition to improving students' conceptual understanding of the greenhouse effect, the implementation of CTL also promoted the development of critical thinking, problem-solving, scientific communication, and higher-order thinking skills, all of which are essential competencies for the twenty-first century. Therefore, an authentic experience-based CTL approach can serve as an effective alternative for science instruction to improve both the quality of the learning process and elementary school students' learning outcomes.

Despite these promising findings, several limitations should be acknowledged. First, the study used a quasi-experimental design with cluster random sampling at the class level, and individual students were not randomly assigned to the experimental and control groups. Second, the experimental and control groups were drawn from two different schools, meaning that school-level and teacher-level factors, such as instructional practices, learning environments, and resource availability, could have influenced the outcomes and were not fully controlled. Third, the group sizes were unequal, with 25 students in the experimental group and 33 students in the control group, which may affect statistical power and internal validity. Fourth, although pretest scores were collected, a separate statistical test of baseline equivalence between the two groups was not conducted. Therefore, the findings should be interpreted with these design limitations in mind. Future studies should consider individual randomization where feasible, use comparable groups within the same school or statistically control for school- and teacher-level factors, adopt more balanced sample sizes, and conduct formal tests of baseline equivalence to strengthen internal validity.

Based on the findings of this study, teachers are encouraged to integrate the contextual teaching and learning (CTL) approach into science instruction as well as other subject areas by utilizing the surrounding environment as an authentic learning resource. Learning activities should not be confined to the classroom but should be enriched through educational field trips, field observations, and the use of authentic learning facilities such as greenhouses, school gardens, laboratories, museums, and conservation centers. Such learning experiences enable students to develop a deeper and more meaningful understanding of scientific concepts through direct engagement with real-world phenomena. Teachers are also encouraged to design inquiry-oriented learning activities that incorporate discussion, reflection, and authentic assessment to maximize the development of students' scientific reasoning skills. Furthermore, schools should support the implementation of contextual learning by providing adequate facilities and learning resources, establishing partnerships with universities and relevant institutions, and offering professional development programs that strengthen teachers' capacity to implement student-centered instructional approaches. These initiatives will expand students' opportunities to participate in authentic learning experiences that are closely connected to their everyday lives. Future studies are recommended to extend this research by involving larger sample sizes, schools from diverse geographical and socio-cultural contexts, and different educational levels to enhance the generalizability of the findings. In addition, future research may investigate the integration of CTL with other

instructional approaches, such as STEM education, project-based learning (PBL), problem-based learning (PBL), virtual field trips, and virtual laboratories. Further studies may also explore the impact of CTL not only on scientific reasoning but also on scientific literacy, creativity, scientific argumentation, problem-solving skills, environmental awareness, and other twenty-first-century competencies, thereby providing a more comprehensive understanding of the effectiveness of contextual learning in preparing students for future educational and societal challenges.

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Data Availability

The datasets generated during and/ or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration on AI Use

The authors declare that no artificial intelligence (AI) or AI-assisted tools were used in the preparation of this manuscript.

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