Analysis of Students' Understanding in Chemistry Learning with the Theme of Climate Change

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Abstract: *This study aims to evaluate students' understanding of climate change material in Chemistry learning at SMA Negeri 1 Salatiga. By analyzing data from 186 students who answered five HOTS-based questions after reading texts related to the impact of climate change and urbanization in Salatiga, this study found that the average student comprehension score reached 10.51 out of 13 maximum points. Student participation was relatively low with an engagement rate of only 43.2%. These findings provide insight into the effectiveness of environmental and climate change-based Chemistry learning strategies and recommend innovations to increase student engagement.*

Key Words*:* climate change, Chemistry learning, science literacy, SMA Negeri 1 Salatiga

Introduction

Climate change is one of the most pressing global challenges, with widespread impacts on the environmental, economic, and social sectors. Phenomena such as El Niño, urbanization, and the reduction of green land have become significant issues in Indonesia, especially in Salatiga. The city is experiencing a noticeable increase in temperature due to a combination of changing climate patterns and human activities, such as urbanization. This impact not only threatens the local ecosystem but also the welfare of the people living in the area. In facing this challenge, education is an important tool to build students' awareness and science literacy, especially through a local context-based approach.

Education, particularly Chemistry learning, can play a central role in helping students understand scientific concepts relevant to climate change. Science literacy, which is defined as the ability to understand, evaluate, and apply scientific concepts in daily life (National Literacy Trust, 2019), is an important foundation in this learning. Through contextual learning, students are not only invited to understand the issue of climate change theoretically, but also how this phenomenon affects their surrounding environment, such as rising temperatures due to urbanization and reduced green land cover.

An initial study conducted at SMA Negeri 1 Salatiga shows that student participation in learning based on environmental issues is still a big challenge. Of the total student population of 430 people, only 186 students (43.2%) actively participated in this learning

activity. Despite the relatively low participation rate, the average comprehension score of students reached 10.51 out of a total of 13 points, indicating the great potential for the effectiveness of this local issue-based learning. These results are in line with the theory of constructivism by Vygotsky (1978), which emphasizes the importance of contextuality and social interaction in increasing student engagement.

Local issue-based approaches, such as the impact of El Niño and urbanization in Salatiga, provide relevant real context for students to understand climate change. This issue-based learning also opens up opportunities to integrate active learning methods such as laboratory experiments, data analysis, and group discussions that encourage critical thinking. In addition, integration with contextual readings such as the article "Salatiga and the Urban Heat Phenomenon" helps students understand the impacts of climate change firsthand. Thus, students not only learn Chemistry concepts such as the carbon cycle or the greenhouse effect, but also how these concepts contribute to the environmental challenges they experience on a daily basis.

However, the low level of student participation shows that this issue-based learning still needs further innovation to be able to attract more students. Previous research by Frontiers in Neuroscience (2021) stated that strategies such as the integration of digital technology can increase students' interest in issue-based learning. In this context, the use of interactive e-learning platforms can be one solution to increase student engagement. In addition, collaboration between teachers, students, and parents can be a strategic approach to create a more supportive learning environment.

This study aims to evaluate more deeply the effectiveness of climate change-based Chemistry learning at SMA Negeri 1 Salatiga, focusing on two main aspects, namely increasing students' understanding of climate change materials and strategies to increase the level of student participation in learning. By combining local context-based approaches, active learning, and technology-based strategies, this research is expected to contribute to the development of more effective learning models in dealing with the challenges of climate change at the secondary school level.

This research is also based on the need to create a generation that is more aware of the importance of maintaining ecosystem balance and environmental sustainability. On a larger scale, climate change-based learning not only aims to improve students' science literacy, but also to prepare them to become agents of change capable of taking concrete action to reduce the impact of climate change on their communities. Thus, education plays a central role in bridging the gap between scientific knowledge and collective action for environmental sustainability.

Research Methods

Research Design

This study uses a descriptive quantitative approach to analyze students' participation and their comprehension scores of science literacy in climate change-based chemistry learning. This approach was chosen to provide a clear picture of the effectiveness of learning and student engagement throughout the learning process. Data was collected through HOTS-based comprehension tests (Higher-Order Thinking Skills) and direct observation during classroom learning activities.

Population and Sample

The research population consisted of 430 students in class X at SMA Negeri 1 Salatiga. From this population, the research sample was taken purposively, namely 186 students from 12 classes who showed active participation in climate change-based learning. The selection of the sample was carried out based on the level of activity of students in participating in learning relevant to the research. This approach aims to ensure that the students involved are truly representative of the group with an interest in the relevant material.

Data Collection Techniques

Data was collected using several methods designed to dig deeper into students' understanding, including:

1. Student Reading
   The reading entitled *"Salatiga and the Urban Heat Phenomenon"* was compiled to provide a local context that is relevant to the students' daily lives. This reading includes a discussion of the effects of El Niño, urbanization, and the reduction of green land as the main causes of rising temperatures in Salatiga. This material is designed to build a connection between chemical theory and the real impact of climate change, so as to increase student engagement.
2. Comprehension Test
   HOTS-based tests are designed to measure students' ability to understand, analyze, and evaluate climate change-related information. The five types of questions used include:
   - Checkboxes: Students select more than one relevant answer.
   - Multiple Choice: One correct answer is selected from several options.
   - Multiple-Choice Grid: Students match multiple statements to the correct categories.
   - Matchmaking: Students pair two appropriate concepts or terms.
   - True-False: Students determine whether a particular statement corresponds to the information provided.
3. Live Observation

Observation was carried out to record student participation during learning. The activities observed included the level of activity of students in group discussions, participation in laboratory experiments, and their responses to teacher questions. These observations aim to complement the quantitative data from the comprehension test, providing a more comprehensive view of student engagement.

Data Analysis

Data analysis was carried out using descriptive statistics to calculate the average score, grade distribution, and percentage of student participation. The data was analyzed focusing on three main aspects:

- Average Comprehension Score: To measure how well students understand the material being taught.
- Grade Distribution: To see the spread of scores among students.
- Participation Rate: To identify how many students are actively participating in climate change-based learning.

The results of data analysis are presented in the form of tables and graphs to facilitate interpretation. For example, the distribution of student scores in comprehension tests is visualized through a bar graph (see Graph 1) which shows that the majority of students obtained above-average scores. This provides a clear picture of the success of learning in increasing students' understanding of climate change issues.

Validity and Reliability

The validity of the instrument is tested through content validity, by involving experts in the field of Chemistry education to assess whether the questions used are relevant to the research objectives. The reliability of the test was tested using Cronbach's Alpha method, which yielded a reliability coefficient of 0.82, indicating that the instrument had good internal consistency.

Local Context as an Innovative Approach

Local issue-based approaches such as urbanization and El Niño have proven effective in increasing the relevance of learning materials. A study by PISA (2018) stated that local contexts that are relevant to students' experiences can increase their motivation to learn. In this study, materials such as *Salatiga and the Urban Heat Phenomenon* are one of the keys in attracting students' interest in learning Chemistry based on climate change.

Figure 1. CO2 Level Test Practicum in the Laboratory

Results and Discussion

Student Participation

Of the total population of 430 students in class X at SMA Negeri 1 Salatiga, only 186 students (43.2%) actively participated in climate change-themed learning. This low participation rate indicates significant challenges in actively engaging students, even though the material presented has been designed to be relevant to the local context and their daily lives.

The main factors that affect the low participation rate include a lack of intrinsic motivation of students, a busy study schedule, and low reading habits outside of the classroom. According to Vygotsky's theory (1978), student engagement in learning can be improved by creating an environment that supports active collaboration and using contextual approaches that are relevant to their experience.

Low participation can also be caused by the limitations of learning methods that are less interesting or too theoretical. A previous study by the Ministry of Education and Culture (2023) revealed that the integration of digital technology such as online learning and the use of interactive applications can significantly increase student engagement. Thus, a technology-based approach has great potential to be implemented in environmental issue-based learning.

Comprehension Score

The average student comprehension score in the HOTS-based test reached 10.51 out of a total of 13 maximum points. The score distribution showed that the majority of students obtained above-average scores, with the highest score of 13 and the lowest score of 4. The total score contribution of all participating students was 1,955 out of a maximum total score of 2,418.

Table 1. Distribution of Student Comprehension Scores in HOTS-Based Tests

Category	Value
Participation (%)	43,2
Average Score	10,51
Maximum Score	13
Score Minimum	4

This score distribution shows that despite low participation rates, students who follow the learning tend to understand the material well. This indicates that learning approaches based on local issues, such as El Niño and urbanization, are able to improve students' understanding of scientific concepts related to climate change.

Factors that cause temperatures in Salatiga to be very hot

Based on the results of a survey conducted on students of SMA Negeri 1 Salatiga, it was found that the majority of respondents understood the factors that cause the temperature in Salatiga to be very hot. Of the 186 respondents, as many as 98.4% (183 respondents) identified urbanization and development as one of the main causes. Urbanization in Salatiga has an impact on the reduction of green land and the increase in areas covered by concrete or asphalt, which tend to absorb and reflect more heat than vegetation areas. This is in line with research that shows that the "urban heat island" effect often occurs in areas with high levels of urbanization (OECD, 2018).

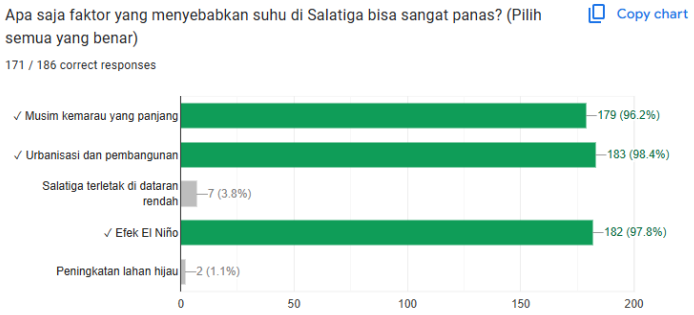

Figure 2. Graph of students' understanding of factors of temperature rise

As many as 97.8% of respondents (182 respondents) also associated the hot temperature phenomenon with **the El Niño Effect**, which is a global climate phenomenon that causes a decrease in rainfall in several regions of Indonesia, including Salatiga. The El Niño effect often increases air temperatures significantly due to prolonged droughts and reduced air humidity. This decrease in rainfall also exacerbates the effects of urbanization due to the lack of natural cooling processes through water evaporation.

In addition, 96.2% of respondents (179 respondents) linked hot temperatures to **a long dry season**. Prolonged dry seasons cause the soil to dry out and lose the capacity to absorb heat effectively. It also lowers the production of vegetation that serves as a carbon sink and a natural cooling effect provider.

Interestingly, only 3.8% of respondents (7 students) considered Salatiga in the lowlands to be the main cause of hot temperatures. This shows that most students understand that anthropogenic factors, such as urbanization and development, as well as global climate phenomena, have a more significant impact than geographical factors.

On the other hand, only 1.1% of respondents (2 students) chose **the increase in green land** as a causal factor. This reflects the students' understanding that increasing green land is actually a solution in reducing hot temperatures, not the cause.

Overall, this data shows that students have a good understanding of the main factors influencing the increase in temperature in Salatiga, especially those related to human activities and global climate phenomena. This understanding is an important basis for engaging students in further discussions on sustainable solutions, such as expanding green areas in cities, reducing the use of fossil-based energy, and raising awareness of the impacts of climate change.

The results of this survey also show the importance of local issue-based learning in improving students' science literacy, in accordance with the theory of constructivism by Vygotsky (1978), which states that learning that is relevant to students' experiences can increase their engagement and understanding of the material. Thus, these results provide important insights for teachers to integrate local issues into the curriculum of Chemistry and other subjects.

The effects of urbanization can cause temperature rise in Salatiga

The results of the data analysis show that the majority of students at SMA Negeri 1 Salatiga have a good understanding of the factors that cause the temperature in Salatiga to be very hot. Based on **Figure 3**, as many as **97.3% of respondents** identified **urbanization and development** as the main factors affecting temperature in this region. This is in line with previous research which stated that the increase in the number of buildings and asphalt roads tends to increase the capacity of the area to absorb and emit heat (Seto et al., 2012). Urbanization reduces green areas, thereby reducing the natural cooling effect provided by vegetation.

Figure 3. Graph of students' understanding related to the causes of rising temperatures in Salatiga

In addition, as many as **97.8% of respondents** understood that **the El Niño effect** also contributed to the increase in temperature. The El Niño phenomenon is known to cause a reduction in rainfall and prolong the dry season, resulting in drier and hotter air conditions (Trenberth, 1997). In regions like Salatiga, which are already facing pressure from urbanization, the impact of El Niño is further exacerbating the situation.

Based on the graph in **Figure 2**, as many as **96.2% of respondents** also attributed **the long dry season** as a contributing factor to high temperatures. The long dry season reduces air humidity and dries out vegetation, thereby increasing local temperatures. This impact is exacerbated by the low level of green land cover in urban areas such as Salatiga, which is only realized by **1.1% of respondents** as an important mitigation factor.

On the other hand, only **3.8% of respondents** chose "Salatiga is located in the lowlands" as the cause of hot temperatures. This understanding suggests that students focus more on dynamic factors such as El Niño and urbanization rather than fixed geographical characteristics. Local context-based approaches, such as linking global phenomena (El Niño) to local climate change, have succeeded in increasing students' awareness of environmental issues (National Research Council, 2012).

These findings confirm that students have a fairly good understanding of the relationship between human activities and natural phenomena to local temperature changes. However, the low percentage of respondents who are aware of the importance of increasing green space indicates the need for more emphasis on mitigation strategies in learning. Ecological literacy, which includes the role of vegetation in balancing local temperatures, can be an additional focus in the environmental education curriculum (Levy & Marans, 2012).

To reinforce this understanding, the integration of technologies such as simulations of the effects of urbanization on local temperatures and simple experiments can help students understand deeper causal relationships. For example, students may be asked to measure the temperature difference between a vegetated area and an asphalt-dominated area within their school environment.

Phenomena and Their Effects on Climate Change

The results of data analysis show that the majority of students at SMA Negeri 1 Salatiga have a good understanding of the impact of the dry season phenomenon on environmental conditions. Based on **Figure 4**, as many as **83.9% of respondents** managed to match the phenomenon of the dry season with its impact, namely **drier and hotter air**. These results show that students understand the direct relationship between the prolonged dry season phenomenon and the increase in air temperature and the reduction of humidity in the surrounding environment.

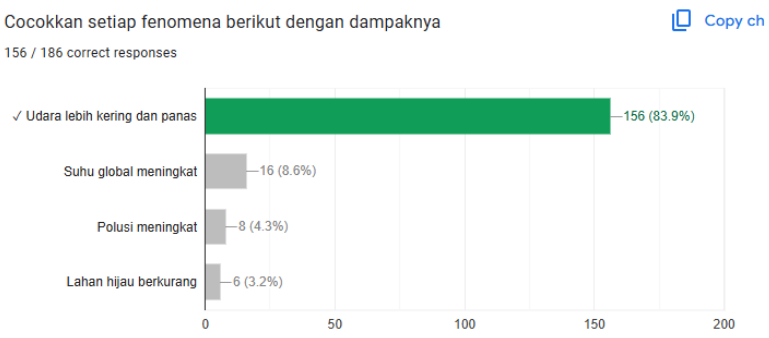

Figure 4. Graph of students' understanding of Phenomena and Their Effects on Climate Change

This understanding is consistent with previous research that shows that the dry season significantly affects soil moisture, evaporation rate, and air temperature (Trenberth et al., 2003). In tropical regions such as Salatiga, prolonged dry seasons can lead to reduced water availability, drying out vegetation, and creating hotter air conditions than during the rainy season.

However, only a small percentage of respondents attributed this phenomenon to other impacts such as rising global temperatures (8.6%), increased pollution (4.3%), and reduced green space (3.2%). This shows that students' understanding is still limited to the direct impacts of the dry season, while indirect impacts such as its contribution to global climate change and air quality reduction have not been fully understood.

Phenomena such as **the reduction of green land** are actually closely related to the dry season, especially in the context of deforestation that often occurs during dry periods due to human activities, such as land clearing for agriculture or development. According to Seto et al. (2012), uncontrolled urbanization in the tropics can exacerbate the impact of the dry season by reducing vegetation cover that functions as a natural cooler.

The low percentage of students who associate this phenomenon with global issues shows the need for a more holistic learning strategy. The theory of science literacy (Bybee, 1997) emphasizes the importance of conceptual understanding that is integrated with the global context so that students can see the long-term impact of local phenomena. In this case, project-based learning approaches, such as observing the impact of the dry season on school ecosystems, can help students understand the more complex relationship between local phenomena and global issues.

Additionally, it is important to integrate technology in learning, such as the use of computer simulations or digital observation tools to show how local phenomena, such as the dry season, can affect the carbon cycle or regional weather patterns. A study by the National Research Council (2012) stated that technology can increase students' interest and understanding of complex phenomena involving many environmental variables.

Conclusion

This study shows that students' understanding of the impact of environmental phenomena, such as the dry season, is quite good, especially in recognizing direct impacts such as increased temperatures and drier air. However, students' participation in climate change-based learning is still low, and their understanding of indirect or global impacts, such as the effects of the dry season on the reduction of green land and its contribution to climate change, requires further improvement. This shows the need for a more holistic and integrated learning strategy.

Technology integration, the use of a project-based approach, and the association of local phenomena with global issues can be effective solutions to improve students' science literacy. This approach not only helps students understand the material more deeply, but also encourages them to become agents of change who care about the environment.

Through relevant, contextual, and interactive learning, it is hoped that students will not only be able to understand scientific concepts but also apply them in daily life. By doing so, they can contribute to climate change mitigation efforts, both at the local and global levels, thereby creating a generation that is more environmentally conscious and responsible for the sustainability of the planet.

Suggestion

Further research is suggested to explore the use of digital technology more intensively, such as simulations and interactive applications, to increase student motivation and participation in learning. In addition, collaboration with parents and the community also needs to be strengthened so that the impact of learning is wider and more sustainable.

Through joint efforts in the world of education, we can build a generation that not only understands climate change but is also actively involved in maintaining environmental balance.

Acknowledgment (Optional)

The authors would like to express their heartfelt gratitude to the **Indonesian Teachers Association (PGRI)** for their support and guidance throughout this research. Their commitment to advancing educational practices has greatly inspired this study.

We also extend our deepest appreciation to **SMA Negeri 1 Salatiga** for providing the platform and resources to conduct this research. The cooperation of the school administration, teachers, and students has been invaluable in ensuring the successful implementation and completion of this study.

This research stands as a testament to the importance of collaboration between educational institutions and organizations in fostering innovative learning approaches and addressing pressing global issues, such as climate change, through education.

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