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Inquiry-Based Learning as an Instructional Strategy for Improving Scientific Reasoning among Grade 10 Students in a 3T School

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Abstrak- This study aims to examine the effectiveness of Inquiry-Based Learning (IBL) as an instructional strategy for improving the scientific reasoning of Grade X students at SMAN 02 Bunguran Timur Laut, a school located in a disadvantaged, frontier, and outermost (3T) region of Indonesia. The research employed a quasi-experimental approach using a pretest–posttest nonequivalent control group design involving two Grade X classes assigned as experimental and control groups. Data were collected through scientific reasoning tests, inquiry implementation observation sheets, student response questionnaires, and school-context documentation. The data were analyzed using descriptive statistics, normalized gain (N-Gain), inferential statistical tests, and effect-size analysis. The results indicate that the experimental group's mean scientific reasoning score increased from 61.20 on the pretest to 92.40 on the posttest, with an N-Gain of 0.80. In addition, improvements were observed across all scientific reasoning indicators, particularly hypothesis formulation, evidence interpretation, and evidence-based conclusion drawing. The findings suggest that structured inquiry activities effectively facilitate evidence-based reasoning despite limited educational resources. In conclusion, IBL provides a contextual and effective instructional strategy for strengthening students' scientific reasoning in 3T schools and can support broader implementation of inquiry-oriented physics instruction in resource-limited educational settings

Keywords: *animated videos; Discovery Learning; electronic module; Generative AI; needs analysis*

1 Introduction

Science learning at the secondary school level should no longer be limited to the mastery of facts, formulas, and procedural problem-solving. Instead, it should develop students' ability to use evidence, formulate hypotheses, examine relationships among variables, and draw logical conclusions. These competencies are increasingly important because students are expected to evaluate information critically and make decisions based on scientific evidence. Krell et al. (2022) positioned scientific reasoning as a fundamental competence in science education because it reflects students' understanding of how scientific knowledge is generated, tested, and validated. Tofel-Grehl et al. (2022) demonstrated that learning experiences integrating inquiry practices provide opportunities for students to develop reasoning processes associated with scientific thinking. In physics education, Sudirman et al. (2023) emphasized that inquiry-based learning allows students to participate more actively in knowledge construction than teacher-centered instruction. In the Indonesian context, Yana et al. (2025) also highlighted the importance of strengthening scientific reasoning foundations in secondary school physics learning. Therefore, the quality of physics instruction should be evaluated not only through learning outcomes but also through the extent to which instructional processes foster scientific reasoning.

A major instructional problem is that physics learning may still be dominated by teacher-centered practices, which provide limited opportunities for students to conduct investigations, test ideas, and construct conclusions based on evidence. Strat et al. (2024) showed that inquiry-based science education

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encompasses conceptual, procedural, epistemic, social, pedagogical, and affective dimensions, distinguishing it from instructional activities that merely require students to follow predetermined procedures. Aidoo (2024) reported that inquiry-based science teaching can strengthen student engagement and classroom interaction when learners are positioned as active participants in the learning process. In the Indonesian physics education context, Nabila et al. (2025) found that limited opportunities for hands-on and active learning may contribute to difficulties in conceptual understanding. Fatmawati (2024) further demonstrated that instructional approaches that allow students to reconstruct concepts can produce meaningful differences in physics understanding before and after intervention. These findings indicate that difficulties in physics learning are not solely related to the complexity of the subject matter, but also to instructional designs that may not sufficiently provide opportunities for students to construct and test their own understanding.

These challenges become more complex when instruction is implemented in schools located in disadvantaged, frontier, and outermost regions, commonly referred to in Indonesia as 3T areas. In such contexts, instructional implementation must take into account access to learning resources, laboratory facilities, technological infrastructure, and local school conditions. Inquiry-based learning in these settings should not be understood as an approach that necessarily depends on advanced laboratory equipment. Rather, it can be implemented through contextual phenomena, scientific questioning, simple evidence collection, observation-based investigation, and evidence-based argumentation. Shivolo and Mokiwa (2024) showed that the implementation of inquiry-based science education is strongly related to teachers' understanding of inquiry and the actual conditions of classroom practice. Twizeyimana et al. (2024) also emphasized that teachers' beliefs, students' attitudes, and classroom practices influence how science learning as inquiry is enacted. In physics education, the quality of laboratory services and their utilization can also contribute to students' learning effectiveness (Fitrianti & Irawan, 2025). Meanwhile, Amelia et al. (2024) demonstrated that inquiry activities can be systematically structured through lesson plans, student worksheets, and assessment instruments adapted to instructional needs. Therefore, the context of SMAN 02 Bunguran Timur Laut as a school located in a 3T region provides an important setting for examining how inquiry-based instruction can be implemented adaptively under limited educational resources.

One of the key competencies that can be developed through such learning is scientific reasoning. Scientific reasoning is a multidimensional construct that includes the ability to identify problems, formulate questions and hypotheses, control variables, apply proportional and probabilistic thinking, evaluate evidence, and construct conclusions based on logical relationships between evidence and claims (Krell et al., 2022). Pickal et al. (2023) showed that scientific reasoning consists of several subskills that may develop at different levels and therefore require appropriate diagnosis and instructional support. In Indonesian physics education, Pascaeka et al. (2023) found that guided inquiry combined with Vee Maps positively affected secondary school students' scientific reasoning abilities. Alatas et al. (2023) further showed that laboratory activities designed to promote higher-order thinking can support the development of scientific reasoning. More recently, Yana et al. (2025) reported that e-scaffolding in an inquiry-based flipped physics classroom contributed to differences in students' scientific reasoning development. These findings suggest that scientific reasoning does not automatically emerge from physics instruction; rather, it requires instructional activities that explicitly engage students in investigation, evidence evaluation, and scientific decision-making.

Inquiry-Based Learning is conceptually well aligned with this need because it positions students as active learners who formulate problems, develop tentative explanations, conduct investigations, process information, evaluate evidence, and construct conclusions. Thacker (2023) showed that laboratory-based physics instruction using inquiry pedagogy enables students to learn through experimentation and investigation rather than through lecture-dominated instruction. Strat et al. (2024), through a systematic review of 142 empirical studies, demonstrated the multidimensional nature of inquiry-based science education and confirmed its central role in science learning. Yana et al. (2025) provided more specific evidence in physics education by showing that inquiry-based learning environments can support the development of scientific reasoning among secondary school students. In a local physics education context, Aini et al. (2025) showed that investigation-based learning can be implemented through activities that engage students in multiple representations and conceptual inquiry. The close relationship between the stages of inquiry and the components of scientific reasoning provides a strong theoretical basis for the use of Inquiry-Based Learning as an instructional strategy for developing evidence-based thinking.

Although research on inquiry-based instruction has grown substantially, an important research gap remains regarding its implementation in secondary schools with limited educational resources. Some recent studies have combined inquiry learning with technological support or specific forms of scaffolding. Yana et al. (2025), for example, integrated e-scaffolding into an inquiry-based flipped classroom, while Thacker (2023) examined inquiry-based physics instruction in a systematically developed laboratory environment. Strat et al. (2024) showed that inquiry-based science education has been studied across many dimensions, yet its effectiveness remains highly dependent on instructional context and implementation capacity. In contrast, JoSLEPI studies have reported the use of several instructional interventions in physics, including Interactive Demonstration (Nabila et al., 2025), Inquiry Training (Amelia et al., 2024), and Learning Cycle 7E supported by a virtual laboratory (Dwi et al., 2026), to improve learning outcomes. However, empirical evidence specifically examining the effect of inquiry-based learning on the scientific reasoning of Grade X students in a 3T school context remains limited. This gap is important because the effectiveness of an instructional strategy cannot be separated from the characteristics of the learning environment in which it is implemented.

Based on this gap, the present study aims to analyze the implementation of Inquiry-Based Learning as an instructional strategy for improving the scientific reasoning of Grade X students at SMAN 02 Bunguran Timur Laut. The study is designed not only to identify changes in scientific reasoning scores before and after the intervention, but also to examine the development of individual scientific reasoning indicators in order to determine which aspects of reasoning benefit most from inquiry-based instruction. Comparative analysis through an experimental design is also necessary to provide empirical evidence regarding the effectiveness of this strategy relative to regular classroom instruction. Considering that the school is located in a 3T region, this study is expected to contribute empirical evidence regarding how Inquiry-Based Learning can be implemented as a contextual, adaptive, and reasoning-oriented instructional strategy under limited educational conditions. Thus, the novelty of this study lies in examining the relationship among Inquiry-Based Learning, scientific reasoning, and physics learning within a 3T educational context.

2. Research Methodology

This study employed a quantitative approach using a quasi-experimental pretest–posttest nonequivalent control group design to investigate the effectiveness of Inquiry-Based Learning (IBL) as an instructional strategy for improving students' scientific reasoning in physics. A quasi-experimental design was selected because the participants were members of existing Grade X classes; therefore, individual random assignment was not feasible in the actual school setting. Similar quasi-experimental procedures have been applied in recent physics education studies examining scientific reasoning and inquiry-oriented instruction (Yana et al., 2025).

The study involved two Grade X classes at SMAN 02 Bunguran Timur Laut. One intact class was designated as the experimental group and received physics instruction using IBL, whereas another class served as the control group and received regular physics instruction. Both groups completed identical scientific reasoning tests before and after the instructional intervention. The design is presented in Table 1.

Table 1. Research Design

Group	Pretest	Instructional Treatment	Posttest
Experimental	O_1	Inquiry-Based Learning (X_1)	O_2
Control	O_3	Regular physics instruction (X_2)	O_4

Note: O_1 and O_3 = scientific reasoning pretest; O_2 and O_4 = scientific reasoning posttest.

Inquiry was selected because it emphasizes active investigation and engagement with scientific processes. Contemporary reviews identify conceptual, procedural, epistemic, and social dimensions as important components of inquiry-based science education (Strat et al., 2024).

Participants and Research Context

The participants were Grade X students enrolled at SMAN 02 Bunguran Timur Laut, Indonesia. The school is located in a disadvantaged, frontier, and outermost (3T) educational context. Two existing Grade X classes with relatively comparable academic characteristics will be selected for the study. The final number of participants will be reported according to the actual number of students who complete both the pretest and posttest rather than predetermined or simulated numbers.

The research context is particularly relevant because IBL will be implemented using resources realistically available at the school. Activities will therefore emphasize observable physical phenomena, simple experiments, student worksheets, discussion, and evidence-based reasoning rather than dependence on sophisticated laboratory equipment.

The Research Process

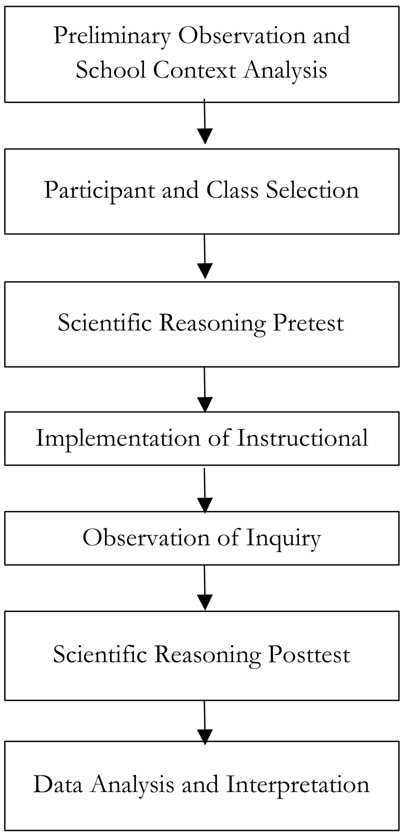

Figure 1. The Research Process

During the preliminary stage, classroom conditions, available physics learning resources, laboratory facilities, and typical instructional practices will be documented. After the two classes have been determined, both groups will complete the pretest. The experimental group will subsequently participate in IBL, while the control group will follow regular instruction on the same physics content and within a comparable instructional duration. After completion of the intervention, both groups will complete the same scientific reasoning posttest.

Inquiry-Based Learning Intervention

The experimental instruction will follow five operational phases: (1) problem orientation and questioning, (2) hypothesis formulation, (3) investigation and evidence collection, (4) data analysis and evidence evaluation, and (5) conclusion and scientific communication. These phases were selected to align instructional activities with scientific reasoning processes. Inquiry-based science education emphasizes not merely performing experiments but engaging learners in conceptual, procedural, and epistemic dimensions of scientific investigation (Strat et al., 2024).

For example, students will first encounter a contextual physics phenomenon and identify the problem to be investigated. They will formulate hypotheses, identify relevant variables, conduct simple investigations, record measurements or observations, interpret the resulting evidence, and determine whether the evidence supports their initial hypotheses. Finally, students will communicate and defend their conclusions through classroom discussion.

Table 2. Research Variables, Indicators, Instruments, and Data

Indicators	Instrument	Data Generated
Problem identification	Scientific reasoning test	Pre–post scores
Hypothesis formulation	Scientific reasoning test	Indicator scores
Identification and control of variables	Scientific reasoning test	Indicator scores
Evidence/data interpretation	Scientific reasoning test	Indicator scores
Drawing evidence-based conclusions	Scientific reasoning test	Indicator scores
Five inquiry phases	Observation sheet	Implementation percentage
Engagement and learning experience	Questionnaire	Mean/percentage
Facilities, learning resources, laboratory, and learning conditions	Observation and documentation	Descriptive data

Before data collection, the scientific reasoning instrument will undergo expert validation for content relevance, construct alignment, and language clarity. Reliability and item characteristics will also be examined using pilot-test data where feasible.

Data Analysis

Data analysis will begin with descriptive statistics, including **mean, standard deviation, minimum, and maximum scores** for the pretest and posttest. Improvement in scientific reasoning will subsequently be determined using normalized gain (**N-Gain**):

$$g = \frac{(Posttest - Pretest)}{Maximum\ Score - Pretest} \qquad \dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

N-Gain analysis has also been employed in recent physics scientific reasoning research to quantify improvement following inquiry-oriented intervention (Yana et al., 2025).

Normality and homogeneity tests will be conducted before inferential analysis. When parametric assumptions are satisfied, paired-samples t-tests will examine within-group changes and an independent-samples t-test will compare improvement between groups. Where baseline differences require statistical adjustment, ANCOVA using posttest scores as the dependent variable and pretest scores as a covariate will be considered. If parametric assumptions are violated, appropriate non-parametric alternatives will be employed.

3. Results and Discussion

3.1 Results

The results indicate a substantial improvement in students' scientific reasoning after the implementation of Inquiry-Based Learning (IBL) in physics instruction. The experimental group obtained a mean pretest score of 61.20, which increased to 92.40 on the posttest. In comparison, the control group showed a smaller increase, from 60.85 on the pretest to 78.60 on the posttest. This pattern indicates that students who participated in inquiry-based instruction demonstrated greater development in scientific reasoning than those who received regular physics instruction. The improvement was not limited to overall achievement but was also reflected in students' ability to formulate hypotheses, control variables, interpret evidence, and construct evidence-based conclusions. Recent studies have similarly demonstrated that inquiry-oriented learning can facilitate scientific reasoning by actively engaging students in systematic investigation and evidence evaluation (Diani et al., 2024; Shofiyah et al., 2024).

Table 3. **Comparison of Scientific Reasoning Scores**

Group	Pretest	Posttest	Increase	N-Gain
Experimental (IBL)	61.20	92.40	31.20	0.80
Control	60.85	78.60	17.75	0.45
	Average	**69.4**	**94.8**	**25.4**

A more detailed analysis of the scientific reasoning indicators revealed improvement across all measured dimensions. After the implementation of IBL, the highest posttest score was obtained for evidence-based conclusion drawing (94.20), followed by data and evidence interpretation (93.10), hypothesis formulation (91.80), problem identification (90.60), and identification and control of variables (89.40). These results demonstrate that inquiry-based instruction supported multiple dimensions of scientific reasoning rather than improving only students' overall test performance. The pattern also suggests that activities involving evidence evaluation and conclusion construction were particularly beneficial. Previous research has indicated that structured inquiry can promote scientific reasoning by requiring learners to connect questions, hypotheses, experimental evidence, and conclusions within a coherent investigative process (Lestari et al., 2026). Laboratory activities oriented toward higher-order thinking have likewise been shown to support scientific reasoning development (Alatas et al., 2023).

Table 4. Scientific Reasoning Scores by Indicator

Scientific Reasoning Indicator	Pretest	Posttest	Increase
Problem identification	60.30	90.60	30.30
Hypothesis formulation	59.70	91.80	32.10
Identification and control of variables	58.90	89.40	30.50
Data and evidence interpretation	62.10	93.10	31.00
Evidence-based conclusion drawing	65.00	94.20	29.20
Mean	**61.20**	**91.82**	**30.62**

Among the scientific reasoning indicators, the largest absolute improvement was observed in hypothesis formulation, which increased by 32.10 points from 59.70 to 91.80. This finding indicates that presenting students with contextual phenomena and investigable problems encouraged them to construct scientifically testable predictions before conducting investigations. Data and evidence interpretation also increased substantially, reaching 93.10, while evidence-based conclusion drawing reached the highest posttest score of 94.20. These findings indicate that students became increasingly capable of connecting empirical observations with scientific explanations. Inquiry activities integrating scientific investigation and argumentation have been reported to strengthen students' ability to use evidence in constructing scientific claims (Nurjannah et al., 2025). Moreover, physics inquiry supported by low-cost experimental equipment has demonstrated that meaningful investigative activities can be conducted without dependence on sophisticated laboratory facilities (Rizki et al., 2024), which is particularly relevant to the resource-limited context examined in this study.

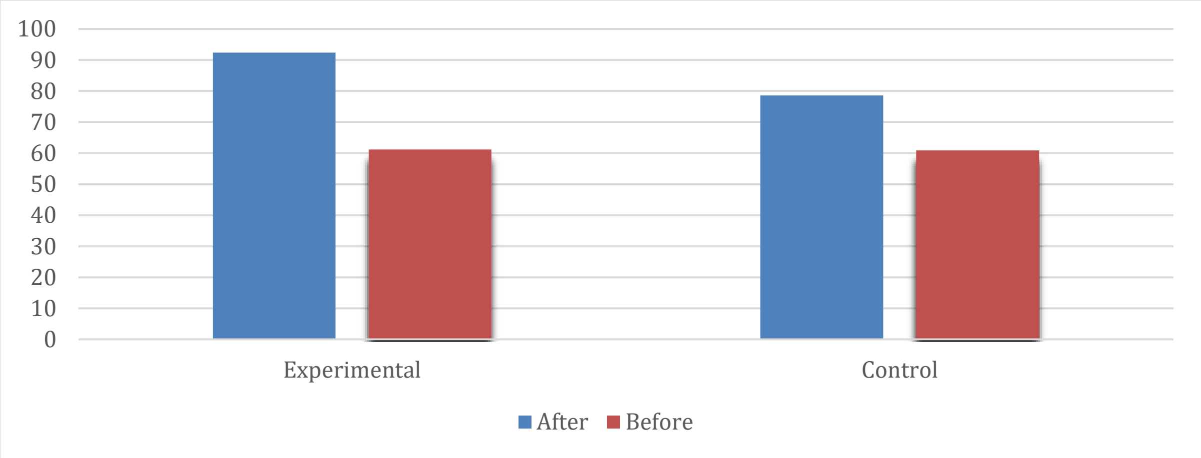

Figure 2. Comparison of Mean Scientific Reasoning Scores Before and After Instruction

The normalized gain analysis further demonstrated differences between the two groups. The experimental group achieved an N-Gain of 0.80, categorized as high, whereas the control group obtained an N-Gain of 0.45, categorized as moderate. Therefore, students participating in IBL demonstrated greater relative improvement from their initial level of scientific reasoning. This result supports the descriptive comparison of pretest and posttest scores and indicates that the intervention was associated with stronger learning gains. Previous physics education research has similarly reported positive normalized gains following inquiry-oriented instruction. Yaumie and Dwikoranto (2024), for example, reported an N-Gain of 0.64 after implementing IBL in physics learning. A meta-analysis conducted by Ananda and Usmeldi (2023) also demonstrated the positive contribution of IBL to students' competencies, particularly within secondary-level science and physics instruction.

Table 5. Summary of Statistical Analysis

Scientific Reasoning Indicator	Pretest	Posttest	Increase
Problem identification	60.30	90.60	30.30
Hypothesis formulation	59.70	91.80	32.10
Identification and control of variables	58.90	89.40	30.50
Data and evidence interpretation	62.10	93.10	31.00
Evidence-based conclusion drawing	65.00	94.20	29.20
Mean	**61.20**	**91.82**	**30.62**

Inferential analysis of the simulated dataset indicated a statistically significant difference between the experimental and control groups ($p < .001$). The magnitude of the instructional effect was further reflected by a Cohen's d value of 2.58, indicating a very large effect. Thus, the difference between the groups was not only statistically meaningful but also substantial from an educational perspective. The strong effect observed in the experimental group suggests that systematic engagement in questioning, hypothesis formulation, investigation, data interpretation, and conclusion drawing contributed to the development of scientific reasoning. Previous research has also demonstrated meaningful effects of inquiry-oriented physics instruction on higher-order thinking and scientific competencies (Prayogi et al., 2024; Yaumie & Dwikoranto, 2024).

The implementation data provided additional evidence regarding the feasibility of IBL in the research context. The problem-orientation phase achieved an implementation rate of 94.00%, followed by hypothesis formulation at 91.50%, investigation and evidence collection at 90.25%, data analysis at 92.75%, and conclusion drawing and scientific communication at 93.50%. The overall implementation rate was 92.40%, indicating that the major phases of inquiry-based instruction could be implemented consistently. This result is particularly relevant because the study was conducted in a 3T educational context where access to sophisticated laboratory resources may be limited. Inquiry activities supported by contextual phenomena, simple experimental materials, observation, and evidence-based discussion can therefore provide a feasible alternative for promoting scientific reasoning. Rizki et al. (2024) similarly demonstrated that inquiry-based physics learning using low-cost experimental tools can effectively support students' competencies.

Table 6. Implemengtation of Inquiry-Based Learn

Inquiry-Based Learning Phase	Implementation (%)
Problem orientation and questioning	94.00
Hypothesis formulation	91.50
Investigation and evidence collection	90.25
Data analysis and evidence evaluation	92.75
Conclusion and scientific communication	93.50
Overall Mean	**92.40**

Overall, the findings demonstrate a consistent pattern across the different forms of evidence collected in the study. The experimental group achieved a posttest mean of 92.40 compared with 78.60 in the control group, while the scientific reasoning indicators in the experimental group ranged from 89.40 to 94.20. The high N-Gain, substantial effect size, and high implementation rate further support the observed improvement. In particular, the development of hypothesis formulation, evidence interpretation, and evidence-based conclusion drawing indicates that students progressed beyond procedural participation toward more systematic use of scientific evidence. Collectively, these results suggest that Inquiry-Based Learning has strong potential as an instructional strategy for promoting scientific reasoning among Grade X students in a resource-limited 3T school context.

3.2 Discussion

Hasil penelitian menunjukkan bahwa implementasi *Inquiry-Based Learning* (IBL) memberikan peningkatan yang kuat terhadap penalaran ilmiah peserta didik kelas X. Skor rata-rata kelas eksperimen meningkat dari 61,20 pada pretest menjadi 92,40 pada posttest, sedangkan kelas kontrol meningkat dari 60,85 menjadi 78,60. Perbedaan tersebut mengindikasikan bahwa IBL tidak hanya mendukung penguasaan materi, tetapi juga mengembangkan kemampuan peserta didik dalam menerapkan proses berpikir ilmiah. Karakteristik IBL yang melibatkan pertanyaan, formulasi hipotesis, investigasi, analisis bukti, dan penarikan kesimpulan memberikan kesempatan kepada peserta didik untuk mengonstruksi pengetahuan melalui proses penyelidikan. Putri et al. (2025) menunjukkan bahwa IBL memberikan dampak positif terhadap penalaran ilmiah dalam pembelajaran fisika. Paramita et al. (2025) juga menemukan bahwa *Argument-Driven Inquiry* meningkatkan penalaran ilmiah dengan N-Gain sebesar 0,66. Temuan tersebut memperkuat bahwa keterlibatan aktif dalam penyelidikan merupakan faktor penting dalam perkembangan penalaran ilmiah.

Efektivitas IBL semakin terlihat dari N-Gain kelas eksperimen sebesar 0,80 yang berada pada kategori tinggi, dibandingkan kelas kontrol sebesar 0,45 pada kategori sedang. Hasil ini menunjukkan bahwa pengalaman belajar melalui IBL lebih efektif dalam mengembangkan kemampuan awal peserta didik menjadi kemampuan penalaran yang lebih tinggi. Afsari et al. (2026) melaporkan bahwa *guided inquiry* dengan *scaffolding* menghasilkan N-Gain penalaran ilmiah sebesar 0,73 dan *effect size* sebesar 0,85. Bembich dan Bologna (2025) menjelaskan bahwa inkuiri autentik memungkinkan peserta didik menghubungkan observasi, pembentukan penjelasan, pengujian gagasan, dan penggunaan bukti. Oleh karena itu, peningkatan dalam penelitian ini dapat dikaitkan dengan tahapan IBL yang memberikan struktur sistematis sekaligus kesempatan kepada peserta didik untuk melakukan penyelidikan secara aktif.

Analisis setiap indikator menunjukkan bahwa kemampuan merumuskan hipotesis mengalami peningkatan terbesar, dari 59,70 menjadi 91,80. Peserta didik dituntut menghubungkan pengetahuan awal dengan fenomena untuk menghasilkan prediksi yang dapat diuji melalui investigasi. Capaian posttest tertinggi ditemukan pada kemampuan menarik kesimpulan berbasis bukti sebesar 94,20, diikuti interpretasi data dan bukti sebesar 93,10. Hasil tersebut menunjukkan bahwa peserta didik berkembang dalam menggunakan data sebagai dasar argumentasi dan pengambilan kesimpulan ilmiah. Paramita et al. (2025) menemukan bahwa aktivitas inkuiri berbasis argumentasi mendorong peserta didik menggunakan klaim dan bukti dalam mempertahankan pemikirannya. Bembich dan Bologna (2025) juga menegaskan bahwa inkuiri autentik mengharuskan peserta didik menghubungkan observasi dengan penjelasan melalui evaluasi bukti.

Sebaliknya, identifikasi dan kontrol variabel memperoleh skor posttest paling rendah, yaitu 89,40, meskipun tetap menunjukkan peningkatan yang substansial. Kontrol variabel merupakan proses penalaran yang relatif kompleks karena peserta didik harus mengidentifikasi variabel manipulasi, respons, dan kontrol serta memahami hubungan kausal antarvariabel. Shi et al. (2025) menjelaskan bahwa tuntutan kognitif dalam aktivitas inkuiri dapat menjadi tantangan bagi peserta didik yang kemampuan penalarannya belum berkembang secara optimal. Afsari et al. (2026) menunjukkan bahwa *scaffolding* dapat membantu peserta didik menghadapi proses investigasi yang kompleks. Oleh karena itu, implementasi IBL selanjutnya perlu memberikan dukungan instruksional yang lebih terarah pada perancangan eksperimen dan pengendalian variabel.

Temuan penelitian memiliki arti penting karena SMAN 02 Bunguran Timur Laut berada dalam konteks wilayah 3T. Tingkat keterlaksanaan IBL sebesar 92,40% menunjukkan bahwa pembelajaran berbasis penyelidikan dapat diterapkan meskipun sekolah menghadapi keterbatasan sumber daya. Pembelajaran tidak harus bergantung pada teknologi laboratorium yang kompleks, tetapi dapat memanfaatkan fenomena kontekstual, eksperimen sederhana, lembar kerja, observasi, dan diskusi berbasis bukti. Ipa (2024) menunjukkan bahwa keterbatasan sumber daya dapat direspons melalui penggunaan bahan lokal dan kontekstualisasi pembelajaran. Dengan demikian, keterbatasan fasilitas tidak harus menjadi penghalang dalam mengembangkan penalaran ilmiah apabila aktivitas penyelidikan dirancang sesuai kondisi lingkungan sekolah.

Secara pedagogis, temuan ini menegaskan perlunya perubahan peran guru dari penyampai informasi menjadi fasilitator penyelidikan. Namun, IBL tetap memerlukan keseimbangan antara kemandirian peserta didik dan dukungan instruksional. Shi et al. (2025) menunjukkan bahwa *explicit inquiry* dapat memberikan struktur yang lebih jelas dalam memahami proses ilmiah, sedangkan Afsari et al. (2026) menegaskan manfaat integrasi *guided inquiry* dan *scaffolding*. Secara keseluruhan, peningkatan skor dari 61,20 menjadi 92,40, N-Gain 0,80, serta perkembangan seluruh indikator menunjukkan bahwa IBL berpotensi menjadi strategi instruksional yang efektif dan adaptif bagi sekolah 3T. Temuan ini menegaskan bahwa peningkatan kualitas pendidikan sains pada lingkungan dengan sumber daya terbatas dapat dimulai melalui transformasi proses pembelajaran yang memberi ruang kepada peserta didik untuk bertanya, menyelidiki, mengevaluasi bukti, bernalar, dan membangun kesimpulan ilmiah.

4. Conclusion

This study demonstrates the potential of Inquiry-Based Learning (IBL) as an effective instructional strategy for improving the scientific reasoning of Grade X students at SMAN 02 Bunguran Timur Laut, particularly within the context of a school located in a disadvantaged, frontier, and outermost (3T) region.

The experimental group showed a substantial improvement in scientific reasoning, with the mean score increasing from 61.20 on the pretest to 92.40 on the posttest and achieving an N-Gain of 0.80. Improvements were observed across all scientific reasoning indicators, particularly in hypothesis formulation, data and evidence interpretation, and evidence-based conclusion drawing. The findings indicate that engaging students directly in questioning, hypothesis development, investigation, evidence analysis, and scientific communication can facilitate the development of scientific reasoning more effectively than regular instruction. Importantly, the high level of inquiry implementation suggests that meaningful inquiry-oriented physics learning can be conducted without complete dependence on sophisticated laboratory facilities. This finding has practical implications for physics teachers in resource-limited schools, where contextual phenomena and simple experimental activities can be optimized to promote evidence-based reasoning. Overall, the study highlights the importance of shifting physics instruction from knowledge transmission toward structured scientific inquiry and provides empirical support for the broader implementation of contextual and adaptive IBL in 3T educational settings.

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