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Investigating the Interaction between Inquiry Learning Models and Cognitive Styles in Predicting Students' Physics Learning Outcomes

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Abstract: This study is a quasi-experimental study with a 2x2 factorial design. The aim of this research is to determine the effect of applying inquiry learning model and cognitive styles on the physics learning outcomes and the interaction between learning models and cognitive styles on physics learning outcomes. The population in this study were all physics students of grade XI, while the sample was taken from grades XI 2 and XI 6, which were selected based on the Cluster Random Sampling Technique. The research data were obtained by giving the GEFT test to students before using the learning model in this study, and the physics learning outcomes test was conducted after the application of the inquiry learning model. The data analysis technique used was ANOVA. Based on the inferential analysis, the F_{count} (5.12) > F_{table} (4.04), can be concluded that there's a significant difference between students taught with GI and OI learning models, the F_{count} (12.63) > F_{table} (4.04), can be concluded that there's a significant difference between students who have FI and FD cognitive styles, and the interaction value F_{count} (4.19) > F_{table} (4.04), can be concluded that there's an interaction between learning models and cognitive styles on physics learning outcomes.

Keywords: Cognitive style; Guided inquiry; Learning outcomes; Open inquiry

Introduction

Educational developments in the 21st century demand a paradigm shift in learning from teacher-centered to learner-centered learning. Education is no longer directed solely at mastering factual knowledge, but also at developing critical thinking, problem solving, creativity, and independent learning skills (Bao & Koenig, 2019; Mustika et al., 2025). This demand is in line with the need for human resources who are adaptive to developments in science, technology, and the dynamics of social life (Hidayatullah et al., 2021). Therefore, the learning process in schools, including physics learning, needs to be designed systematically in order to accommodate these demands (Dani et al., 2023; Musfiroh et al., 2024).

Physics is one of the science subjects that plays an important role in shaping students' scientific thinking skills. Physics education aims not only to master physics concepts, principles, and laws, but also to train logical reasoning skills, analyze natural phenomena, and apply concepts in solving everyday problems (Khaeruddin et al., 2025). However, in school teaching practices, physics is often perceived as a difficult and abstract subject. This condition has an impact on the low motivation to learn and the learning outcomes of students in physics, which remains a classic problem at various levels of education (Sidik et al., 2024).

The low learning outcomes of students in physics cannot be separated from various factors, both internal and external. One external factor that has a significant influence is the learning model used by teachers (Juliyasa et al., 2018). Learning models that are teacher-centered and do not actively involve students tend to

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make them passive recipients of information without the opportunity to construct knowledge independently (Hikmawati et al., 2020; Pangestika & Budiningarti, 2014). This situation indicates a conceptual gap in physics learning practices, particularly regarding the extent to which the level of independence given to students in the inquiry process contributes to knowledge formation. Therefore, it is important to analyze more deeply how varying levels of independence in inquiry activities can optimize cognitive engagement and improve learning outcomes (Mukhlisa et al., 2021; Rediyono, 2025). Furthemor, this condition can lead to a shallow understanding of concepts, which are easily forgotten, and contribute to low physics learning outcomes for students (Rahmah et al., 2024; Vuztasari & Diyana, 2024). Therefore, a learning model is needed that can encourage student activity in the learning process and provide meaningful learning experiences.

One learning model that is relevant to addressing these issues is the inquiry learning model. The inquiry learning model is an approach that emphasizes active student involvement in discovering concepts through a scientific investigation process, thereby improving conceptual understanding and critical thinking skills. The inquiry learning model emphasizes the active involvement of students in discovering concepts through the scientific investigation process, such as formulating problems, proposing hypotheses, conducting experiments, analyzing data, and drawing conclusions (Nurussaniah et al., 2017; Sudiartha, 2022). This model has variations in the form of guided inquiry and open inquiry, which are differentiated based on the level of student independence (Indawati et al., 2023; Riben et al., 2024). Guided inquiry involves more intensive teacher direction and is appropriate for students who still need support in scientific thinking, while open inquiry gives students greater freedom to conduct independent investigations with the teacher as a facilitator (Abaniel, 2021; Fitriyana et al., 2025). The difference in the level of guidance in the two models is thought to have different effects on students' physics learning outcomes (Antonio & Prudente, 2023; Depin et al., 2024; Romadhona & Suyanto, 2020).

In addition to learning models, internal factors of learners that also influence learning success are cognitive styles. Cognitive styles describe the unique ways in which individuals receive, process, and organize information. One classification of cognitive styles that is widely used in educational research is field independent and field dependent cognitive styles (Witkin et al., 1977). Learners with a field-independent cognitive style tend to be more analytical, independent, and able to separate information from its context, while learners with a field-dependent cognitive style are more dependent on the context of their environment and social support in understanding information (Sukaryaningsih et al., 2023; Samsun et al., 2024). Learners with a field-independent (FI) cognitive style tend to process information analytically by separating each component from its context, making them more adaptable to open-ended, low-structure inquiry situations. Conversely, field-dependent (FD) learners understand information holistically by relying on the interrelationships between elements and external support, benefiting more from directed learning environments (Arifin et al., 2020; Menap et al., 2021). These differences in cognitive characteristics reinforce the assumption that the fit between the level of learning structure and cognitive style plays a crucial role in optimizing the knowledge-building process for the students (Hardiansyah et al., 2024; Nozari & Siamian, 2015).

This explanation can also be strengthened through Cognitive Load Theory, which states that learning effectiveness is greatly influenced by the limited capacity of working memory to process new information. Less structured learning environments, such as open inquiry, have the potential to increase cognitive load because they require students to independently organize information, design strategies, and draw conclusions. In this context, field-independent students tend to be better able to manage the complexity of information so that cognitive load remains manageable, while field-dependent students are more susceptible to overload if structural support is inadequate. Therefore, cognitive style can be positioned as a moderating variable that determines the match between the level of learning structure and students' cognitive processing capacity (Sweller, 1988).

These differences in cognitive styles have implications for how learners respond to the learning models applied. Learners with a field-independent cognitive style are thought to perform better when faced with learning that requires independence and in-depth analysis, while learners with a field-dependent cognitive style tend to benefit more from learning that provides clear structure and social interaction (Mustofa et al., 2024; Xie et al., 2025). Therefore, the effectiveness of a learning model cannot be separated from its suitability to the characteristics of students' cognitive styles.

Based on the results of research at Makassar State High School 8, it was found that the physics learning outcomes of grade XI students on fluid material were still not optimal, as indicated by the dominance of achievements in the moderate to low categories and the low ability of students to interpret, analyze, and systematically conclude physics problems. The choice of fluid material is based on its abstract characteristics and the interrelationships between several variables, which often trigger misconceptions among students. This situation necessitates the implementation of an inquiry-based learning model that allows students to directly explore phenomena through experimentation and analysis. Therefore, the inquiry model is considered appropriate for helping build a more accurate conceptual understanding while increasing cognitive engagement. This condition indicates that the ongoing physics learning process has not been fully able to empower students' higher-order thinking skills, which are greatly influenced by the application of learning models and differences in students' cognitive styles. Students with different cognitive styles show diverse responses to the learning strategies used, so an appropriate learning model is needed to accommodate these differences (Irwan et al., 2021; Zhang, 2023).

Based on these conditions, this study has a high urgency to empirically examine the influence of inquiry learning models (guided inquiry and open inquiry) and cognitive styles (field independent and field dependent) on students' physics learning outcomes. The urgency of this study is based on the low physics learning outcomes, the need for student-centered learning innovation, and the need for a more comprehensive understanding of the suitability between learning models and students' cognitive characteristics in order to improve the quality of physics learning in schools.

Thus, this study is expected to contribute theoretically to the development of physics learning studies, particularly regarding the interaction between learning models and cognitive styles, as well as practically to teachers in designing and implementing learning strategies that are more effective and adaptive to student characteristics. This study aims to analyze the effect of guided inquiry and open inquiry learning models and field independent and field dependent cognitive styles on students' physics learning outcomes, both partially and in terms of the interaction between the two variables.

Method

This study used a quasi-experiment method. The research design used is a 2 × 2 factorial design. This design is used by researchers to examine the effect of two independent variables, namely learning models and cognitive styles, on the dependent variable of students' physics learning outcomes, both the main effect of each variable and the interaction effect between the two variables.

In this study, the first factor is the learning model, which consists of two levels, namely the guided inquiry and open inquiry learning models. The second factor is cognitive style, which consists of two levels, namely field independent and field dependent. The combination of these two factors resulted in four treatment groups, namely, students with a field dependent cognitive style who learned using the open inquiry model, students with a field independent cognitive style who learned using the open inquiry model, students with a field dependent cognitive style who learned using the guided inquiry model, and students with a field independent cognitive style who learned using the guided inquiry model.

Table 1. Interaction factorial experimental design A and B

Cognitive Style (B)	Learning Model (A)	
	Guided Inquiry (A1)	Open Inquiry (A2)
Field Independent (B1)	Y[A1B1]	Y[A2B1]
Field Dependent (B2)	Y[A1B2]	Y[A2B2]
Amount (∑)	Y[A1B1] + Y[A1B2]	Y[A2B1] + Y[A2B2]

Through this true experimental design with a 2 × 2 factorial design, researchers can obtain a more comprehensive picture of the effectiveness of the inquiry learning model in terms of differences in students' cognitive styles and the interaction between these two variables in influencing physics learning outcomes.

Population and Sample

The population in this study was all 11th grade physics students at SMA Negeri 8 Makassar odd semester of the 2025/2026 academic year. This population was chosen because it had relatively homogeneous academic characteristics and used the same curriculum and learning system.

The research sample was determined using cluster random sampling techniques, with the sampling unit being the class. From the population, two 11th grade Physics classes were selected as research samples, namely class XI 6 as experiment class 1, which was taught using the guided inquiry learning model, and class XI 2 as experiment class 2, which was taught using the open inquiry learning model. Each class was given a GEFT test to identify students with field independent and field dependent cognitive styles.

Instruments and Data Collection

The research instruments included are a test of cognitive domain C3–C6 physics learning outcomes (applying, analyzing, evaluating, and creating) in the form of multiple-choice questions with a score of 1 for correct answers and 0 for incorrect answers, which had been tested for validity and reliability, cognitive style instruments in the form of the Group Embedded Figures Test (GEFT) developed by Witkin to classify students' cognitive styles and learning tools in the form of teaching modules based on the Merdeka Curriculum with a guided inquiry and modified open inquiry model.

Data collection in this study was conducted in several stages. Physics learning outcome data was obtained by administering a posttest to students after all learning treatments had been completed. This test was used to measure student learning outcomes in the C3 to C6 cognitive domains. Data on students' cognitive styles were collected using the Group Embedded Figures Test (GEFT) instrument, which was given to all research subjects to classify students into appropriate cognitive style categories. Students with scores of 0–11 are classified as field dependent (FD), namely individuals who tend to process information globally and require external structure or direction in learning, while students with scores of 12–18 are categorized as field independent (FI), which shows a tendency to think analytically and the ability to separate information from its context independently. In addition, data on the implementation of learning were obtained through observation during the learning process using observation sheets to ensure that the learning stages were carried out in accordance with the predetermined design.

Data Analysis Technique

Data analysis techniques in this study were carried out in stages using several statistical software programs. Descriptive statistical analysis was performed using Microsoft Excel to obtain an overview of the students' learning outcomes data, including the mean, median, standard deviation, maximum value, and minimum value. Next, prerequisite testing was conducted using SPSS version 29. Data normality was tested using the Shapiro–Wilk test to determine whether the data was normally distributed. Variance homogeneity was tested using the Levene test to ensure the similarity of variance between data groups.

Based on the result obtained the Shapiro–Wilk test results show that the significance value of the learning outcome data in each group is greater than 0.05 ($p > 0.05$), so it can be concluded that the students' physics learning outcome data is normally distributed. With the assumption of normality fulfilled, the data is suitable for analysis using parametric statistical techniques. The Levene test results show a significance value greater than 0.05 ($p > 0.05$), so it can be concluded that the variance in physics learning outcomes between groups is homogeneous. Thus, there is no significant difference in variance between the groups learning using the guided inquiry and open inquiry models, both in terms of field independent and field dependent cognitive styles.

After the normality and homogeneity tests have been conducted, hypothesis testing was conducted using a t-test to determine the difference in learning outcomes between the two experimental classes based on differences in learning models, namely guided inquiry and open inquiry, as well as based on differences in students' cognitive styles, namely field independent (FI) and field dependent (FD). Furthermore, to examine the effect of the interaction between learning models and cognitive styles on physics learning outcomes, a Two-Way ANOVA test was conducted in accordance with the 2×2 factorial design used in this study.

Result and Discussion

Generative Distribution of Learning Score

The research data consists of two independent variables, namely independent variable (A) learning model. The learning models used are guided inquiry and open inquiry. Meanwhile, the independent variable that acts as a moderator variable (B) is cognitive style. Cognitive style is divided into two types, namely field independent and field dependent. The dependent variable (Y) is learning outcomes. This study aims to observe and test the effect of independent variables (A and B) on the dependent variable (Y) using a two-way ANOVA analysis. This section also presents a description of the science learning outcomes data for each experimental class based on the data obtained in the field.

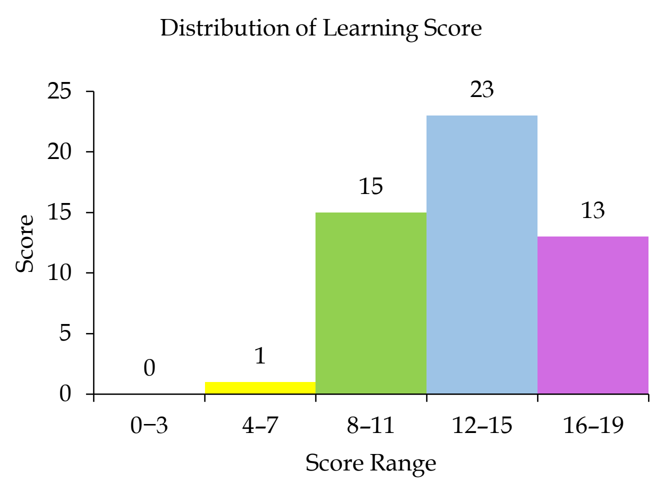

Figure 1. Learning outcome scores of the experimental classes

Based on the distribution of learning outcome scores, student achievement categories can be interpreted in stages. There were no students in the very low category (0–3), only 1 student were found in the low category (4–7), 15 students were in the sufficient category (8–11), 23 students were concentrated in the high category (12–15), and 13 students were in the very high category (16–19). This distribution pattern shows that the learning methods used were able to encourage the majority of students to achieve good learning outcomes and minimize low learning outcomes.

Table 2. Description of learning outcomes

N	Learning Model		Cognitive Style	
	Guided Inquiry (GI)	Open Inquiry (OI)	Field Independent (FI)	Field Dependent (FD)
N	26	26	26	26
Mean	14.92	12.38	14.46	12.84

Results of the Two-Way Anova

The following is a summary of the results of the two-way ANOVA test in this study:

Table 3. Summary of Two-Way Anova test

Source Variation	SS	df	MS	F	P-value	F crit
Between A	33.923	1	33.92	5.12	0.03	4.04
Between B	83.769	1	83.77	12.63	0.0008	4.04
AB Interaction	27.769	1	27.77	4.19	0.04	4.04
Within	318.307	48	6.63			
Total	463.769	51				

Discussion

This study aims to analyze the effect of guided inquiry and open inquiry learning models as well as field independent and field dependent cognitive styles on students' physics learning outcomes, both partially and in terms of the interaction between the two variables. Data analysis was performed using two-factor ANOVA with replication, allowing for testing of the main effects of each variable and the interaction between learning models and cognitive styles.

The Effect of Learning Models on Physics Learning Outcomes

The results of the two-factor ANOVA analysis show that the learning model (Between A) has a significant effect on students' physics learning outcomes, as indicated by an F value of 5.12 with a p-value of 0.03 (< 0.05). These findings indicate that there is a significant difference in learning outcomes between students who learn using the guided inquiry model and those who learn using the open inquiry model. This research is in line with Yulianti & Zhafirah (2020) that the selection of learning models is an important factor in determining the success of science learning.

Descriptively, the difference in influence is reflected in the average value of student learning outcomes, where the guided inquiry group obtained an average of 14.92, while the open inquiry group obtained an average of 12.38. This finding indicates that the guided inquiry model provides a more optimal contribution in improving physics learning outcomes compared to open inquiry. Theoretically, open inquiry does offer a higher level of independence and has the potential to encourage deeper cognitive engagement; however, in the context of this study, too much independence without adequate scaffolding support actually has the potential to increase students' cognitive load. As a result, some students experienced difficulty in organizing the investigation process effectively, so that more structured learning through guided inquiry proved to be more capable of supporting conceptual understanding and achieving learning outcomes.

The learning outcomes of students taught using guided inquiry showed better and more consistent achievements compared to students taught using open inquiry. The superiority of guided inquiry can be explained through the main characteristics of this model, namely the systematic guidance from the teacher at every stage of the inquiry activity, starting from problem formulation, investigation design, data collection, to drawing conclusions. This guidance serves as scaffolding that helps students understand physics concepts in a gradual and structured manner, thereby reducing the possibility of misconceptions and procedural errors.

In contrast, in the open inquiry model, students are given greater freedom in determining the steps of the investigation. Although this approach has the potential to develop independence and creativity, in the practice of physics learning in secondary schools, this approach often presents challenges. Students who do not have sufficient inquiry experience tend to have difficulty formulating problems, determining variables, and relating the investigation data to relevant physics concepts. This condition causes the learning process to be less effective and results in lower learning outcomes compared to guided inquiry.

The findings of this study are in line with the results of Sholikhan et al. (2020), which states that guided inquiry produces a significantly higher understanding of physics concepts than open inquiry. Based on descriptive analysis, students who learned using guided inquiry obtained an average concept understanding score of 76.25, while students who learned using open inquiry obtained an average score of 72.50. This difference in average scores shows that, empirically, guided inquiry is more effective in improving students' understanding of physics concepts than open inquiry. Sholikhan et al. (2020) explains that the presence of guidance and feedback from teachers in guided inquiry allows students to construct concepts more accurately and systematically. The similarity of these results shows that in the context of high school physics learning, the level of guidance in the inquiry model is a key factor that determines the effectiveness of learning.

In addition, the results of this study also support the view that guided inquiry is more suitable for conceptual and analytical physics material, such as fluids, which requires an understanding of the relationship between variables, the application of physics principles, and the ability to interpret data. With a clear learning structure, students can focus more on the scientific reasoning process without being burdened by complex procedural difficulties (Sholikhan et al., 2020).

The advantages of guided inquiry in this study are explained through the role of more structured teacher guidance during the learning process. In guided inquiry, teachers provide sufficient direction, scaffolding, and feedback at each stage of the investigation, thereby helping students avoid misconceptions, procedural confusion, and ineffective use of time. Conversely, in open inquiry, limited guidance causes some students to experience difficulties in formulating problems, designing investigations, and constructing physics concepts appropriately, which results in lower conceptual understanding.

The Influence of Cognitive Style on Physics Learning Outcomes

The ANOVA results show that the cognitive style factor (Between B) has an F_{count} = 12.63 with a p-value = 0.0008, which is much smaller than α = 0.05 and greater than F_{table} = 4.04. These results indicate that field independent and field dependent cognitive styles have a significant effect on students' physics learning outcomes.

In terms of average scores, students with a field-independent cognitive style had an average learning outcome score of 14.46, while students with a field-dependent cognitive style had an average score of 12.84. This difference indicates that students with a field-independent cognitive style tend to have higher physics learning outcomes than field-dependent students.

Descriptively, students with a field-independent cognitive style showed an average learning outcome of 14.46, while students with a field-dependent cognitive style had an average score of 12.84. This is due to the main characteristics of field-independent students, who tend to be more analytical, independent, and able to separate information from its context. In physics learning, which requires conceptual understanding, mathematical reasoning, and the ability to analyze relationships between variables, these characteristics provide significant cognitive advantages. Field independent learners are better able to organize information, identify core concepts, and construct understanding independently, which has a positive impact on learning outcomes.

Conversely, field dependent learners tend to be more dependent on environmental context, external guidance, and social support in understanding information. These characteristics cause field dependent learners to experience difficulties when faced with abstract physics material that requires in-depth information processing. As a result, without adequate support, the physics learning outcomes of field dependent learners tend to be lower than those of field independent learners.

The findings of this study are in line with the research by Hidayatullah & Irawan (2025), which shows that cognitive style has a significant effect on students' critical thinking skills, with field independent students achieving better results than field dependent students. This research confirms that differences in cognitive styles affect how students process information and solve academic problems, especially in science subjects that require high-level reasoning (Hidayatullah & Irawan, 2025).

The results of this study also reinforce the classical view put forward by Witkin and Goodenough, that field independent students excel in academic tasks that require structural analysis, problem solving, and separation of information from the surrounding context. In the context of physics learning, these abilities are highly relevant because students are required to understand concepts objectively, perform mathematical analysis, and interpret physical phenomena logically (Witkin et al., 1977).

Thus, differences in physics learning outcomes reviewed from a cognitive style perspective show that students' cognitive characteristics need to be an important consideration in learning planning. Physics teachers need to understand that students differ not only in their initial abilities but also in the way they process information (Bahri et al., 2024; Nirwana, 2017; Yulianci et al., 2019). Without considering differences in cognitive style, learning has the potential to be suboptimal for some students, especially those with field-dependent tendencies.

The Effect of Learning Model Interaction and Cognitive Style on Physics Learning Outcomes

The two-factor ANOVA results show that the interaction between the learning model and cognitive style has an F_{count} = 4.19 with a p-value = 0.04, which is smaller than α = 0.05 and greater than F_{table} = 4.04. These results indicate that there is a significant interaction effect between learning models and cognitive styles on students' physics learning outcomes.

This interaction can be explained by the fact that field independent learners are better able to take advantage of the freedom and cognitive challenges provided by open inquiry, while field dependent learners tend to need clearer direction and structure in learning. Therefore, when field dependent learners are faced with a learning model that demands a high degree of independence without adequate scaffolding, the learning outcomes achieved are less than optimal.

An important implication of these findings is the need for physics teachers to consider the diversity of cognitive characteristics before determining learning strategies. The selection of inquiry models should not be done generally, but should be tailored to the needs and abilities of students so that the learning process becomes more adaptive. An approach that considers cognitive differences has the potential to create a more meaningful learning experience, improve conceptual understanding, and help students achieve more optimal learning outcomes. Thus, the interaction between learning models and cognitive styles is not only a statistical finding but also an important pedagogical basis for designing effective physics learning.

Thus, the results of this study emphasize the importance of physics teachers considering the variation in students' cognitive styles in selecting and maximizing appropriate learning models so that physics learning outcomes can be optimally improved.

Conclusion

This study shows a significant difference in physics learning outcomes between students taught using guided inquiry and open inquiry models, with guided inquiry proving more effective in improving learning outcomes. Furthermore, students with a field-independent (FI) cognitive style achieved higher learning outcomes than those with a field-dependent (FD) cognitive style, confirming that analytical skills and independence in processing information contribute positively to academic achievement. The ANOVA test also revealed a significant interaction between learning model and cognitive style ($F_{count} = 4.19 > F_{table} = 4.04$), indicating that the effectiveness of learning models differs significantly depending on students' cognitive characteristics. Specifically, guided inquiry provides more appropriate structural support for most students, while the high level of independence in open inquiry results in varying learning outcomes according to students' ability to manage the inquiry process.

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Author Contributions

Conceptualization, formal analysis, investigation, data curation, writing—original draft preparation, N.A.; methodology, A.S.A.W.; validation, resources, K.; writing—review and editing, visualization, A.C. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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