

## Enhancing Science Process Skills and Learning Outcomes: The Impact of ChatGPT-Assisted Inquiry Learning on Environmental Change Education

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**Abstract:** This study examined the effect of Artificial Intelligence (AI)-assisted inquiry learning on students' science process skills and cognitive learning outcomes in environmental change material for grade X students at SMAN 1 Singaparna. The research used a quasi-experimental method with a matching-only posttest control group design. The population consisted of 12 grade X classes, and the sample was selected using purposive sampling. Research instruments included a science process skills test with 12 essay questions and a cognitive learning outcomes test with 30 validated multiple-choice questions. Data were analyzed using an independent sample t-test with SPSS. The results showed a significance value of 0.000 for both science process skills and learning outcomes, indicating that AI-assisted inquiry learning has a significant effect on students' abilities. These findings demonstrate that ChatGPT-assisted inquiry learning positively influences science process skills and cognitive learning outcomes, making it a promising strategy for teaching environmental change topics.

**Keywords:** ChatGPT; Environmental Change Education; Inquiry Learning; Learning Outcomes; Science Process Skills.

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## **Introduction**

The education system in Indonesia has undergone various changes and curriculum improvements, resulting in the current new curriculum known as the independent curriculum. One of the skills emphasized in the independent curriculum is the development of science process skills (Hamdi et al., 2022). Science process skills include the ability to observe, formulate questions, design experiments, collect data, analyze results, and draw conclusions. Thus, science process skills involve students actively in the learning process, building problem-solving skills, developing scientific habits, and being able to design experiments and apply scientific knowledge (Aisah & Agustini, 2024).

Science process skills are very important in the independent curriculum because they actively involve students in the learning process and help students understand scientific concepts more deeply. If students already understand the concepts taught by teachers, it will affect their learning outcomes (Sari & Shofiyah, 2023). However, Indonesian students' science process skills are still relatively low on the international stage. This is evidenced by Indonesia's participation in the Trends in Mathematics and Science Study (TIMSS), a special study on trends in mathematics and science learning in 2015, which placed Indonesia 45th out of 48 countries with a score of 297 in science (Hamidah, 2023). Meanwhile, in the 2022 Program for International Student Assessment (PISA), Indonesia ranked 69th out of 80 countries with a score of 383 on the science test. Indonesia's scores in both surveys are still far from the overall average, indicating that Indonesian students' science process skills remain low. Similar issues are also found at smaller levels, such as in one school in Tasikmalaya Regency.

Based on the results of interviews with biology teachers of grade X at SMAN 1 Singaparna on September 2, 2024, several problems were found among students, including that many students were still unable to present data and draw conclusions. A preliminary test of science process skills, specifically on the topic of environmental change, was conducted using an essay test, yielding an average score of 48. Based on the categorization of science process skills according to Nismalasari et al (2016) a score range of 41-60 falls into the "adequate but needs improvement" category. The results of observations conducted by Shofiana & Melisa (2022) show that students have not achieved maximum results when formulating hypotheses, collecting and analyzing data. Marwan et al., (2025) states that the low level of these skills is often caused by the lack of practical activities that facilitate experience-based learning, accompanied by teachers' limited understanding of the urgency of science process skills.

The low level of scientific process skills among students indicates the need for improvements in the quality of education. This aspect is closely related to the quality and success of the learning process involving teachers and students in the school environment (Uki & Liunokas, 2021). The success of education can be seen from student learning

outcomes. However, in reality, students' cognitive learning achievements in biology, especially in the subject of environmental change, are still lacking (Safitri et al., 2023). In addition, observations at SMAN 1 Singaparna on cognitive learning outcomes in the subject of environmental change showed an average score of 55, indicating that students' learning outcomes in the subject of environmental change still need improvement. The lack of science process skills and student learning outcomes based on preliminary studies at SMAN 1 Singaparna necessitates a learning model that can support students to become more accustomed to and demonstrate aspects of science process skills. One alternative learning model that can improve science process skills and learning outcomes is the inquiry learning model. This is in line with Fitriani et al (2023) , which states that the inquiry learning model needs to be applied because the learning process does not only emphasize knowledge aspects but also the development of students' process skills.

Based on the results of an interview conducted with a biology teacher at SMAN 1 Singaparna on October 2, 2024, it was stated that teachers had already implemented the inquiry learning model in biology lessons. However, in reality, during the learning process, the implementation of this learning model was not optimal, especially in terms of formulating hypotheses, testing hypotheses, and drawing conclusions. Many students still make mistakes in formulating hypotheses and interpreting research results. In line with Prasetyo & Rosy (2020) the implementation of the inquiry learning model requires a relatively long duration, so teachers often find it difficult to adjust to the predetermined schedule. To overcome time constraints when implementing inquiry learning, one solution is to utilize Artificial Intelligence technology

Interest in the use of Artificial Intelligence to facilitate personalized learning in educational settings has increased significantly in recent years (Ayala-Pazmiño, 2023). Artificial Intelligence can also help teachers and students obtain information about data quickly and accurately (Mambu et al., 2023). The role of Artificial Intelligence can be applied to inquiry learning syntax, thereby overcoming time constraints. One of the increasingly popular applications of Artificial Intelligence is the use of ChatGPT (Diantama, 2023). Research conducted by Suharmawan (2023) states that the use of ChatGPT in education has the potential to simplify several aspects, such as data search, information summarization, and reference discovery. ChatGPT excels in natural language processing, making it easy to understand. Meanwhile, other Artificial Intelligence systems have limitations in understanding context or generating natural text. ChatGPT is also more accessible to students.

Previous research conducted by Mardianti et al., (2020) discusses inquiry learning models in general and analyzes several articles that are considered to meet the criteria related to inquiry. It does not focus on any particular subject matter or use artificial intelligence technology, and analyzes the effect of inquiry learning on science literacy and its equivalence in analyzing the same thing, namely science process skills. The research conducted by Indri (2023) discusses the Discovery Learning model with the help of

Artificial Intelligence on communication skills and cognitive learning outcomes. In this study, the researchers used a learning model accompanied by Artificial Intelligence and analyzed the same thing, namely cognitive learning outcomes. However, the learning model did not use inquiry learning and did not measure science process skills. Therefore, the research to be conducted differs in terms of the learning model, the measurement of science process skills, and the material used, namely environmental change.

Considering the problems and potential that exist, research is needed to determine the effect of ChatGPT-assisted inquiry learning on students' science process skills and cognitive learning outcomes in environmental change education.

## Methods

This research is quantitative in nature, using a quasi-experimental research method. The independent variable in this study is inquiry learning assisted by artificial intelligence. The dependent variables in this study are science process skills and cognitive learning outcomes. The research design uses a matching-only posttest control group design. An overview of the design can be seen in Table 1.

**Table 1.**

Research Design The Matching Only Posttest Control Group Design

<i>Treatment group</i>	M	X	O
<i>control group</i>	M	C	O

(Source: Fraenkel et al., 2012)

Explanation:

- M : Research Subject
- X : Treatment, namely the application of the *Inquiry Learning* model assisted by *Artificial Intelligence*.
- C : Control is the application of the *Inquiry Learning* model without the assistance of *Artificial Intelligence*.
- O : Final test (*posttest*)

The design above is almost the same as the pretest-posttest control group design, except that in this design, neither the experimental group nor the control group is selected randomly (Sugiyono, 2018). The research was conducted in April–May 2025 at SMA Negeri 1 Singaparna. The population in this study consisted of all 12 classes of 10th grade students at SMA Negeri 1 Singaparna. The research sample was taken using purposive sampling, which was based on the joint consideration of biology teachers, taking into account the enthusiasm and activity during the learning process, as well as their similar daily test scores. Thus, the experimental class (X-6) consisting of 38 students was selected to receive treatment using inquiry learning assisted by ChatGPT, and the control class (X-5) consisting of 38 students was selected to receive treatment using

inquiry learning without the assistance of ChatGPT. The data collection technique used a test in the form of essay questions and multiple-choice questions. The test to measure science process skills consisted of essay questions with six indicators, namely observing, classifying, formulating hypotheses, designing experiments, interpreting, and communicating. The learning outcome research instrument was a cognitive learning outcome test in the form of multiple-choice questions referring to Bloom's Taxonomy, which was limited to the levels of remembering (C1), understanding (C2), applying (C3), analyzing (C4), and evaluating (C5) as well as the dimensions of knowledge consisting of factual (K1), conceptual (K2), and procedural (K3). Both tests used material on environmental change with a maximum score of 3 for essay questions and 1 for multiple-choice questions.

The research instruments have undergone validity and reliability tests. The validity and reliability tests were conducted on 11th grade students, because 11th grade students have already learned about environmental change. The validity test results for the science process skills instrument from 18 questions showed that 12 questions were in the significant and very significant categories. For the learning outcome instrument, out of 50 questions, 30 questions were categorized as significant and very significant. Then, the reliability test results for the science process skills instrument reached a score of 0.85 and for cognitive learning outcomes reached a score of 0.88. These scores indicate that both instruments have very high reliability. Furthermore, the research results data were analyzed through a normality test using the Kolmogorov Smirnov test with a significance criterion above 0.05 and a homogeneity test using the Levene test with a significance criterion above 0.05. Then, the hypothesis test for the research data on science process skills and learning outcomes was analyzed using the Independent Sample T-Test with the criteria that if the significance value was  $> 0.05$ ,  $H_0$  was accepted, but if the significance value was  $< 0.05$ ,  $H_0$  was rejected.

## **Results & Discussion**

### **A. The Effect of ChatGPT-Assisted Inquiry Learning on Science Process Skills**

The results of the posttest on science process skills in the experimental and control classes were then analyzed using prerequisite tests, including normality and homogeneity of variance tests. These tests were conducted to ensure that the data were normally distributed and homogeneous, so that they could be used to proceed to the hypothesis testing stage using the t-test. The normality test used was the Kolmogorov-Smirnov test with the help of IBM SPSS software version 25 for Windows. After the normality test was conducted, the significance value of the posttest data for science process skills in the experimental class was 0.155 and in the control class was 0.200\*. The results of the normality test are presented in Table 2.

**Table 2.**

Results of the Normality Test for the Posttest of Science Process Skills

Data			Kolmogorov-Smirnov Statistic	df	Sig.
Science	Process	<i>Experimental Class Posttest</i>	0,123	38	0,155
Skills		<i>Control Class Posttest</i>	0,093	38	0,200*

The data was normally distributed, and the homogeneity test was then performed using the Levene test with the help of IBM SPSS software version 25 for Windows. Based on the analysis results, the significance value of the posttest for science process skills was 0.568. This means that the variance of the data between groups is homogeneous. Thus, the research data has met the assumption of homogeneity so that hypothesis analysis can be continued using parametric statistical tests. The results of the homogeneity test are presented in Table 3.

**Table 3.**

Results of the Pottest Homogeneity Test for Science Process Skill

Data	Levene Statistic	df1	df2	Sig	
KPS	<i>Posttest</i>	0,329	1	74	0,568

The prerequisite test results show that the data comes from a normally distributed and homogeneous population. Thus, the data meets the requirements for further analysis using the t-test (Independent Sample T-Test). This testing process was carried out using IBM SPSS software version 25 for Windows. Based on the analysis results, the significance value of the posttest for science process skills was 0.000, which means that the significance value was  $< 0.05$ . This figure indicates that there was a significant difference between the experimental class and the control class. The results of the independent sample t-test for science process skills are presented in Table 4.

**Table 4.**

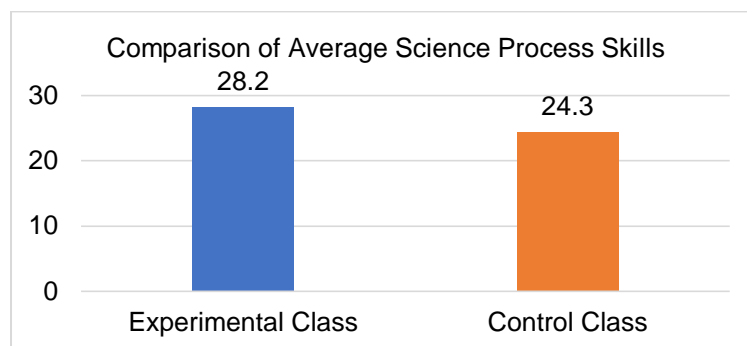
Results of the Independent Sample T-Test Posttest for Science Process Skills

Data	t	df	Sig (2-tailed)
Science Process Skills	3.705	74	0,000

To determine the effect of ChatGPT-assisted inquiry learning on students' science process skills, the researcher used a test instrument consisting of 12 valid essay questions. The essay questions about science process skills were given to students after the final learning process on the topic of environmental change. The researcher measured 6 indicators of science process skills by Jufri (2017) is observing, classifying, formulating hypotheses, designing experiments, interpreting, and communicating. The posttest data are presented in Figure 1.

**Figure 1.**

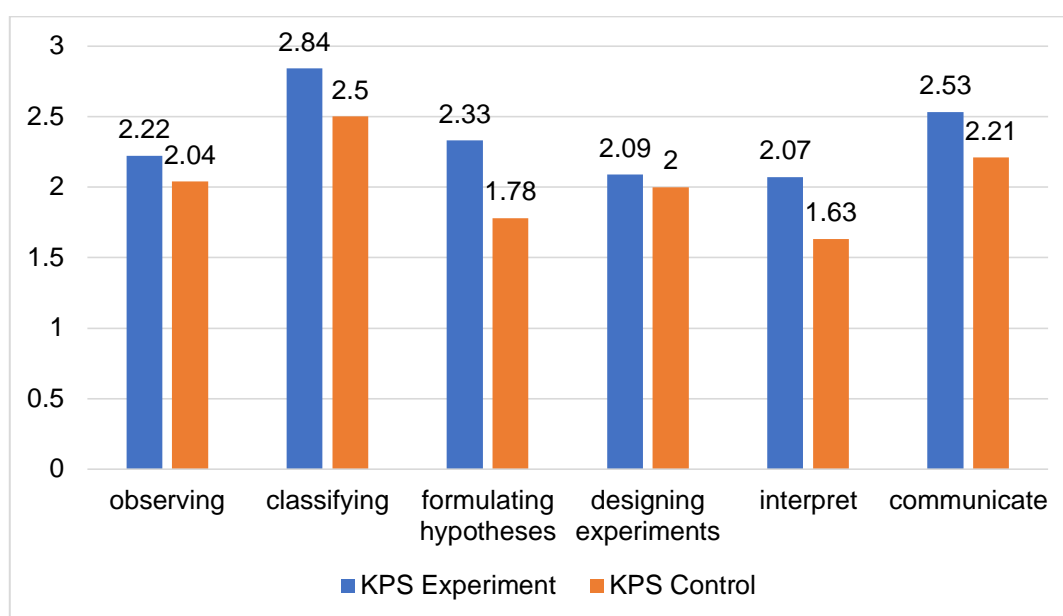
Comparison of Posttest Averages for Science Process Skills



Then, a hypothesis test was conducted on the posttest scores of science process skills of students in the experimental class and control class. The results of the analysis in Table 3 show that the significance value of the science process skills posttest is  $< 0.000$ , which means that the significance value is  $< 0.05$ . This figure shows that there is a significant difference between the science process skills of the experimental class and the control class. Sururina & Kowi (2024) stated that ChatGPT-assisted learning can increase the effectiveness of innovative learning models by accelerating the process of discovery and reflection of students on the concepts being studied. Inquiry learning provides a framework for students to develop science process skills, while ChatGPT support is able to strengthen this process through providing suggestions, clarifying information, and instant feedback. For more details, the average posttest data for each science process skill indicator is presented in Figure 2.

**Figure 2.**

Comparison of Average Posttest Scores for Science Process Skills per Indikator



Based on Figure 2, overall, each indicator of science process skills in the experimental class was higher than in the control class. Thus, the ChatGPT-assisted inquiry learning model can influence students' science process skills. The detailed discussion is as follows.

The indicator of observing environmental change learning material includes students observing cases of environmental change phenomena. This indicator obtained an almost balanced average in both classes. The higher score in the experimental class can be explained by the syntax of ChatGPT-assisted inquiry learning through the problem orientation stage. Students were directed to open ChatGPT to identify variables that could be observed from the phenomena presented earlier. Through the explanations and images presented by ChatGPT, students became more thorough and focused in observing the phenomena. The difference was not too significant because both the experimental and control classes were directed to pay attention to environmental change phenomena by reading and observing images or videos presented by the teacher. Then, in the data collection stage, both classes conducted practical work. Therefore, the ability to observe did not depend too much on technological intervention, but rather on the students' focus and accuracy in observing objects or events (Jannah et al., 2025). However, the experimental class still showed higher scores than the control class. This is because the role of AI in the form of ChatGPT provides additional stimuli to explore concepts through images or videos that can clarify the objects of observation (Maharani et al., 2025).

Classification indicators are developed during the data collection stage. In learning about environmental change, these skills include grouping the factors that cause natural and human-induced environmental change, classifying types of environmental pollution, and grouping the impacts of pollution on humans, animals, plants, and the environment. ChatGPT helps by providing examples of grouping and explaining the differences between categories in the phenomenon of environmental change. In line with Luan et al., (2025)

ChatGPT provides examples and feedback that help students group concepts and learning materials systematically.

The next indicator formulates hypotheses, including formulating assumptions about cause-and-effect relationships, for example: If water is polluted by detergent waste, then the aquatic ecosystem will be disrupted. This indicator shows the most significant improvement. This difference can be explained in the syntax of ChatGPT-assisted inquiry learning through the hypothesis formulation stage, where students are provided with assistance from ChatGPT in the form of instructions for determining variables and formulating hypotheses. Students are also directed to ask ChatGPT whether the hypotheses they have formulated with their group are appropriate for the issues being studied. In line with Josephine Oranga (2020) ChatGPT is able to provide immediate responses to questions, making it easier for students to recognize their mistakes and make immediate corrections . Unlike the control class that was not assisted by ChatGPT, the hypothesis formulation process still depended on teacher guidance and group discussions without the support of direct reflective thinking triggers. As a result, students tended to have difficulty determining the relationship between variables and formulating appropriate hypotheses.

Experiment design indicators are developed at the stage of formulating hypotheses and collecting data. In learning about environmental change, experiment design skills include determining independent, dependent, and control variables in practical work. Students are directed to use ChatGPT to ask questions about experiment designs they do not understand. However, the average score is almost balanced because the experiment designs are provided by the teacher, limiting the students' creativity. In line with (Rahayu et al., 2025) , the dominant role of teachers in developing experimental designs limits the space for students to develop their own experimental designs, resulting in less significant improvement in their experimental design skills. The higher scores of the experimental class are due to students utilizing ChatGPT to obtain guidance and improve the accuracy of variables, as well as to facilitate their understanding of the concept of experimental design.

Next, the interpretation indicator was developed at the hypothesis testing stage. In learning about environmental change, this skill includes interpreting the results of environmental change practical observations. Students were instructed to use ChatGPT to help find patterns or relationships from the observation results. After finding patterns or relationships, ChatGPT also validated the relationships made by students and corrected them to better match the observation results. This question and answer process shows that students learn to interpret patterns of change and establish cause-and-effect relationships based on data. In contrast to control classes that did not use ChatGPT, data interpretation activities were more limited to conventional discussions that relied on teacher guidance. This made students less optimal in interpreting observation results or scientific information independently. Research by (Anam et al., 2025) suggests that AI

technology can deepen analysis and conceptual understanding through personalized data simulation and evaluation.

The final indicator is communication, which is developed in the syntax of collecting data and drawing conclusions. In learning about environmental change, this skill includes presenting observation results in the form of tables, graphs, and practical reports. At the data collection stage, students are asked to convert research data into diagrams. Students are directed to use ChatGPT to understand the type of data obtained and determine the appropriate graph format. Then, at the conclusion stage, students are asked to make conclusions based on the research results. Students are directed to use ChatGPT to correct the conclusions they have made so that they become more scientific and in accordance with the observation data. Meanwhile, in the control class that did not use ChatGPT assistance, the process of converting data into graphs or diagrams tended to be mechanical and did not involve a deep understanding of the meaning of the graphs. Students often struggle to choose the appropriate type of graph and interpret the relationships between variables accurately because they only follow instructions without the support of tools that can enhance their understanding of data analysis (Maulidina et al., 2024).

### B. The Effect of ChatGPT-Assisted Inquiry Learning on Learning Outcomes

The posttest results of learning outcomes in the experimental class and control class were then analyzed through prerequisite tests, which included normality and homogeneity tests. These tests aimed to ensure that the data were normally distributed and homogeneous, so that the data met the requirements to proceed to the hypothesis testing stage using the t-test. The normality test used was the Kolmogorov-Smirnov test with the help of IBM SPSS software version 25 for Windows. After the normality test was conducted, the significance value of the posttest data for learning ability was obtained at 0.130 for the experimental class and 0.181 for the control class. The overall data showed a normal distribution because the significance value was greater than 0.05. The results of the normality test are presented in Table 5.

**Table 5.**  
Results of the Normality Test of Learning Outcomes

	Data	Kolmogorov-Smirnov Statistic	df	Sig
Learning Outcomes	Experimental Class <i>Posttest</i>	0.126	38	0.130
	Control Class <i>Posttest</i>	0.120	38	0.181

The data was normally distributed, and the homogeneity test was conducted using the Levene test with the help of IBM SPSS software version 25 for Windows. Based on the analysis results, the significance value of the posttest learning outcomes was 0.629. This indicates that the data is homogeneous because both posttest significance values are greater than 0.05. The results of the homogeneity test are presented in Table 6.

**Table 6.**  
Results of the Homogeneity Test of Learning Outcomes

	Data	Levene Statistic	df1	df2	Sig
Learning Outcomes	Posttest	0.236	1	74	0.629

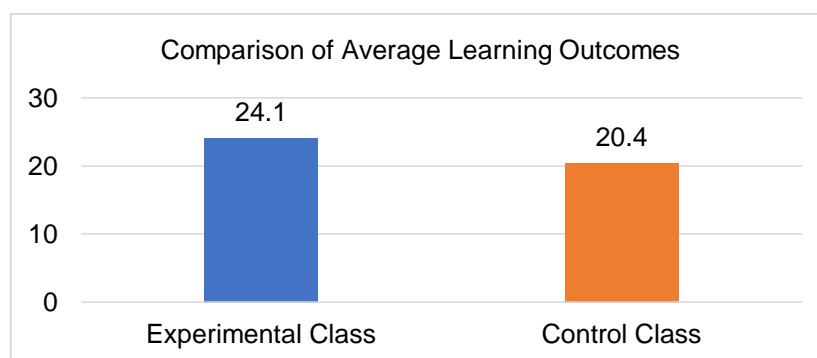
The prerequisite test results show that the data are normally distributed and homogeneous, meeting the requirements for analysis using an independent sample t-test. The analysis was conducted using IBM SPSS version 25 for Windows. The posttest significance value was 0.000 ( $< 0.05$ ), indicating a significant difference between the experimental and control classes. The results of the independent sample t-test are presented in Table 7.

**Table 7.**  
Results of the Independent Sample T-Test for Learning Outcomes

Data	t	df	Sig (2-tailed)
Learning Outcomes	3.730	74	0,000

Furthermore, to determine the effect of ChatGPT-assisted inquiry learning on student learning outcomes, the researcher measured cognitive learning outcomes using a test instrument in the form of 30 multiple-choice questions that had been validated. The researcher measured students' cognitive learning outcomes according to the cognitive aspects of Anderson & Krathwohl, (2001) is remembering (C1), understanding (C2), applying (C3), analyzing (C4), and evaluating (C5). The posttest data are presented in Figure 3.

**Figure 3.**  
Comparison of Average Learning Outcomes

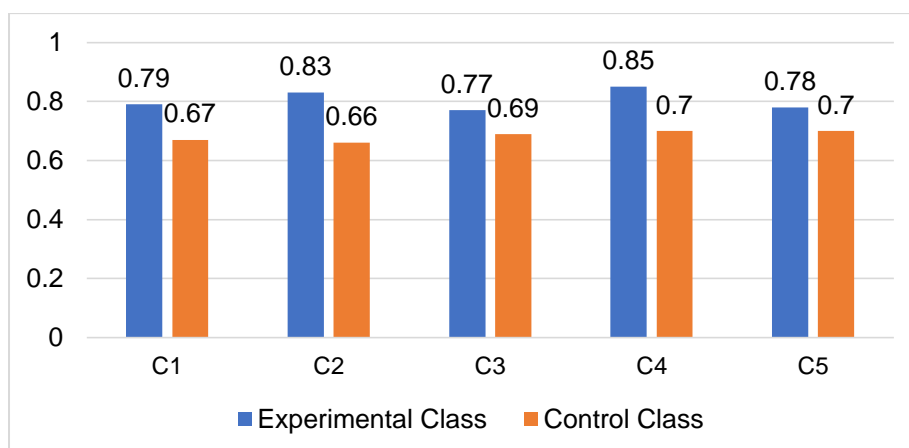


Based on Figure 3, the average cognitive learning score was 24.1 in the experimental class and 20.4 in the control class. Hypothesis testing on the posttest scores showed a significance value of  $< 0.000$  ( $< 0.05$ ), indicating a significant difference between the two classes. This finding aligns with Xie (2023), who reported that AI-based inquiry learning can significantly improve student learning outcomes. Similarly, Almasri (2024) stated that

the use of artificial intelligence in science education consistently has a positive impact on student learning outcomes. The average posttest scores for each cognitive aspect are presented in Figure 4.

**Figure 4.**

Comparison of Average Posttest Learning Outcomes by Cognitive Dimension



Based on Figure 4, overall, each cognitive dimension of the experimental class was higher than that of the control class. Thus, the ChatGPT-assisted inquiry learning model can influence student learning outcomes. For a more detailed discussion on the aspect of remembering (C1), it was trained at the problem orientation and problem formulation stages, because students were directed to relate their prior knowledge to the problems presented. In the context of environmental change material, this includes remembering the definition of environmental change, mentioning the factors causing environmental change, mentioning the types of environmental pollution, and formulating problems. ChatGPT's role helps strengthen students' memory by providing explanations, summaries, and lists of important points that facilitate concept recall. findings are in line with the results of (Baidoo-Anu & Ansah, 2023) that students who use the ChatGPT feature for summarizing material, lists of important points, and explanations to reinforce concept recall have higher memory test scores. Conversely, in the control class that used inquiry learning without the help of ChatGPT, the recall process tended to be monotonous and lacked variety in stimuli.

The aspect of understanding (C2) is developed during the problem orientation stage, hypothesis formulation, and data collection. At this stage, students explain the cause-and-effect relationship of environmental change phenomena, put forward initial assumptions based on available facts or data, and understand the results of practical observations. In the context of environmental change material, this includes explaining the relationship between human activities and environmental change, interpreting examples of pollution in the surrounding environment, and classifying the impacts of environmental pollution based on type. ChatGPT assists this process by providing feedback in the form of concept

clarification, additional examples, and explanations delivered in easy-to-understand language.

The application aspect (C3) is developed during the data collection stage. In the context of environmental change material, this skill is evident when students apply the concept of environmental pollution in practical activities, utilize experimental data to support hypotheses, and provide examples of simple actions to overcome the impacts of environmental change. ChatGPT helps students understand experimental procedures, provides examples of concept application, and offers additional explanations regarding the data collection stage.

The analyzing aspect (C4) is developed during the data collection and hypothesis testing stages, encouraging students to analyze information in depth. In the context of environmental change, this involves students identifying causal factors, comparing experimental data, and linking environmental impacts to appropriate solutions. 's Role ChatGPT provides stimulus in the form of additional explanations, alternative perspectives, and concrete examples that strengthen their arguments.

The final aspect, evaluation (C5), is developed during the hypothesis testing and conclusion drawing stage. Here, students assess the validity of hypotheses, evaluate experimental results, and present supporting arguments. In the context of environmental change material, this skill is evident when students assess the effectiveness of various efforts to address environmental issues. ChatGPT provides alternative arguments and clarifications if students have difficulty interpreting the results of the experiment. Bhatt & Muduli, (2022) also emphasize that AI technology can support learning evaluation. Thus, students are more focused in their assessments and avoid misconceptions.

### **Conclusion & Recommendation**

The author concludes that the ChatGPT-assisted Inquiry Learning model has an effect on students' science process skills and cognitive learning outcomes in class X of SMA Negeri 1 Singaparna in the 2024/2025 academic year. Therefore, this learning model can be used as a learning strategy by teachers to improve students' science process skills and learning outcomes. In addition, teachers are advised to apply this learning model to other learning materials. This is because this study only focused on the topic of environmental change. Teachers can also explain the stages of inquiry learning and how to use ChatGPT in advance so that students can carry out the learning process smoothly and wisely in using ChatGPT so that the learning process is carried out effectively. This study has several limitations that need to be considered. The type of AI studied is limited to ChatGPT, so the findings cannot be generalized to all AI. The scope of the material studied is limited to the topic of environmental change in grade X, so the findings cannot be generalized to other materials. In addition, the research in schools was conducted in a relatively short period of time, so it was not possible to observe the long-term effects of

using the Artificial Intelligence-assisted inquiry learning model on science process skills and cognitive learning outcomes in a sustainable manner.

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