

Effects of Guided Inquiry on Students' Motivation and Critical Thinking in Renewable Energy Physics

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Article Info	ABSTRACT
Article history Received : 18-08-2026 Revised: 19-09-2026 Accepted : 29-09-2026 Published : 30-09-2026 Keywords Guided Inquiry, students' motivation, critical thinking skills, Renewable Energy, physics education Corresponding Author Muhammad Luqman Hakim Abbas Universitas Islam Negeri Sayyid Ali Rahmatullah Tulungagung, Jawa Timur, Indonesia *E-mail: mluqman.abbas@uinsatu.ac.id	<i>This study examined differences in students' learning motivation and critical thinking skills following Guided Inquiry learning in Renewable Energy physics. A quantitative quasi-experimental method with a Post-test Only Control Group Design was conducted at SMAN 1 Gondang Tulungagung. The participants were 69 Grade X students selected through purposive sampling, comprising 36 students in the experimental class (X-5) and 33 students in the control class (X-4). The study was conducted over five meetings from January 23 to February 29, 2024. The experimental class received Guided Inquiry learning, while the control class received Direct Instruction. Learning motivation was measured using a 25-item questionnaire, and critical thinking skills were assessed using five essay questions based on the respective study indicators. Cronbach's alpha coefficients were 0.862 for motivation and 0.621 for critical thinking skills. The experimental group obtained higher mean scores for motivation ($M = 88.64$, $SD = 9.708$) and critical thinking ($M = 87.50$, $SD = 7.020$) than the control group ($M = 82.30$, $SD = 7.768$; $M = 82.58$, $SD = 5.019$). Independent-samples <i>t</i>-tests showed significant between-group differences in motivation, $t(67) = 2.976$, $p = .004$, Cohen's $d = 0.717$, and critical thinking, $t(67) = 3.324$, $p = .001$, Cohen's $d = 0.801$. MANOVA indicated a significant multivariate difference, Pillai's Trace = .203, Wilks' Lambda = .797, $F(2,66) = 8.414$, $p < .001$, partial $\eta^2 = .203$. Practically, Guided Inquiry can be implemented through Renewable Energy investigations involving questions, hypotheses, experiments, data analysis, and conclusions to support active learning and evidence-based reasoning.</i>
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INTRODUCTION

Physics learning is concerned not only with understanding scientific concepts but also with developing students' ability to engage in scientific processes, solve problems, and construct evidence-based explanations. Therefore, effective physics instruction should provide learning experiences that encourage students to actively construct knowledge rather than merely receive information from teachers. Students' motivation and critical thinking skills are two important aspects that need to be developed through physics learning. Learning motivation encourages students to participate actively and persist in learning activities. Accordingly, learning approaches that provide opportunities for students to investigate phenomena and construct explanations are relevant to the development of both affective and cognitive aspects of learning (Harahap & Harahap, 2021; Wandira et al., 2023).

The learning conditions at SMAN 1 Gondang Tulungagung indicate that physics instruction still requires greater student involvement. Based on preliminary observations and interviews conducted by the researcher, learning activities were predominantly implemented through conventional instruction, particularly teacher explanations and the delivery of instructional content. The teacher played a dominant role in presenting information, while students had relatively limited opportunities to formulate questions, conduct investigations, interpret data, and develop conclusions independently. Such learning conditions may limit students' opportunities to engage in higher-order thinking processes and actively participate in learning. Student-centered learning is important because students need opportunities to construct knowledge through direct involvement in the learning process.

Students' motivation is an important factor influencing their involvement and persistence during learning activities. Learning motivation can direct students' attention toward learning objectives and encourage them to maintain their efforts when encountering learning difficulties. In physics learning, inquiry-oriented activities can provide meaningful learning experiences because students are directly involved in investigating phenomena and identifying relationships between concepts. (Sukma et al., 2016) found that guided inquiry learning was related to students' physics learning outcomes in interaction with learning motivation. Furthermore, (Ute et al., 2021) reported that guided inquiry learning could support students' conceptual understanding and learning motivation in physics. Thus, inquiry-based activities can provide students with opportunities to participate more actively in the learning process.

Recent empirical studies have also examined the relationship between inquiry-oriented learning and students' motivation. (Fahrurnisa & Nurfadilah, 2024) investigated the implementation of guided inquiry learning in physics and reported its relevance to students' motivation. Similarly, (Subiki et al., 2024) examined guided inquiry learning assisted by a virtual laboratory and reported differences in students' physics learning outcomes and learning motivation. These findings indicate that guided inquiry learning can create learning experiences that involve students directly in the investigation process and provide opportunities for active participation in learning activities.

In addition to learning motivation, critical thinking skills are essential competencies in physics learning because students are expected to analyze phenomena, interpret information, evaluate evidence, and formulate logical conclusions. Learning activities that primarily emphasize the delivery and reproduction of information provide limited opportunities for

students to practice these processes. In contrast, inquiry-based learning involves students in investigating problems and constructing explanations based on evidence. (Harahap & Harahap, 2021) reported differences in students' critical thinking skills following the implementation of guided inquiry and modified free inquiry. (Harjilah et al., 2019) also reported a significant difference in students' critical thinking skills following the implementation of guided inquiry learning in physics. Similar findings were reported by (Nasution, 2018) and (Parwati et al., 2020), who demonstrated the relevance of inquiry-based learning to the development of students' critical thinking skills. (Sarifah & Nurita, 2023) further showed that guided inquiry learning could support the development of students' critical thinking and collaboration skills.

The role of guided inquiry learning in developing critical thinking skills has also been examined in more recent studies. (Illahi & Yunetti, 2023; Nisa & Chusni, 2026) reported differences in students' critical thinking skills following the implementation of guided inquiry learning assisted by scientific worksheets. (Sari et al., 2023) developed a guided inquiry-based e-module to facilitate the development of students' critical thinking skills. At a broader level, (Yaumie et al., 2025), through a systematic review of Indonesian studies, highlighted the role of guided inquiry learning in developing critical thinking skills in physics education. In addition, (Arifin et al., 2025) examined inquiry-based learning through a systematic review and meta-analysis and reported evidence concerning its relationship with students' critical thinking skills in science education. These findings provide an empirical basis for further investigating guided inquiry learning as an instructional approach for developing students' critical thinking skills.

The relationship between guided inquiry learning and students' motivation can be explained by the active role assigned to students throughout the learning process. In guided inquiry learning model, students are given opportunities to investigate questions or problems, formulate hypotheses, collect information or data, and construct conclusions while receiving appropriate guidance from the teacher. These activities can provide meaningful learning experiences and opportunities for active participation. (Rizkiana et al., 2016) found that practical activities and demonstrations within guided inquiry learning were related to students' motivation. (Wartini, 2021) also reported differences in students' motivation and critical thinking skills following the implementation of guided inquiry learning. At a broader level, (Stefvannof et al., 2025) identified students' motivation as one of the learning outcomes associated with inquiry-based learning across K–12 science education.

The relationship between guided inquiry learning and critical thinking skills can similarly be explained by the sequence of activities involved in the inquiry process. Students are encouraged to identify questions or problems, propose hypotheses, conduct investigations, collect data, analyze findings, and formulate conclusions based on evidence. These activities provide opportunities for students to interpret information, analyze relationships, evaluate evidence, and make reasoned decisions. Recent research has continued to examine the relevance of guided inquiry learning model to critical thinking skills in physics. (Husen & Amni, 2025) investigated the implementation of guided inquiry learning to develop students' critical thinking skills in physics. (Maolani et al., 2025; Jannah et al., 2024) examined guided inquiry learning in physics involving the Renewable Energy topic and reported its relevance to students' critical thinking skills and dispositions. (Sabrina et al., 2026) also examined laboratory-based physics

learning involving guided inquiry and its relationship with students' critical thinking skills. Thus, the inquiry process provides both theoretical and empirical foundations for examining the relationship between guided inquiry learning and the development of critical thinking skills.

The Renewable Energy topic provides an appropriate context for implementing guided inquiry learning model because it involves scientific phenomena and real-world problems that can be examined through investigation, data interpretation, evidence evaluation, and consideration of alternative solutions. Learning about Renewable Energy can connect physics concepts with technological applications and contemporary energy issues. (Puspaningsih et al., 2021) emphasized the importance of connecting science learning with phenomena and problems relevant to students' lives. More specifically, recent studies have highlighted the relevance of the Renewable Energy topic to the development of critical thinking skills. (Budimansyah & Niswati, 2026) examined students' critical thinking skills profiles on the Renewable Energy topic using a science-literacy-based physics assessment instrument. (Fransiska & Lestari, 2026) investigated students' critical thinking skills on the Renewable Energy topic within the context of Education for Sustainable Development. (Rachmawati & Wiyatmo, 2025) also examined a Renewable Energy e-worksheet integrated into STEM project-based learning and its relationship with students' critical thinking and collaboration skills. These studies indicate that the Renewable Energy topic provides a meaningful context for learning activities involving scientific evidence, data analysis, and problem solving.

The importance of active and student-centered learning is also reflected in previous physics education research in Indonesia. (Manalu, 2018) investigated problem-based learning in relation to students' science process skills. (Aini et al., 2023) developed problem-based learning worksheets to facilitate the development of students' critical thinking skills, while (Liyani et al., 2023) investigated discovery learning assisted by Lectora Inspire in relation to students' learning motivation and physics learning outcomes. These studies demonstrate continued interest in instructional models that increase student participation and address both cognitive and affective dimensions of physics learning.

Although previous studies have established the relevance of guided inquiry learning to students' motivation and critical thinking skills, several research gaps remain. First, previous studies have frequently focused on a single primary outcome, such as critical thinking skills, learning outcomes, or learning motivation. Second, previous research has employed various approaches, including development research, classroom action research, and experimental studies, while empirical studies simultaneously examining learning motivation and critical thinking skills using multivariate analysis remain limited. Third, research specifically examining both outcomes in the context of the Renewable Energy topic at the senior high school level remains relatively limited. Therefore, further empirical investigation is needed to examine whether differences exist in students' motivation and critical thinking skills between students who receive guided inquiry learning and those who receive direct instruction within the same instructional context.

The novelty of this study lies in the simultaneous examination of students' motivation and critical thinking skills following the implementation of the guided inquiry learning model in Renewable Energy physics learning. Rather than focusing on a single learning outcome, this study considers both an affective outcome, represented by learning motivation, and a cognitive

outcome, represented by critical thinking skills. The study also compares students who receive guided inquiry learning with those who receive direct instruction in a real senior high school setting. Furthermore, the two dependent variables are analyzed both separately and simultaneously using independent-samples t-tests and multivariate analysis of variance (MANOVA). This analytical approach provides a comprehensive examination of differences between instructional groups in Renewable Energy physics learning.

Based on the identified research gap, this study aims to examine differences in students' motivation and critical thinking skills between students who learn through guided inquiry and those who learn through direct instruction on the Renewable Energy topic. The research questions are as follows: (1) Is there a significant difference in students' motivation between the guided inquiry learning model and direct instruction groups? (2) Is there a significant difference in students' critical thinking skills between the two groups? and (3) Is there a significant multivariate difference in students' motivation and critical thinking skills between the two groups? Accordingly, the hypotheses are formulated as follows: H₁, Guided inquiry significantly affects students' motivation.; H₂, Guided inquiry significantly affects students' critical thinking; and H₃, Guided inquiry simultaneously affects motivation and critical thinking.

METHOD

This study employed a quantitative quasi-experimental method with a Post-test Only Control Group Design. The research design is presented as follows:

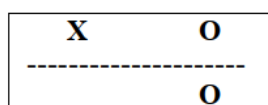


Figure 1. Post-test Only Control Group Design

Information:

X : Guided Inquiry treatment administered to the experimental group

O : Post-test measuring the observed dependent variables

The study was conducted at SMAN 1 Gondang Tulungagung with a population of 397 Grade X students. The sample was selected using purposive sampling, with the class as the sampling unit, consisting of class X-5 (36 students) as the experimental group and class X-4 (33 students) as the control group. The experimental group received the Guided Inquiry learning model, whereas the control group received Direct Instruction on the Renewable Energy physics topic for five meetings from January 23 to February 29, 2024. The Guided Inquiry learning process consisted of problem presentation, hypothesis formulation, investigation, data collection and analysis, and conclusion drawing, supported by student worksheets (LKPD) and experiments.

Data were collected using a 25 item learning motivation questionnaire and a 5 item essay test measuring critical thinking skills. The instruments were analyzed using validity and reliability tests. Data analysis was conducted using SPSS through descriptive statistics, normality test, homogeneity test, independent-samples t-test, MANOVA, and effect size analysis. MANOVA was used to simultaneously analyze learning motivation and critical

thinking skills. The research flow consisted of sample selection, instrument preparation and validation, treatment implementation, post-testing, and data analysis.

RESULTS AND DISCUSSION

RESULT

Instrument Validity and Reliability Testing

The research instruments consisted of a 25 item learning motivation questionnaire and a 5 item essay test measuring critical thinking skills. Before being used in the study, the instruments were validated by an expert lecturer and a physics teacher. The instruments were subsequently tested for validity and reliability. The results indicated that all items in the students' motivation questionnaire and the critical thinking skills test were valid. Reliability testing was then conducted, as presented in the following tables.

Table 1. Reliability Test Results for the Students' Motivation Questionnaire

Cronbach's Alpha	N of Items
.862	25

Table 2. Reliability Test Results for the Critical Thinking Skills Test

Cronbach's Alpha	N of Items
.621	5

The reliability analysis yielded Cronbach's alpha values of 0.862 for the students' motivation questionnaire and 0.621 for the critical thinking skills test. Therefore, both instruments were considered reliable and suitable for data collection. The validation and instrument testing procedures were also conducted to ensure that the measurement of both variables was aligned with the objectives of the study.

Descriptive Statistics

The study involved two groups: Grade X-5 as the experimental group, which received the guided inquiry learning model, and Grade X-4 as the control group, which received the direct instruction learning model. Data were collected after the learning intervention through a post-test. Descriptive statistics included the number of students (N), mean, standard deviation (SD), minimum score, and maximum score for each variable.

Table 3. Descriptive Statistics of Students' Motivation and Critical Thinking Skills

	N	Minimum	Maximum	Mean	Std. Deviation
Students' Motivation Control Group	33	52	93	82.30	7.768
Students' Motivation Experimental Group	36	63	115	88.64	9.708
Critical Thinking Skills Control Group	33	75	90	82.58	5.019
Critical Thinking Skills Experimental Group	36	75	100	87.50	7.020
Valid N (listwise)	33				

As shown in Table 3, the guided inquiry learning model group obtained higher mean scores than the direct instruction learning model group for both variables. These mean differences were subsequently analyzed inferentially using an independent-samples t-test to determine whether the differences between the groups were statistically significant. The descriptive results showed that the experimental group had a mean students' motivation score of 88.64, compared with 82.30 for the control group, while the mean critical thinking skills scores were 87.50 and 82.58, respectively.

Normality and Homogeneity Testing

Before the inferential analysis was conducted, the data were examined to meet the assumptions of parametric analysis. The tests included normality and homogeneity of variance tests. Because MANOVA was subsequently employed, the multivariate assumptions were also examined using Box's M test to assess the homogeneity of the variance-covariance matrices and the relationships among the dependent variables.

Table 4. Results of the Covariance Matrix Homogeneity Test

Box's Test of Equality of Covariance Matrices^a

Box's M	5.890
F	1.900
df1	3
df2	1080418.199
Sig.	.127

The results indicated that the data met the assumptions of normality and homogeneity, allowing the parametric analysis to proceed. The multivariate test results provided the basis for determining the suitability of conducting MANOVA.

Independent Samples T-test and Cohen's d Effect Size

Table 5. Independent-Samples t-Test Results for Learning Motivation

		Independent Samples Test							
		Levene's Test for Equality of Variances		t-test for Equality of Means					
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference
Motivasi Belajar	Equal variances assumed	2.861	.095	2.976	67	.004	6.336	2.129	Lower 2.086 Upper 10.586
	Equal variances not assumed			3.005	65.838	.004	6.336	2.109	Lower 2.126 Upper 10.546

Table 6. Effect Size on Students' Motivation

Independent Samples Effect Sizes

		Standardizer ^a	Point Estimate	95% Confidence Interval	
				Lower	Upper
Motivasi Belajar	Cohen's d	8.835	.717	.227	1.202
	Hedges' correction	8.935	.709	.224	1.189
	Glass's delta	7.768	.816	.298	1.323

An independent samples t-test was used to examine differences in students' motivation and critical thinking skills between the groups receiving the guided inquiry learning model and the direct instruction learning model. The results are presented in the following tables.

The analysis revealed a statistically significant difference in students' motivation between the experimental and control groups, with $t(67) = 2.976$, $p = 0.004$, and a mean difference of 6.336, with a 95% CI of [2.086, 10.586]. The Cohen's d value of 0.717 indicates a practically meaningful effect size.

Table 7. Independent-Samples t-Test Results for Critical Thinking Skills

		Independent Samples Test							
		Levene's Test for Equality of Variances		t-test for Equality of Means					
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference
Keterampilan Berpikir Kritis	Equal variances assumed	3.842	.054	3.324	67	.001	4.924	1.481	Lower 1.968 Upper 7.881
	Equal variances not assumed			3.372	63.364	.001	4.924	1.460	2.006 7.842

Table 8. Effect Size on Critical Thinkig Skills

Independent Samples Effect Sizes					
		Standardizer ^a	Point Estimate	95% Confidence Interval	
				Lower	Upper
Keterampilan Berpikir Kritis	Cohen's d	6.146	.801	.307	1.290
	Hedges' correction	6.216	.792	.304	1.275
	Glass's delta	5.019	.981	.445	1.505

For critical thinking skills, the analysis yielded $t(67) = 3.324$, $p = 0.001$, with a mean difference of 4.924 and a 95% CI of [1.968, 7.881]. The Cohen's d value of 0.801 indicates a larger effect size than that observed for students' motivation. Thus, in addition to demonstrating statistically significant differences, implementation of the guided inquiry learning model produced substantively meaningful effects on both variables.

MANOVA and Partial Eta Squared Effect Size

MANOVA was used to examine the simultaneous effect of the guided inquiry learning model on two dependent variables, namely students' motivation and critical thinking skills. The use of MANOVA enabled both variables to be analyzed simultaneously while accounting for the relationship between the dependent variables.

Table 7. MANOVA Results

Multivariate Tests ^a							
Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.996	8387.023 ^b	2.000	66.000	.000	.996
	Wilks' Lambda	.004	8387.023 ^b	2.000	66.000	.000	.996
	Hotelling's Trace	254.152	8387.023 ^b	2.000	66.000	.000	.996
	Roy's Largest Root	254.152	8387.023 ^b	2.000	66.000	.000	.996
Model_Pembelajaran	Pillai's Trace	.203	8.414 ^b	2.000	66.000	.001	.203
	Wilks' Lambda	.797	8.414 ^b	2.000	66.000	.001	.203
	Hotelling's Trace	.255	8.414 ^b	2.000	66.000	.001	.203
	Roy's Largest Root	.255	8.414 ^b	2.000	66.000	.001	.203

a. Design: Intercept + Model Pembelajaran

b. Exact statistic

The MANOVA results indicated a statistically significant multivariate effect of the guided inquiry learning model on the combination of students' motivation and critical thinking skills, based on Pillai's Trace = 0.203, $F(2,66) = 8.414$, $p < 0.001$, and partial $\eta^2 = 0.203$. Consistent results were obtained using Wilks' Lambda = 0.797, $F(2,66) = 8.414$, $p < 0.001$, and partial $\eta^2 = 0.203$. Therefore, univariate analyses were conducted to determine the contribution of each dependent variable.

Tabel 8. Effect Size on MANOVA

Tests of Between-Subjects Effects							
Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	Motivasi_Belajar	691.160 ^a	1	691.160	8.855	.004	.117
	Keterampilan_Berpikir_Kritis	417.490 ^b	1	417.490	11.051	.001	.142
Intercept	Motivasi_Belajar	503111.797	1	503111.797	6446.111	<.001	.990
	Keterampilan_Berpikir_Kritis	498026.186	1	498026.186	13183.309	<.001	.995
Model_Pembelajaran	Motivasi_Belajar	691.160	1	691.160	8.855	.004	.117
	Keterampilan_Berpikir_Kritis	417.490	1	417.490	11.051	.001	.142
Error	Motivasi_Belajar	5229.275	67	78.049			
	Keterampilan_Berpikir_Kritis	2531.061	67	37.777			
Total	Motivasi_Belajar	511611.000	69				
	Keterampilan_Berpikir_Kritis	503175.000	69				
Corrected Total	Motivasi_Belajar	5920.435	68				
	Keterampilan_Berpikir_Kritis	2948.551	68				

a. R Squared = .117 (Adjusted R Squared = .104)

b. R Squared = .142 (Adjusted R Squared = .129)

The univariate analysis showed that students' motivation had $F(1,67) = 8.855$, $p = 0.004$, with partial $\eta^2 = 0.117$. Meanwhile, critical thinking skills had $F(1,67) = 11.051$, $p = 0.001$, with partial $\eta^2 = 0.142$. These findings indicate that both variables individually contributed to the multivariate effect identified by MANOVA. The partial η^2 values also indicate a larger effect for critical thinking skills than for students' motivation.

DISCUSSION

Guided Inquiry Learning Model and Students' Motivation

The results showed that students who received the guided inquiry learning model had a higher mean students' motivation score than those who received the direct instruction learning model. This difference was supported by the independent-samples t-test, $t(67) = 2.976$, $p = 0.004$, with Cohen's $d = 0.717$. This finding indicates that the guided inquiry learning model was associated with not only a statistically significant difference but also a practically meaningful effect size.

Pedagogically, this finding may be explained by the characteristics of the guided inquiry learning model, which positions students as active participants in the learning process. Through

problem formulation, hypothesis development, investigation, data collection, and conclusion drawing, students have opportunities to engage directly in constructing knowledge. Such engagement may provide a more active and meaningful learning experience than instruction that relies predominantly on teacher explanations. This finding is consistent with (Ute et al., 2021) who reported an association between guided inquiry approaches and students' physics learning motivation.

This finding is also supported by recent studies. (Subiki et al., 2024) reported that the implementation of guided inquiry accompanied by a virtual laboratory affected students' physics learning motivation. (Fahrurnisa & Nurfadilah, 2024) likewise found higher learning motivation following guided inquiry implementation compared with a control group. Furthermore, a literature review by (Stefvannof et al., 2025) indicated that inquiry-based learning is consistently associated with increased intrinsic motivation through engagement, autonomy, and contextualized learning.

In the context of renewable energy physics, learning activities provide opportunities for students to connect physics concepts with energy-related issues encountered in everyday life. This context may enhance the relevance of learning because students do not merely receive information about renewable energy; they also engage in questioning phenomena, investigating problems, and constructing conclusions based on the results of their activities. Thus, the characteristics of the renewable energy topic and the guided inquiry learning process may complement each other in fostering more active learning engagement.

Nevertheless, the increase in students' motivation should be interpreted cautiously because motivation was measured using a self-report questionnaire. To reduce the potential for common method bias, the study used validated and reliable instruments and standardized questionnaire administration procedures. Because the study employed a post test only design, the findings indicate differences between groups after the intervention rather than individual changes in motivation from pre intervention to post intervention.

Guided Inquiry Learning Model and Critical Thinking Skills

The results showed that the guided inquiry learning group had a mean critical thinking skills score of 87.50, whereas the direct instruction learning group had a mean score of 82.58. The difference was statistically significant, with $t(67) = 3.324$, $p = 0.001$, a mean difference of 4.924, a 95% CI of [1.968, 7.881], and Cohen's $d = 0.801$.

This finding may be explained by the characteristics of the guided inquiry learning model, which provides students with opportunities to address problems, develop hypotheses, collect evidence, analyze information, and draw conclusions. These processes directly involve cognitive activities associated with critical thinking skills, particularly when students are required to provide evidence-based reasoning, compare investigation results with relevant information, and formulate conclusions consistent with the available evidence. This finding is consistent with (Sarifah & Nurita, 2023), and (Sukarno et al., 2022), who emphasized the role of inquiry learning in promoting active engagement and the development of critical thinking skills.

In the context of renewable energy physics, these processes are relevant because students can be presented with problems that require investigation and evidence evaluation,

such as comparing the characteristics of energy sources, analyzing experimental results, and determining alternatives based on the available data. Consequently, learning extends beyond conceptual understanding and encourages students to apply physics concepts to problem solving and scientific reasoning.

The findings are also consistent with recent empirical evidence. Through a systematic review and meta-analysis of science learning studies, (Arifin et al., 2025) reported a large average effect of inquiry-based learning on critical thinking skills (effect size = 1.27), although substantial heterogeneity was observed across studies. In addition, (Yaumie et al., 2025) specifically reviewed studies of Guided Inquiry in physics education in Indonesia and identified Guided Inquiry as a relevant approach for developing critical thinking skills.

The findings are also consistent with recent research in the energy context. (Maolani et al., 2025) examined the implementation of guided inquiry in alternative energy learning by comparing a guided inquiry group with a problem-based learning group. This contextual difference is important because the present study used the direct instruction learning model as the control condition and focused on renewable energy physics. Therefore, differences across studies may be influenced by the characteristics of the control group, learning content, intervention duration, instruments, and implementation context. Recent meta-analytic evidence also indicates that the magnitude of inquiry learning effects on critical thinking may vary according to the type of control group used.

Simultaneous Effect of the Guided Inquiry Learning Model on Students' Motivation and Critical Thinking Skills

The MANOVA results indicated a statistically significant multivariate effect of the guided inquiry learning model on the combination of students' motivation and critical thinking skills, with Pillai's Trace = 0.203, $F(2,66) = 8.414$, $p < 0.001$, and partial $\eta^2 = 0.203$. The same result was obtained using Wilks' Lambda = 0.797. Because the multivariate effect was significant, the analysis proceeded to univariate tests, which indicated significant effects on both students' motivation and critical thinking skills. The corresponding partial η^2 values were 0.117 and 0.142, respectively.

These simultaneous findings indicate that the guided inquiry learning model is associated with both affective and cognitive learning outcomes. Conceptually, both variables may develop through the same learning experiences: students are presented with problems, conduct investigations, test hypotheses, process evidence, and formulate conclusions. This sequence of activities creates cognitive demands while simultaneously providing opportunities for students to participate actively in learning.

In the context of this study, renewable energy physics provides a learning environment in which both processes can occur simultaneously. Renewable energy problems are contextual and can be examined through observation, experimentation, evidence collection, data analysis, evaluation of alternatives, and conclusion drawing. Thus, students are required not only to understand physics concepts but also to use evidence to solve problems. The characteristics of inquiry-based learning, which emphasize questioning, investigation, data interpretation, and reflection, have also been identified as important components of inquiry based science learning.

The present findings extend previous research, which has generally examined motivation or critical thinking separately. The studies cited in this article have reported relationships between guided inquiry and learning motivation (Ute et al., 2021) and between guided inquiry and critical thinking skills ((Parwati et al., 2020); (Sarifah & Nurita, 2023)). The present study adds evidence that these two variables can be examined simultaneously using MANOVA in the context of renewable energy physics.

Research Limitations

This study has several limitations that should be considered when interpreting the findings. First, the study was conducted at only one school, SMAN 1 Gondang Tulungagung; therefore, generalization to schools with different characteristics should be made cautiously. Second, the study involved only two classes, comprising a total of 69 students, and used purposive sampling; consequently, the sample may not fully represent the population of Grade 10 students.

Third, the intervention was implemented over five sessions, so the observed effects of the guided inquiry learning model reflect conditions within a relatively limited intervention period. Fourth, the post test only control group design did not provide baseline data for comparing individual changes before and after the intervention. Therefore, the findings are more appropriately interpreted as differences in post-test outcomes between groups after the intervention.

Fifth, students' motivation was measured using a self-report questionnaire, meaning that students' responses may have been influenced by subjective perceptions and social desirability. Instrument validation and reliability testing were conducted to improve measurement quality; however, future research could strengthen the measurement of students' motivation through triangulation with observations of student engagement, interviews, or other data sources. These limitations should be considered when applying the findings to broader learning contexts.

CONCLUSION

This study demonstrates that the implementation of the guided inquiry learning model was associated with differences in students' motivation and critical thinking skills compared with the direct instruction learning model in renewable energy physics instruction. These findings provide empirical support for the hypothesis that the use of guided inquiry is associated with differences in both variables. In particular, the study contributes to the literature by demonstrating that students' motivation and critical thinking skills can develop concurrently through learning experiences that emphasize active engagement, investigation, the use of evidence, and evidence based conclusions in the renewable energy topic.

From an educational perspective, these findings have practical implications for physics teachers in designing renewable energy instruction through contextual problems, investigative activities, data analysis, evidence evaluation, and solution evaluation. Such activities can promote more active learning while providing students with opportunities to construct understanding based on evidence and to develop both critical thinking skills and students' motivation.

However, the contributions and implications of this study are limited to its research context, involving 69 tenth-grade students from two classes at a single school, selected through purposive sampling, with the intervention conducted over five instructional sessions using a post-test-only control group design. Therefore, the findings cannot be broadly generalized to different populations or instructional contexts. Future research should involve more diverse samples, longer intervention periods, and a pre-test–post-test design to further examine the consistency and development of both variables in a more comprehensive manner.

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