

The Effect of the INSPIRE Learning Model on Students' Mastery of Environmental Change Material

Nurul Faizah^{1*}, Paidi², Mualimin², Atik Kurniawati², Kurnia Padmawati¹, Shynthya Ratu Shima¹, & Crescentia Mishi Juniorita Ngangi¹

¹Master Program of Biology Education, Universitas Negeri Yogyakarta, Indonesia

²Department of Biology Education, Universitas Negeri Yogyakarta, Indonesia

*Corresponding email: nfaizah1@gmail.com

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Abstract: This study aims to examine the effectiveness of the INSPIRE learning model in improving students' mastery of environmental change material. The study is motivated by the persistent issue of low student learning outcomes and limited active engagement resulting from the dominance of teacher-centered instructional approaches. The INSPIRE model integrates inquiry-based learning and deep learning principles to promote conceptual understanding and meaningful learning processes. This research employed a quasi-experimental design with a pretest–posttest control group. The participants were two groups of 10th-grade students at SMAN 1 Piyungan, Yogyakarta, for a total of 36 students. The experimental group was taught using the INSPIRE model, while the control group received conventional instruction. Data were collected using a material mastery test and analyzed with an independent-samples t-test at a significance level of 0.05. The results showed a statistically significant difference between the two groups, with the experimental group achieving a higher mean posttest score (93.17) compared to the control group (62.85) ($p < 0.001$). These findings indicate that the INSPIRE learning model is associated with higher student mastery of environmental change material compared to conventional methods. Theoretically, the INSPIRE model is grounded in constructivist, social cognitive, and humanistic learning theories, which emphasize active learning, collaborative inquiry, and student engagement. The findings suggest that integrating inquiry-based and deep learning approaches can support improved conceptual understanding and overall learning outcomes. However, the results should be interpreted with caution, given the quasi-experimental design and the limited number of cognitive test items. Therefore, the INSPIRE learning model may serve as an alternative instructional strategy for enhancing biology learning and supporting the development of 21st-century competencies.

Keywords: INSPIRE learning model, inquiry-based learning, deep learning, environmental change.

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■ INTRODUCTION

Education is a critical foundation for developing high-quality human resources. In the era of globalization and rapid technological advancement, individuals are expected not only to possess strong disciplinary knowledge but also to demonstrate essential competencies such as critical thinking, creativity, collaboration, and problem-solving (Ballen et al., 2017). These competencies are particularly important in addressing global challenges, including

environmental degradation, climate change, and sustainability issues, which require interdisciplinary understanding and the ability to analyze complex socio-scientific problems (Anderson, 2019; Zahra et al., 2024). Therefore, the effectiveness of the learning process depends heavily on the instructional models and pedagogical approaches employed in the classroom, as these determine how students construct knowledge, engage with learning materials, and apply their understanding in real-world contexts. Integrating environmental

topics, such as climate change, into curricula is essential for fostering awareness and strengthening students' critical thinking skills to analyze and address these challenges (Monroe et al., 2019; Devi & Hariyono, 2024). Mastery of environmental change concepts goes beyond rote memorization of theoretical knowledge; it involves the ability to interpret data, evaluate evidence, and propose scientifically grounded solutions to complex and often ambiguous environmental issues (Ismiandini et al., 2024). However, achieving such learning outcomes remains a significant challenge in many educational contexts.

Students' limited mastery of material is frequently associated with teacher-centered instructional approaches that restrict active engagement and position students as passive recipients of information (Freeman et al., 2014; Deslauriers et al., 2019). In such learning environments, students are often limited to listening, memorizing, and reproducing information, with minimal opportunities to explore concepts, ask questions, or construct their own understanding. Traditional lecture-based teaching has consistently been shown to produce lower levels of engagement, reduced motivation, and weaker learning outcomes compared to active learning strategies that directly involve students in the learning process (Freeman et al., 2014; Chen et al., 2021). As a result, students may struggle to develop deep conceptual understanding and are less likely to retain and apply knowledge in new or complex contexts. Learning models, therefore, play a crucial role in enhancing students' content mastery by promoting motivation, supporting conceptual understanding, and encouraging active participation in knowledge construction (Chi & Wylie, 2017; Dewi et al., 2019; Yulianingsih et al., 2022). Effective learning models are designed not only to deliver content but also to engage students cognitively, emotionally, and behaviorally in meaningful learning experiences. In this sense, student

engagement involves not only physical participation but also cognitive processes such as reasoning, analyzing, and reflecting, which are essential for achieving deeper learning outcomes. Consequently, instructional approaches that emphasize active learning, collaboration, and inquiry are increasingly recognized as more effective in fostering higher-order thinking skills and long-term knowledge retention. In this regard, teachers are expected to shift their roles from knowledge transmitters to facilitators of learning who guide students in exploring ideas, constructing meaning, and reflecting on their understanding (Rieuwpassa, 2023). This shift requires teachers to design learning environments that are interactive, student-centered, and inquiry-oriented, where learners are encouraged to take an active role in the learning process. By providing opportunities for discussion, investigation, and reflection, teachers can support the development of students' autonomy, critical thinking, and problem-solving skills, which are essential competencies in addressing complex scientific and environmental issues.

Mastery of subject matter is particularly crucial in senior high school biology, especially in the topic of environmental change, which is inherently complex, interdisciplinary, and closely linked to real-world issues. Given its global relevance, students are required not only to understand scientific concepts but also to develop deep conceptual understanding in order to interpret environmental phenomena, evaluate evidence, and propose scientifically grounded solutions (Zahra et al., 2024). However, environmental change topics are often perceived as abstract, dynamic, and cognitively demanding, making it difficult for students to grasp key concepts, analyze causal relationships, and apply knowledge in authentic contexts (Putri et al., 2019). As a consequence, students frequently demonstrate limited mastery of material and insufficient development of higher-order thinking

skills, particularly in analysis, evaluation, and problem-solving. Previous studies consistently report that learning in biology classrooms at the senior high school level remains dominated by teacher-centered approaches, which tend to limit student participation and reduce opportunities for inquiry, discussion, and conceptual exploration (Plutzer et al., 2016; Permata et al., 2021; Sudarsono et al., 2024). Such instructional conditions contribute to low engagement and hinder the development of meaningful, transferable understanding, especially in complex scientific topics such as environmental change, which require active cognitive involvement. In response to these challenges, innovative learning models that promote active engagement and inquiry processes have been widely recommended, as they have been shown to improve students' conceptual understanding and critical thinking skills (Jensen & Lawson, 2019; Devi & Hariyono, 2024).

In particular, inquiry-based learning encourages students to construct knowledge through questioning, investigation, and evidence-based reasoning, thereby fostering scientific thinking and deeper understanding. At the same time, the deep learning approach emphasizes meaningful learning processes by encouraging students to connect concepts, apply knowledge across contexts, and engage in reflective thinking, thereby supporting long-term retention and knowledge transfer. Despite the growing body of research on inquiry-based learning and deep learning, studies that explicitly integrate both approaches into a coherent and structured instructional model for environmental change topics at the senior high school level remain limited, particularly in the Indonesian educational context (Isnayanti et al., 2025). This gap is significant because addressing complex environmental issues requires not only inquiry skills but also deep conceptual understanding and reflective thinking. Therefore, there is a critical

need for an instructional model that systematically combines these approaches to enhance both student engagement and learning outcomes. In response to this need, this study introduces the INSPIRE learning model as an integrative framework that combines inquiry-based learning with deep learning principles in a systematic instructional design. Conceptually, this model extends previous inquiry-based approaches by incorporating structured stages that emphasize reasoning, reflection, and conceptual integration, thereby supporting deeper cognitive processing. Methodologically, this study contributes empirical evidence by employing a quasi-experimental design in the context of environmental change learning at the senior high school level, an underexplored setting in prior studies.

Based on these considerations, this study aims to examine the effectiveness of the INSPIRE Learning Model in improving students' mastery of environmental change compared with conventional learning methods. This study addresses the following research questions:

1. Does the implementation of the INSPIRE Learning Model lead to higher student mastery of environmental change material compared to conventional learning methods?
2. Is there a statistically significant difference in learning outcomes between students taught using the INSPIRE model and those taught using conventional approaches?

Thus, this study is expected to provide empirical evidence on the effectiveness of integrative learning models and offer practical implications for designing biology instruction that supports deeper conceptual understanding and the development of higher-order thinking skills in addressing complex environmental issues.

■ **METHOD**

The participants of this study were 72 tenth-grade students from SMAN 1 Piyungan, Bantul,

Yogyakarta, Indonesia. Two intact classes were selected using purposive sampling, with one class assigned as the experimental group and the other as the control group, each consisting of 36 students. Purposive sampling was employed due to practical constraints that made random assignment infeasible in the school setting. The selected classes had relatively similar academic characteristics, indicating baseline comparability. However, this approach may introduce selection bias; therefore, the findings should be interpreted with caution, particularly regarding generalizability.

Research Design and Procedures

This study employed a quasi-experimental design with a pretest-posttest control-group model to compare learning outcomes between students taught with the INSPIRE learning model and those receiving conventional lecture-based instruction. The research was conducted from September to October 2025. The procedure consisted of three stages.

First, both groups were given a pretest to assess their prior knowledge of environmental change. Second, the experimental group received instruction using the INSPIRE learning model, while the control group was taught using conventional lecture-based methods. The intervention was conducted over four consecutive weeks, with one 90-minute instructional session per week. In the experimental class, learning activities followed the seven phases of the INSPIRE learning model: Identifying Basic Concepts, Nurturing Problems from Phenomena, Setting Up Hypotheses, Planning Investigations, Investigating Empirical Evidence, Reasoning and Concluding, and Ending with Reflection.

During the Identifying Basic Concepts phase, students studied fundamental concepts related to environmental change, including pollution, ecosystem degradation, biodiversity loss, climate change, and waste management. In the Nurturing Problems from Phenomena phase,

students were presented with authentic environmental issues and worked collaboratively to identify problems and formulate investigable questions.

During the Setting Up Hypotheses and Planning Investigations phases, students developed hypotheses and designed investigation procedures to gather relevant evidence. Subsequently, in the Investigating Empirical Evidence phase, students collected and analyzed information from observations, environmental reports, scientific references, and other relevant learning resources. Some investigation activities were conducted independently outside regular classroom hours to provide students with opportunities to engage directly with environmental issues.

In the Reasoning and Concluding phase, students interpreted the collected evidence, evaluated their hypotheses, and formulated evidence-based conclusions. Finally, during the Ending with Reflection phase, students reflected on their learning experiences, evaluated their investigation strategies, and identified the knowledge gained throughout the learning process.

In contrast, students in the control group learned the same material through conventional lecture-based instruction consisting of teacher explanations, note-taking activities, question-and-answer sessions, classroom discussions, and individual assignments. Finally, both groups completed a posttest to measure improvement in material mastery. The posttest was administered with the same instrument as the pretest, and the collected data were analyzed using descriptive and inferential statistics to assess the effectiveness of the INSPIRE learning model.

Instruments

The instrument used in this study was a concept mastery test consisting of 8 essay questions. The test was designed to measure

students' cognitive learning outcomes related to environmental change topics, with a focus on conceptual understanding, application, and analysis levels, as defined by the revised Bloom's taxonomy (Anderson & Krathwohl, 2001). Compared with multiple-choice tests, essay-based items were used to assess deeper conceptual understanding and students' ability to explain, interpret, and apply biological concepts in the context of environmental phenomena.

The instrument was developed from previous studies in environmental science assessment and aligned with the senior high school biology curriculum. Each item was constructed based on real-world environmental issues to ensure contextual relevance and to support the measurement of meaningful learning outcomes within the INSPIRE learning model framework.

Content validity of the instrument was established through expert judgment involving two biology education experts and one experienced high school biology teacher. The experts evaluated the relevance, clarity, and representativeness of each item in relation to the learning objectives and indicators of concept mastery. In addition, they also assessed the suitability of the items in measuring higher-order cognitive skills. Based on the validation results, all items were categorized as valid with minor revisions in wording for clarity. Students' responses were scored using a standardized analytic rubric covering concept accuracy, completeness, application, and conceptual integration. The total score was then converted to a 0–100 scale for further statistical analysis, including N-Gain and effect size calculations. The instrument's reliability was assessed using Cronbach's alpha, yielding $\alpha = 0.82$, indicating a high level of internal consistency. Each item was further analyzed using item difficulty and discrimination indices to assess test quality.

The indicators measured in this instrument include: (1) understanding of basic concepts of

environmental change (e.g., identifying causes and impacts of environmental issues), (2) application of concepts in real-world contexts (e.g., relating environmental problems to daily life situations), and (3) analytical skills in interpreting environmental data or scenarios (e.g., evaluating relationships between variables in environmental cases). These indicators reflect students' ability not only to recall information but also to apply and analyze knowledge in meaningful contexts.

Data Analysis

Learning outcome data were analyzed using an independent sample t-test to determine differences between the experimental and control groups after treatment. The analysis was conducted at a 0.05 significance level to evaluate the effectiveness of the INSPIRE learning model compared with conventional learning.

A total of 72 tenth-grade students participated in this study. The participants were assigned to two intact classes, each consisting of 36 students. One class served as the experimental group and received instruction using the INSPIRE learning model, whereas the other class served as the control group and received conventional lecture-based instruction. Both classes were selected because they had similar academic characteristics, as indicated by school records and teacher recommendations.

■ RESULT AND DISCUSSION

Implementation of the INSPIRE Model on Environmental Change Material

The INSPIRE Learning Model was developed to operationalize a deep learning approach oriented toward conceptual understanding, higher-order thinking skills, and reflective abilities. In this study, deep learning is defined as a learning process in which students actively construct meaning by connecting prior knowledge with new information, applying concepts in real-world contexts, analyzing and

evaluating evidence, and reflecting on their learning to achieve deeper understanding and knowledge transfer.

Within the INSPIRE model, these principles are embedded in its instructional syntax. The early stages (Identifying Basic Concepts and Nurturing Problem) activate prior knowledge and contextual understanding, while the core inquiry stages (Setting Up Hypothesis, Planning Investigation, and Investigating Empirical Evidence) engage students in evidence-based reasoning. The distinguishing feature of INSPIRE compared to standard inquiry lies in the final stages, Reasoning

and Concluding, and Ending with Reflection, which explicitly emphasize conceptual integration and metacognitive reflection. These stages ensure that learning goes beyond information acquisition toward deeper understanding, critical thinking, and ability to apply knowledge in new contexts.

The INSPIRE Learning Model was developed by integrating the principles of Guided Inquiry-Based Learning (IBL) with deep learning approaches to promote conceptual understanding, inquiry skills, and reflective thinking. The following is the theory underlying the INSPIRE model as shown in Figure 1.

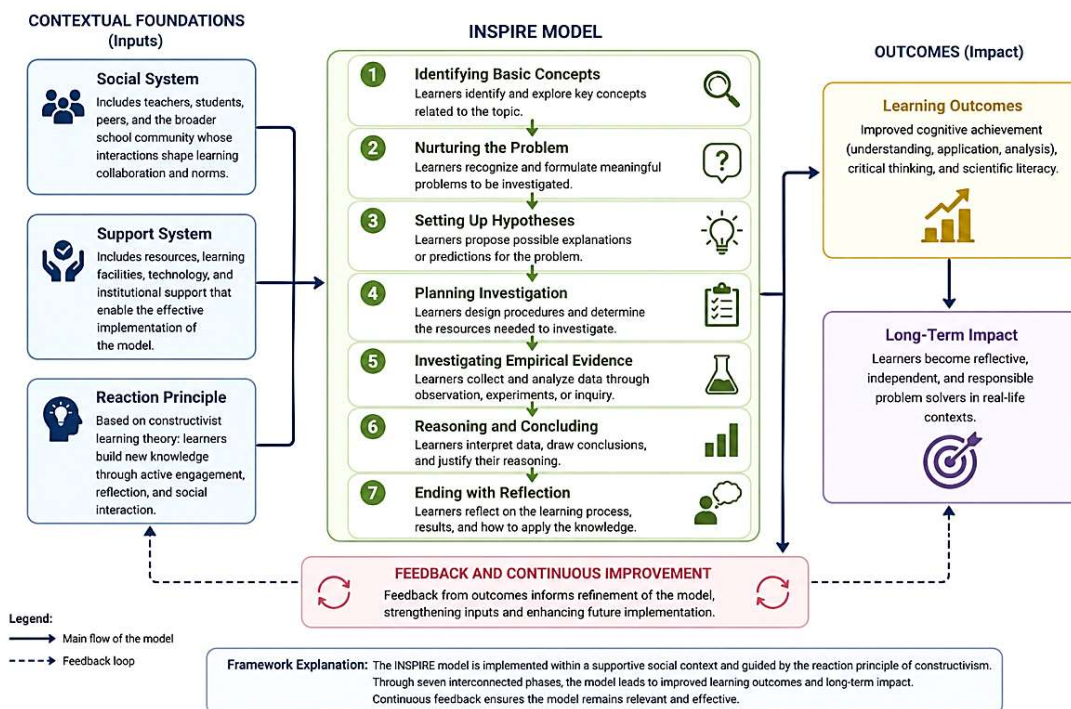


Figure 1. Structure of the INSPIRE learning model

The INSPIRE model is based on three main theories, namely constructivism, social cognitive learning theory, and humanistic learning theory. The effectiveness of the INSPIRE learning model in improving students' mastery of environmental change material can be understood through its strong theoretical foundation and the causal contribution of each instructional stage.

From a constructivist perspective, learning is viewed as an active process in which learners

construct knowledge through interaction with their environment. According to Piaget, this occurs through the processes of assimilation and accommodation, which enable students to build new understanding based on prior knowledge and direct experience. This principle is reflected in the early stages of the INSPIRE model, particularly in identifying basic concepts and nurturing the problem, where students activate prior knowledge and engage with meaningful,

real-world problems. These stages help establish a conceptual foundation and increase cognitive readiness, which are essential for deeper learning.

The social cognitive learning theory proposed by Bandura emphasizes the role of observation, imitation, and self-efficacy in shaping learning behavior. Learning occurs through processes of attention, retention, reproduction, and motivation, and is influenced by both individual cognition and social interaction. This theoretical perspective is structured into stages such as formulating hypotheses, planning the investigation, and examining empirical evidence, where students collaboratively explore ideas, observe peers' strategies, and build confidence in their ability to solve problems. These processes enhance students' analytical skills and engagement, which contribute directly to improved learning outcomes.

Meanwhile, humanistic learning theory focuses on the development of the whole person and emphasizes the importance of self-actualization, motivation, and learner autonomy. According to Rogers and Freiberg (1994), teachers act as facilitators who create a supportive learning environment, guide students in setting goals, and encourage self-reflection. This perspective is clearly reflected in the later stages of the INSPIRE model, particularly in reasoning and concluding, and in the final stage of reflection,

where students evaluate their understanding, draw conclusions, and reflect on their learning processes. These stages foster metacognitive awareness, which plays a crucial role in knowledge consolidation and long-term retention.

Each stage of the INSPIRE model contributes causally to improving students' mastery of the material by guiding learners through a structured progression of cognitive processes, from basic understanding to higher-order thinking. The investigating empirical evidence stage, in particular, serves as a critical point where abstract concepts are connected to real-world data, thereby deepening conceptual understanding. This is followed by reasoning and concluding, which strengthens students' ability to interpret and evaluate evidence, directly supporting their performance in posttest assessments. Finally, the reflection stage reinforces learning by enabling students to internalize knowledge and transfer it to new contexts.

Overall, the integration of constructivist, social cognitive, and humanistic principles within the INSPIRE model creates a comprehensive learning framework that promotes active engagement, collaborative inquiry, and reflective thinking. The following is the syntax of the INSPIRE learning model, which comprises seven stages emphasizing a collaborative inquiry approach, as shown in Table 1.

Table 1. Stages of the INSPIRE learning model

Models	Stages	Student Activities
I	Identifying basic concepts	Reviewing the presentation of environmental change material in IT-based modules or self-study materials, which contain conceptual and procedural knowledge.
N	Nurturing Problem	Observing actual issues/phenomena related to environmental change material to identify gaps/problems contained therein. Formulating research questions related to these gaps/problems.
S	Setting Up Hypothesis	Formulating hypotheses based on existing principles, theories, and expert opinions.
P	Planning Investigation	Designing an investigation to answer the questions and/or prove the hypotheses that have been formulated.

I	Investigating Empirical Evidence	Collecting empirical data/evidence based on the investigation design that has been formulated.
R	Reasoning & Concluding	Organizing, processing data, and formulating conclusions containing answers to questions or the results of hypothesis testing.
E	Ending with Reflection	Reflecting on and evaluating the process and results of examining issues/phenomena up to the conclusions that have been made.

As shown in Table 1, the INSPIRE Learning Model consists of seven sequential stages that guide students through a structured inquiry process. The model begins with concept identification and problem exploration, followed by hypothesis formulation, investigation planning, and empirical evidence collection. Students then analyze findings, formulate conclusions, and engage in reflective activities. These stages are designed to promote active knowledge construction, inquiry skills, evidence-based reasoning, and metacognitive reflection, which are essential components of deep learning.

The implementation of the INSPIRE learning model was conducted over four consecutive weeks, with one 90-minute instructional session per week. During the first meeting, students explored fundamental concepts related to environmental change through the Identifying Basic Concepts and Nurturing Problem stages. Students analyzed authentic environmental issues and identified problems that could be investigated further. During the second meeting, students formulated hypotheses and designed investigation plans to address the identified environmental problems. The third meeting focused on collecting, analyzing, and interpreting empirical evidence obtained from various information sources and observations. During the final meeting, students organized their findings, presented evidence-based conclusions, and engaged in reflective learning activities to evaluate both the investigation process and the knowledge gained throughout the learning experience.

Classroom observations indicated that students in the experimental group actively participated in collaborative discussions, hypothesis formulation, evidence collection, data analysis, and classroom presentations. Students demonstrated higher levels of engagement during inquiry-based activities and were more willing to express opinions, ask questions, and defend their arguments using scientific evidence. In contrast, students in the control group primarily engaged in teacher-centered learning activities, including listening to lectures, taking notes, and responding to the teacher's questions. As a result, opportunities for collaborative inquiry and active knowledge construction were more evident in the experimental group than in the control group. These observations indicate that the INSPIRE Learning Model was successfully implemented and created a more active, collaborative, and inquiry-oriented learning environment compared with conventional instruction.

RQ1: Does the Implementation of the INSPIRE Learning Model Improve Students' Mastery of Environmental Change Material?

Preliminary data analysis indicated that the experimental and control groups had comparable initial abilities before the intervention, suggesting that any differences observed after treatment can be attributed to the applied learning model. Descriptive statistics and normalized gain (N-Gain) analysis were employed to evaluate students' learning improvement following the implementation of the INSPIRE Learning Model.

Table 2. Comparison of posttest scores between control and experimental groups

Group	N	Mean	Std. Deviation	Std. Error	t	df	Sig. (2-tailed)
Control	36	62.85	4.03	0.67	36.892	70	0.000
Experimental	36	93.17	2.84	0.47			

As presented in Table 2, the control group obtained a mean posttest score of 62.85 (SD = 4.03), whereas the experimental group achieved a substantially higher mean score of 93.17 (SD = 2.84). This substantial difference indicates that students taught using the INSPIRE Learning Model demonstrated higher mastery of the material on environmental change than those receiving conventional lecture-based instruction. The N-Gain analysis revealed a notable difference in learning gains between the experimental and control groups. The experimental group, which was taught using the INSPIRE learning model, achieved an average N-Gain score of 0.894, categorized as high, whereas the control group obtained a moderate gain of 0.425. The results indicate that the INSPIRE model was effective in enhancing students' conceptual understanding compared to conventional instruction. Overall, these findings suggest that the INSPIRE learning model was effective in improving students' learning outcomes. The substantial difference between the experimental and control groups demonstrates that this instructional approach facilitates deeper conceptual understanding and more meaningful learning experiences compared to conventional teaching methods.

This result is consistent with previous studies showing that student-centered and active learning approaches significantly improve learning outcomes compared to conventional lecture-based instruction (Freeman et al., 2014; Deslauriers et al., 2019; Theobald et al., 2020). In the context of biology and environmental education, inquiry-based and context-based learning models have been shown to strengthen students' scientific reasoning, engagement, and ability to solve real-world problems (Cebrián &

Junyent, 2015; Ardoin et al., 2020; Lehtonen et al., 2019). Therefore, the effectiveness of the INSPIRE Learning Model can be interpreted as evidence that integrating inquiry-based learning with deep learning principles provides meaningful pedagogical advantages in biology education.

The use of the INSPIRE Learning Model to integrate inquiry-based and deep learning yields significant improvements in learning outcomes in the experimental group. This model does not merely transmit information; it engages students in actively searching for, analyzing, and connecting ideas to real-world contexts. The principles of inquiry-based learning emphasize students as active constructors of knowledge through questioning, investigation, and discovery, which has been shown to enhance conceptual understanding and scientific reasoning (Jensen & Lawson, 2019; Hmelo-Silver et al., 2017). Therefore, students become more capable of independent thinking and develop a deeper understanding of scientific concepts.

In addition, the deep learning approach embedded in the INSPIRE Model aligns with the 21st-century learning demands that require critical thinking, conceptual understanding, and contextual awareness. Deep learning emphasizes meaningful learning by linking theoretical knowledge with real-world applications, which is essential for addressing complex issues such as climate change (Anderson, 2019; Monroe et al., 2019). Integrating active learning strategies into climate science education also improves engagement and understanding of environmental concepts (Lombardi et al., 2021). From a cognitive perspective, the improvement in students' mastery of material can be explained through higher-order thinking processes within

Bloom's taxonomy. Active learning strategies have consistently been shown to increase student performance and deepen understanding compared with passive instruction (Freeman et al., 2014; Deslauriers et al., 2019). These findings suggest that the INSPIRE Learning Model supports comprehension, application, and analysis, encouraging students to move beyond rote memorization toward meaningful conceptual learning.

Mastery of material involves students' ability to understand, apply, and transfer knowledge in new situations. Research in biology education shows that systems thinking and contextual environmental learning help students better understand ecosystem change and environmental processes (Dauer et al., 2017; Dauer et al., 2018). Contextual and environment-based learning strategies also improve environmental literacy and engagement, especially when students connect scientific knowledge with real environmental issues (Schuttler et al., 2019).

Overall, the results indicate that the INSPIRE Learning Model effectively improves students' ability to understand and respond to environmental change. By combining inquiry-based learning with deep conceptual learning, students develop stronger critical thinking, problem-solving ability, and environmental literacy.

RQ2: Is There a Significant Difference Between Students Taught Using the INSPIRE Learning Model and Those Receiving Conventional Instruction?

To provide a visual comparison of students' learning gains in both groups, a scatter plot of pretest and posttest scores was constructed in Figure 2.

Before hypothesis testing, Levene's test confirmed the homogeneity of variances ($F = 0.303, p = 0.584$), indicating that the assumption of equal variances was met. The results of the independent-samples t-test revealed a statistically

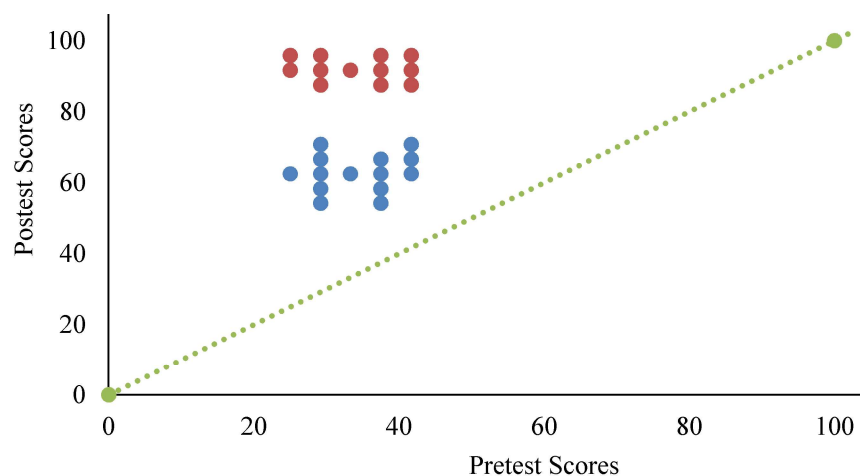


Figure 2. Scatter plot of pretest and posttest scores by student

significant difference between the experimental and control groups, $t(70) = -36.892, p < 0.001$, with a 95% confidence interval ranging from -31.96 to -28.68. These findings indicate that students taught using the INSPIRE Learning Model achieved significantly higher learning

outcomes than those who received conventional lecture-based instruction.

Furthermore, the effect size analysis using Cohen's d demonstrated extremely large effects in both posttest and N-Gain comparisons. The Cohen's d values of 8.71 (based on posttest

scores) and 7.81 (based on N-Gain scores) indicate a very big difference between the two groups. According to Cohen's interpretation criteria, values above 0.8 are considered large; therefore, the obtained results suggest that the impact of the INSPIRE model is not only statistically significant but also practically substantial.

The significant differences observed between the experimental and control groups may be attributed to the instructional characteristics of the INSPIRE Learning Model. Through the stages of Identifying Basic Concepts, Nurturing Problems, Setting Up Hypotheses, Planning Investigations, Investigating Empirical Evidence, Reasoning and Concluding, and Ending with Reflection, students were actively involved in constructing knowledge rather than passively receiving information. These learning experiences encouraged inquiry, collaboration, evidence-based reasoning, and reflective thinking, which contributed to deeper conceptual understanding of environmental change topics. In contrast, students in the control group primarily engaged in teacher-centered learning activities, resulting in fewer opportunities for active knowledge construction and scientific investigation. These findings support previous studies suggesting that student-centered and inquiry-based learning approaches enhance engagement, self-efficacy, critical thinking, and academic achievement (Ballen et al., 2017; Theobald et al., 2020).

■ CONCLUSION

Research consistently shows that the INSPIRE Learning Model has a highly significant positive impact on students' mastery of the material compared to conventional learning methods. The substantial improvement in the experimental group indicates that the INSPIRE Learning Model, through its integration with inquiry-based learning and deep learning approaches, has succeeded in: (1) The implementation of the INSPIRE

Learning Model leads to higher student mastery of environmental change material compared to conventional learning methods. This is evidenced by the higher posttest mean score of the experimental group, indicating that the INSPIRE model effectively improves students' overall mastery of the subject matter. (2) There is a statistically significant difference in learning outcomes between students taught using the INSPIRE Learning Model and those taught using conventional approaches. The independent-samples t-test results confirm that this difference is significant ($p < 0.001$), demonstrating the effectiveness of the INSPIRE model relative to traditional instruction.

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■ DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS

During the writing of this manuscript, the author (n) utilized generative AI tools to assist with language refinement, grammar checking, and clarity improvement. All content generated by the AI tools was critically reviewed, revised, and validated by the author (n). The author takes full responsibility for the integrity, originality, and accuracy of the content presented in this article

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