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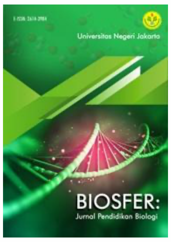

Students' conceptual change through modeling of forest and peatland fires: A case study in Palembang, South Sumatra, Indonesia

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A B S T R A C T

Students in South Sumatra are familiar with the direct impacts of forest and peatland fires, yet understanding their connection to global warming remains limited and requires targeted educational interventions. This study investigates conceptual change among 16 students in Palembang after participating in modeling-based learning activities about forest and peatland fires. Although Palembang does not experience such fires directly, the city is heavily affected by the resulting haze, which impacts health, visibility, and daily activities, including school attendance. A qualitative approach was used, and data were collected through multiple-choice questions and student-generated drawings to capture shifts in understanding. The results revealed varied levels of conceptual understanding, categorized as scientific conception from the beginning (37%), static understanding (20%), disorientation (17%), revision or reconstruction (8%), and construction of new understanding (18%). A total of 26% of students demonstrated positive conceptual change after the intervention. These findings suggest that modeling serves as an effective tool to help students visualize complex environmental processes and make connections between local phenomena and global issues. The study highlights the importance of incorporating interactive, visual learning strategies in environmental education to foster deeper, more accurate understanding among students, particularly in areas indirectly affected by ecological disasters. Such approaches can empower students to become more informed and responsible citizens in the face of climate change.

INTRODUCTION

Forest and peatland fires in Indonesia have emerged as significant disasters that have attracted both national and international attention. The repercussions of these fires extend beyond Indonesia's borders, impacting neighboring countries. This widespread impact is due to factors such as the extensive burning of vegetation, the properties of peat soil, and prevailing wind patterns. The resulting smog has affected approximately 80 million people across neighboring regions (Carmenta et al., 2021; Lim, 2018; Zhang et al., 2016). Forest and peatland fires are particularly concerned due to their complex causes, including both natural phenomena and human activities (Cattau et al., 2016; Syaufina, 2009). Globally, one of the significant impacts of these fires is their contribution to global warming, as they release large amounts of carbon dioxide and other greenhouse gases into the atmosphere (Cochrane, 2009; Singh, 2022; van der Werf et al., 2017).

It is essential for students, as future generations, to understand the link between forest and peatland fires and global warming. Such knowledge helps them recognize the complexity of environmental issues facing the planet (IPCC, 2019; Kolenatý et al., 2022). Forest and peatland fires contribute significantly to greenhouse gas emissions, such as carbon dioxide and methane, which in turn drive global warming and extreme climate change (Singh, 2022). Understanding these impacts enables students to appreciate the urgency of reducing human activities that trigger these fires, such as peatland clearing for agriculture or uncontrolled logging. Moreover, this understanding provides a foundation for students to engage in climate change mitigation and adaptation efforts, including raising public awareness and advocating for sustainable environmental policies. Thus, understanding the relationship between forest and peatland fires and global warming is crucial not only for ecosystem balance but also for preparing students to address increasingly complex global environmental challenges (Prestemon, 2010; Stephens et al., 2023; Suryawirawati et al., 2018).

South Sumatra is one of the Indonesian provinces with extensive peatland areas, spanning 1.7 million hectares. The region frequently experiences forest and peatland fires due to both human activities and environmental conditions, such as the recurring El Niño events every five years (Nurhayati et al., 2021). These fires have caused severe health problems for residents in Palembang, South Sumatra, as smoke from the fires pollutes the air (Horton et al., 2022). Palembang is especially affected, being surrounded by fire-prone areas in the districts of Ogan Ilir and Musi Banyuasin. While students in Palembang are familiar with the immediate effects of forest and peatland fires, such as respiratory issues and ecological damage, the link between these fires and global warming is less obvious. Modeling offers an effective approach to fostering students' understanding of this connection (Nadelson et al., 2018; Schwarz et al., 2022; Vo et al., 2019).

Incorporating modeling into environmental education helps students grasp abstract issues by engaging them in problem-solving processes that include identifying problems, creating models, establishing connections between models and real-life scenarios, predicting real-world situations, and verifying these predictions (Amelia et al., 2024; Bal & Doganay, 2014; Campbell & Oh, 2015; Meilinda et al., 2017). The objective of modeling is to reveal students' thinking processes, promote collaborative idea-sharing among students and teachers, and enable the application of modeling skills to everyday life (Batlolona & Souisa, 2020; Gungordu et al., 2017; Imaduddin et al., 2023).

Previous studies have employed modeling in environmental and forestry education, covering topics like schematic diagram summaries (Crabbe, 2008), greenhouse gas modeling (Suryawirawati et al., 2018), climate change modeling (Rima et al., 2020), modeling forest and land fires with scrapbooks (Prestemon, 2010) and chemistry magazines (Hutagalung, 2022), and predicting forest and land fires (Reams et al., 2005). However, modeling remains limited to topics that aim to relate local environmental phenomena, such as floods and forest fires to broader issues like the greenhouse effect, global warming, and climate change (Widyastuti et al., 2016).

This study seeks to explore strategies to improve educational access and quality for children in various areas, particularly urban regions affected by haze from forest and land fires. Through a participatory and collaborative approach, we engage teachers and students in studying fire-related issues that address local needs. The goal of this research is to assess students' understanding of the relationship between forest and peatland fires and the greenhouse effect after experiencing real forest and peatland fires and participating in modeling activities. Conceptual changes are measured through multiple-choice questions and student-created drawings.

The modeling applied in this study is categorized as conceptual and visual modeling, designed to help students construct mental representations of the relationships between forest and peatland fires, the greenhouse effect, and climate change. This modeling activity involved a series of guided steps, starting with observing images and simulations of fire events, identifying key components (such as carbon emissions, atmospheric changes, and health impacts), and creating visual diagrams to map cause-and-effect relationships. Students then developed their own models, individually or in groups, using drawings and annotations to represent their understanding of how local fire events are linked to broader environmental systems. The results of this study underscore the importance of using concrete modeling to enhance students' comprehension as the next generation, fostering sustainable improvements in educational quality aligned with the Sustainable Development Goals (SDGs).

METHODS

This study used a qualitative descriptive approach to explore students' conceptual changes after participating in science learning that incorporated modeling activities. The sampling technique applied was purposive sampling, with specific criteria: students aged 12 to 13 years, enrolled in the first year of junior high school, living in urban areas of Palembang that are frequently affected by haze due to forest and land fires, and who had previously received basic environmental science instruction. A total of 16 students who met these criteria were selected as participants.

The research was conducted in Palembang, a city situated amid regions severely affected by forest and land fires, resulting in persistent haze. This environmental issue has had a profound impact on the lives of residents, including the 16 students who participated in this study. Palembang, surrounded by South Sumatran districts with high hotspot occurrences, has faced this environmental challenge consistently over the past five years. Notable hotspot-prone districts include Musi Banyuasin, Banyuasin, Ogan Komering Ilir, and the Pali border with Musi Banyuasin, as shown in Figure 1. The adverse effects of haze have disrupted various aspects of daily life, particularly for students, whose educational routines and health have been compromised.

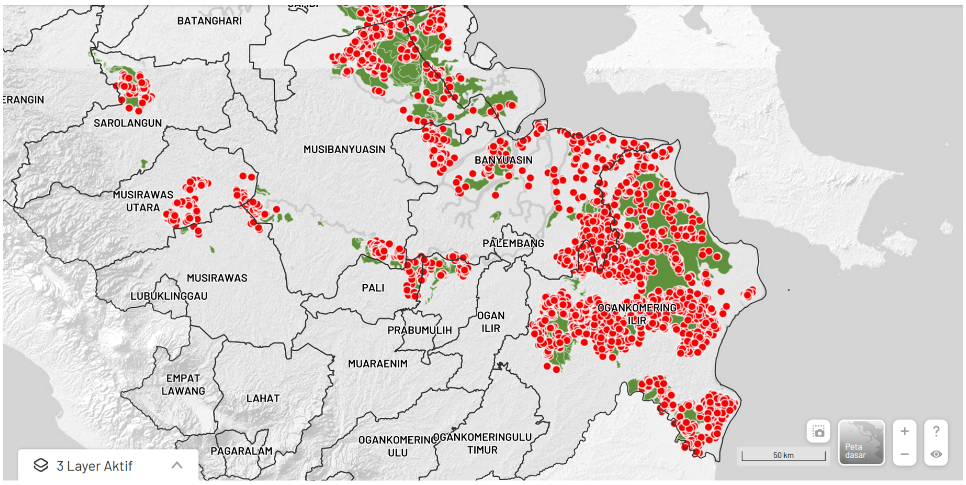


Figure 1. Distribution of fire points around Palembang City for 2019-2024

Research Design

This study employs a qualitative research design to investigate students' conceptual change, describing empirical studies that assess educational interventions through a pre-experimental design without a control or comparison group (Phye et al., 2005). In this design, the focus is on observing a single group without manipulation or comparison to other groups. With a sample of 16 students, researchers explore phenomena or relationships within this specific group, primarily aiming to generate hypotheses or preliminary insights. Although this design lacks the control necessary to establish causality or allow direct comparisons between groups, it provides valuable initial data for further investigation. The emphasis lies in understanding the characteristics and behaviors of the sampled group, laying a foundation for future research. While limited in drawing definitive conclusions, such designs are instrumental as exploratory tools in the scientific inquiry process.

Modeling Design

The initial model design for this research consisted of two terrariums covered with plastic wrap, two temperature gauges (thermometers), two light bulbs, two stands, and a burner containing spirit and leaves (Figure 2.a). The final model used in the study included two terrariums also covered with plastic wrap. Each terrarium represented a terrestrial ecosystem, incorporating soil, grass, crickets, and grasshoppers. This model was further equipped with two thermometers, two stands for positioning the thermometers, two light bulbs, and a burner containing spirit, dry twigs, and leaves (Figure 2.b). Students engaged with this model through an experimental design guide (Figure 3), using the 5M learning model—a commonly applied approach focused on enhancing student understanding of the effects of modeling in learning.

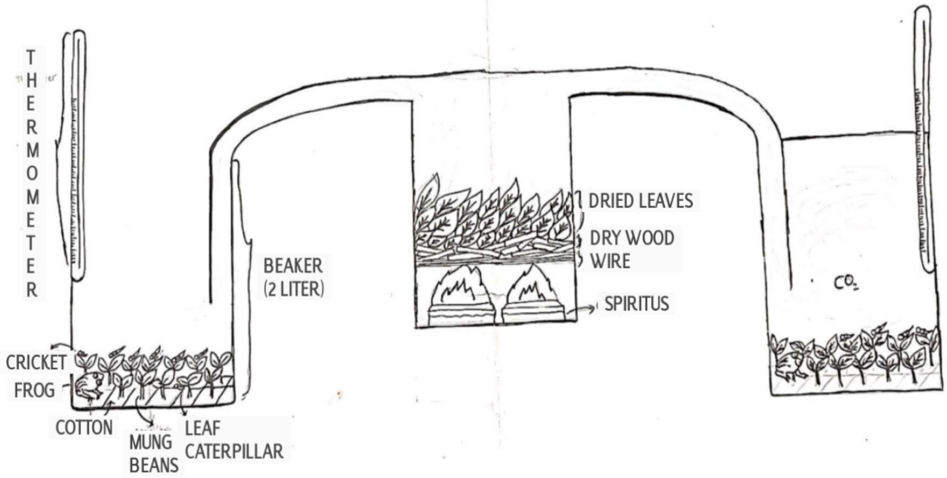


Figure 2. Final forest and peatland fire modeling. The final model used in this study consisted of two terrariums covered with plastic wrap. Each terrarium was equipped with a terrestrial ecosystem model containing soil, grass, crickets, and grasshoppers. The model also included two temperature gauges (thermometers), two stands for hanging thermometers, two light bulbs, and a burner with spirits, dry twigs, and leaves.

Subject	Science	Time Allocation	2 Periods (80 minutes)
Grade/Semeter	7^{th}/ Event	Academic Year	2019-2020
Basic Competition	KD. 3.9	K.D. 4.9	
Learning objective	Through modeling learning, student will be able to : 1. Understand the phenomenon of forest and land fire and their causes. 2. Analyze the short-term and lpong-term impacts of forest and land fire on human life and the environment, especially on greenhouse gas effects, global warming, climate change, and prevention effect. 3. Understand the concepts related to forest and land fire topics as evidenced by the results of concept efforts.		
Learning materials	Forest and land fire causes and impact on the environment especially greenhouse effect, global warming and climate change.	Time (Minutes)	
Model 5M	Learning Step		
Description: Collaboratively, observe the forest and land fire modeling and pay attention to the teacher demonstrating forest and land fire event. Then, together in groups, construct a depiction of the relationship between forest and land fire, greenhouse effect	**Introduction** The teacher ensures student to join google meet Greetings, leading prayer, checking attendance, stating objective. Motivation: the teacher provides an overview of the impact of forest and land fire in Indonesia, such as haze disaster, then motivated students to be part of the disaster prevention by studying it. Description: collaboratively observe forest and land fire modeling and pay attention to the teacher demonstrating forest and land fire events, then together in group create a description of the relationship between forest and land fire, greenhouse effect and global warming, Core: 1. Observing - Teacher displays images of haze disasters in Indonesia. - Teacher facilities students to observe the displayed images	7	

and global warning.	- Students observe and pay attention to the image/videos of haze disasters 2. Questioning - The teacher asks students about the displayed images. - Teacher guides students to answer. - Teacher facilities classroom Q&A discussion.	
	3. Gathering information/Trying (Experimenting) - The teacher explains the definition and causes of forest and land fire aided by PowerPoint media. - The teacher displays a learning video about forest and land fire modeling. - The teacher directs students to leave the google meet room and switch to WhatsApp video call to answer 2 discussion questions at the end of the video.	10
	- Students listen to the teacher's explanation, watch and discuss in groups regarding the assigned tasks - Students gather various supporting information through discussion.	20
	4. Reasoning/Associating - The teacher directs students back to the google meet room. - The teacher facilities the class in determining the sequence of brief presentations from each group about the discussion result. - Students observe the presentation results from each group representative. - The teacher facilities classroom Q&A discussion. - Students engage in Q&A about each group's presentation and gather various supporting information related to forest and land fires.	20
	5. Communicating - The teacher draws conclusions from the discussion - The teacher further explains the impacts of forest and land fire on greenhouse gas effect and global warming through modeling and graphics. - Students actively communicate discoveries from the connected modeling.	20
	Closing Guidance for posttest implementation The teacher reflects, appreciates and follow up	3
Assessment 1. The teacher gives pretests and posttests to students' conceptions on the forest and land fire topic. 2. The teacher evaluates the results of student discussion and their participation in learning. 3. The teacher provides instruments for student responses to forest and land fire modeling in learning. 4. Note: the pretest is conducted 1 week before meeting.		

Figure 3. Lesson study modeling forest and peatland fire

Participant and data collection

This research involved 16 students aged between 12 and 13 years living in Palembang, South Sumatra. Sample selection was conducted using a purposive sampling method, targeting students whose residential areas were severely affected by forest and land fires. This sample size was also chosen to test the practicality of the modeling approach in a limited field setting (Anggraeni et al., 2021). The students studied science subjects in the second semester of their first year in junior high school. Data collected included written notes and observations of the ongoing learning process. Written notes comprised conceptions and assignments, with 16 students (coded A01-A16) providing responses and participating in modeling lessons on forest and peatland fires.

Research Instrument and Procedures

The data on students' understanding was measured using true-false questions accompanied by a Certainty of Response Index (CRI) scale (Hasan et al., 1999; Hermita et al., 2017). Drawing assignment data involved four groups illustrating the relationship between forest and peatland fires and the greenhouse effect before and after learning. The CRI in conception data reflects students' confidence levels in answering true-false questions, as shown in Table 1 (Hasan et al., 1999).

Table 1.
Confidence levels and categories of students' conceptions

Certainty Index	Category
0	Completely Guessed Answer: If, in answering the questions, students are 100% guessing with no confidence in their response.
1	Almost Completely Guessed Answer: If, in answering the questions, 75%-99% of the response reflects guessing, indicating they are almost completely guessing.
2	Not Confident: If, in answering the questions, 50%-74% of the response reflects guessing, showing the students are not sure of their answer.
3	Confident: If, in answering the questions, 25%-49% of the response reflects guessing, indicating that students feel fairly sure of their answer.
4	Almost Certain: If, in answering the questions, 1%-24% of the response reflects guessing, meaning students are almost positive about their answer.
5	Certain: If, in answering the questions, 0% of the response reflects guessing, showing they are fully confident in their answer.

Conception data with the Certainty Response Index (CRI) were analyzed to categorize students' conceptions, combining correct or incorrect answers to the conception questions (Hasan et al., 1999), as presented in Table 2.

Table 2.
The matrix for determining students' conceptions.

Answer Type	Low CRI < 2.5	High CRI >2.5
Correct Answer	Number of correct answers and low CRI, guessing	Number of correct answers and high CRI, correct concept knowledge
Incorrect answer	Number of incorrect answers and low CRI, lack of knowledge	Number of incorrect answers and high CRI, misconception

The analysis focused on categories of students' conceptions (Table 2). A comparison of responses before and after learning was then used to categorize the level of conceptual change, as outlined in Table 3.

Table 3.
Guidelines for determining the level of change in conception.

Levels of Conceptual Change	Leveling Guidelines	
	Initial Response (Pretest)	Final Response (Posttest)
Scientific Conception from the Beginning (SCFB)	Right Concept	Right Concept
Static (S)	Guess/ Lack of Knowledge/ Misconception	Guess/ Lack of Knowledge/ Misconception
Disorientation (D)	Right Concept	Guess/ Lack of Knowledge/ Misconception
	Guess	Lack of Knowledge/ Misconception
Revision or Reconstruction (R)	Misconception	Right Concept
Construction (C)	Guess	Right Concept
	Lack of Knowledge	Right Concept

Modification (Hermita et al., 2017).

RESULTS AND DISCUSSION

Analysis of Student Conception Categories

The research findings indicate variations in students' initial conceptions, as shown in Table 4. Scientific conceptions were predominant, suggesting that students already possessed accurate scientific understanding from the outset. This also indicates an increase in students' confidence levels when answering CRI questions after participating in the modeling-based learning activity.

Table 4.
Student conception before and after learning modelling

No	Student code	Before				After			
		SC	G	LK	MI	SC	G	LK	MI
1	A1	23.33	46.67	26.67	3.33	66.67	0.00	33.33	00.00
2	A2	70.00	0.00	0.00	30.00	60.00	0.00	0.00	40.00
3	A3	80.00	0.00	0.00	20.00	70.00	0.00	0.00	30.00
4	A4	40.00	10.00	6.67	43.33	43.00	16.67	23.33	16.67
5	A5	26.67	13.33	30.00	30.00	50.00	0.00	46.67	3.33
6	A6	46.67	3.33	3.33	46.67	60.00	0.00	0.00	40.00
7	A7	40.00	26.67	16.67	16.67	56.67	6.67	26.67	10.00
8	A8	63.33	13.33	10.00	13.33	56.67	10.00	13.33	20.00
9	A9	76.67	3.33	0.00	20.00	56.67	0.00	0.00	43.33
10	A10	23.33	26.67	30.00	20.00	86.67	0.00	0.00	13.33
11	A11	66.67	0.00	3.33	30.00	73.33	0.00	0.00	26.67
12	A12	36.67	10.00	16.67	36.67	53.33	3.33	6.67	36.67
13	A13	60.00	6.67	13.33	20.00	70.00	3.33	3.33	23.33
14	A14	33.33	20.00	10.00	36.67	30.00	16.67	16.67	36.67
15	A15	56.67	30.00	3.33	10.00	70.00	6.67	6.67	16.67
16	A16	56.67	3.33	6.67	33.33	60.00	0.00	0.00	36.67
Total		800.00	213.33	176.67	410.00	963.33	66.67	176.67	393.33
Average		50.00	13.33	11.14	25.63	60.21	4.17	11.04	24.58

Note. SC: Scientific Conception, G: Guessing, LK: Lack of Knowledge, MI: Misconception.

The second data shows the level of misconception, which was also quite large in the initial conception.

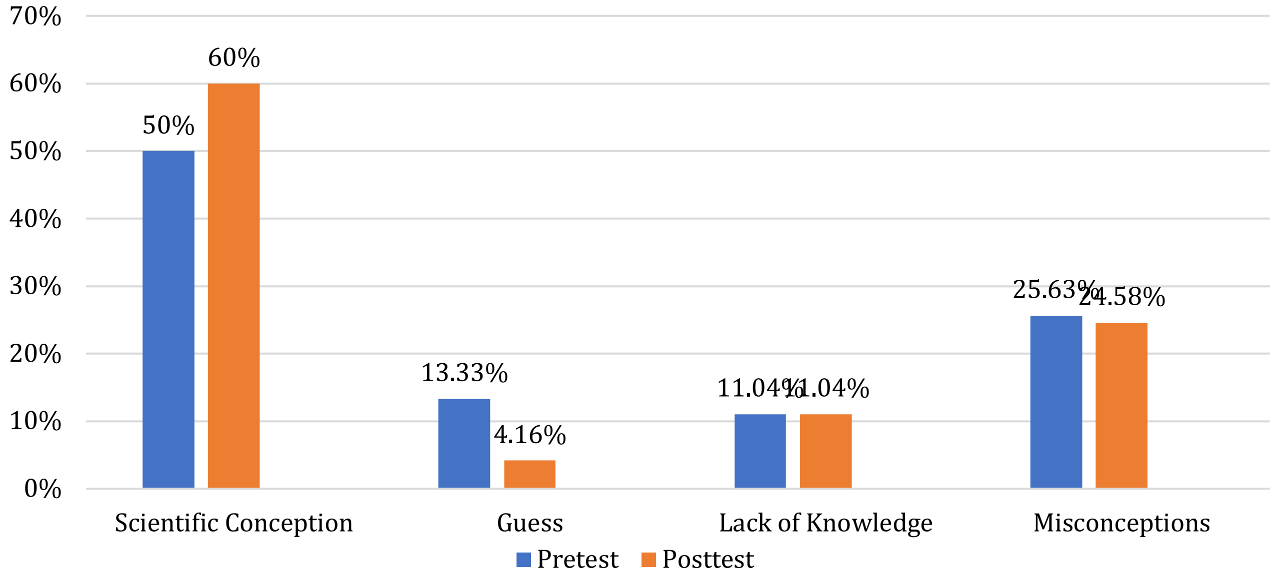
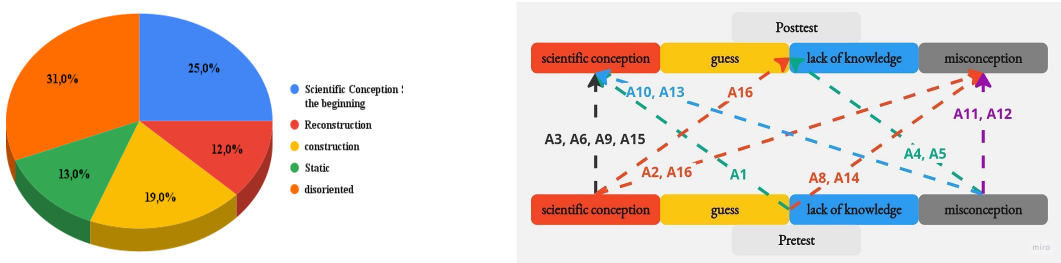


Figure 4. Student conception category data on before and after

Overall, the change in student conceptions, presented in Figure 4, shows a 10% increase in the scientific conception category and a 9.17% decrease in the guessing category. This shift demonstrates positive outcomes from the learning intervention on students' conceptual understanding. Notably, there was a decrease in the number of students guessing after engaging in the modeling activity.

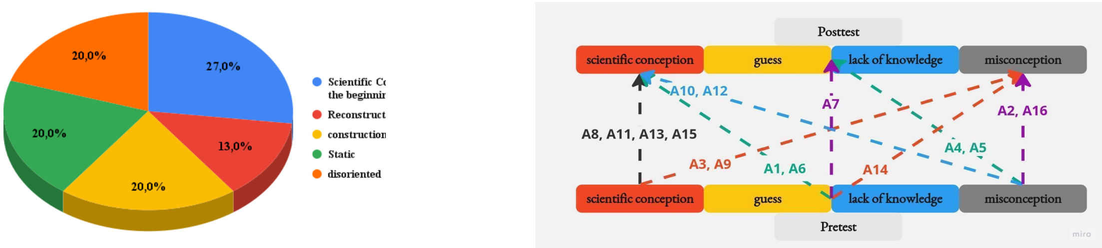
Students who achieved scientific conceptions by the end of learning either had these conceptions initially or gained enhanced knowledge and increased confidence in scientific concepts. Initial scientific conceptions were often influenced by media sources such as the internet, reading materials, and television, as well as everyday life experiences. Learning activities can strengthen these conceptions, making them more robust (Chiu, 2007; Steer et al., 2005; Taslidere & Yıldırım, 2023).

Changes in students' conceptions were analyzed based on five indicators: the causes of the greenhouse effect, the causes of global warming, the effects of global warming, efforts to mitigate global warming, and the relationship between forest and peatland fires and the greenhouse effect. These changes are represented in diagrams and pretest-posttest charts (Figures 5-9). The diagrams illustrate overall conception changes, while the charts depict individual conception shifts, including scientific understanding, guessing or lack of knowledge, and misconceptions. The second data show the level of misconception which was also quite large in the initial conception.



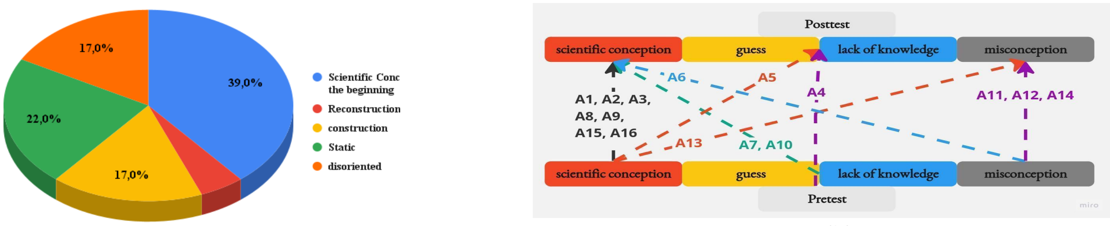
(a) (b)

Figure 5. Percentage of changes in conception indicators for the causes of the greenhouse effect (5a) and distribution of student conceptual change (5b)



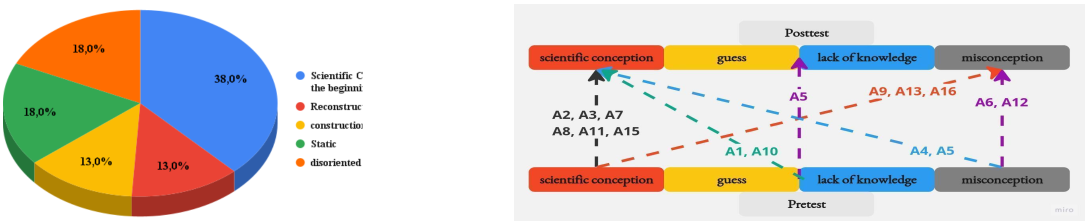
(a) (b)

Figure 6. Percentage of changes in the conception of Indicators for the causes of global warming (6a) and distribution of student conceptual change (6b)



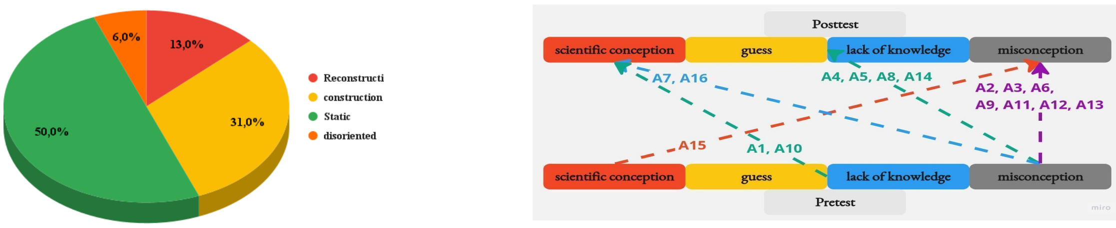
(a) (b)

Figure 7. Percentage of changes in conception on global warming impact indicators (7a) and distribution of student conceptual change (7b)



(a) (b)

Figure 8. Percentage of changes in conception of indicators for combating global warming (8a) and distribution of student conceptual change (8b)



(a) (b)

Figure 9. Percentage of changes in the conception of indicators of the relationship between forest and peatland fires and the greenhouse effect (8a) and distribution of student conceptual change (8b)

The findings of this study reveal a clear trend towards the prevalence of students with pre-existing scientific conceptions. This was evident in the number of students who not only answered questions correctly but also showed high confidence in their responses. The next most prominent group included those who demonstrated enhanced understanding through constructing and reconstructing their knowledge, as shown in Figure 10. Together, these groups comprised 26% of the total participants, highlighting the importance of prior scientific conceptions in shaping students' understanding and potential for growth through active engagement and reevaluation of their knowledge.

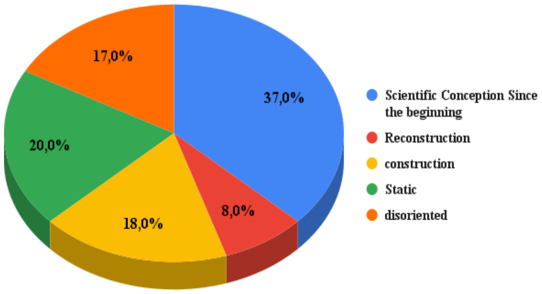


Figure 10. Percentage of Student Conception Changes

Changes in students' conceptions align with constructivist theory through the processes of assimilation and accommodation (Hermita et al., 2017). Students enter the class with varying levels of understanding or conceptions of the topics being taught; some already possess knowledge from previous learning or general knowledge gained outside the classroom, while others lack this foundational knowledge (Steer et al., 2005; Taslidere & Yıldırım, 2023). Students who start with scientific conceptions only need to reinforce their understanding through learning, a process known as assimilation. In contrast, students without prior knowledge experience cognitive conflict and subsequently develop scientific conceptions through accommodation. A detailed description of individual students' conceptual changes is presented in Table 5.

Table 5.
Changes in student conception based on indicators

No	Student code	Conceptual Change (%)				
		SCFB	R	C	S	D
1	A1	16.67	3.33	46.67	20.00	13.33
2	A2	53.33	6.67	0.00	23.33	16.67
3	A3	63.33	3.33	0.00	13.33	20.00
4	A4	16.67	13.33	30.00	16.67	23.00
5	A5	23.33	3.33	46.67	16.67	10.00
6	A6	30.00	23.33	6.67	23.33	16.67
7	A7	33.33	3.33	20.00	36.67	6.67
8	A8	53.33	0.00	6.67	20.00	20.00
9	A9	53.33	0.00	3.33	20.00	23.00
10	A10	23.33	16.67	46.67	3.33	10.00
11	A11	63.33	6.67	3.33	23.33	3.33
12	A12	20.00	20.00	13.33	20.00	26.67
13	A13	43.33	6.67	23.33	10.00	16.67
14	A14	16.67	10.00	10.00	36.67	26.67
15	A15	53.33	3.33	16.67	13.33	13.33
16	A16	40.00	13.33	6.67	20.00	20.00
Total		603.33	133.33	280.00	316.67	266.67
Average		37.71	8.33	17.50	19.79	16.67

Note. SCFB: Scientific conception from beginning, R : Reconstruction, C: Construction, S: Static, D : Disorientation

Changes in the Drawing of the Relationship Model of Forest and Peatland Fires with the greenhouse effect

Students' conceptual changes were also observed through a drawing task, illustrating their understanding of the relationship between forest and peatland fires and the greenhouse effect. Each change in students' conceptions is represented by four individuals from each study group, as shown in Figure 11.

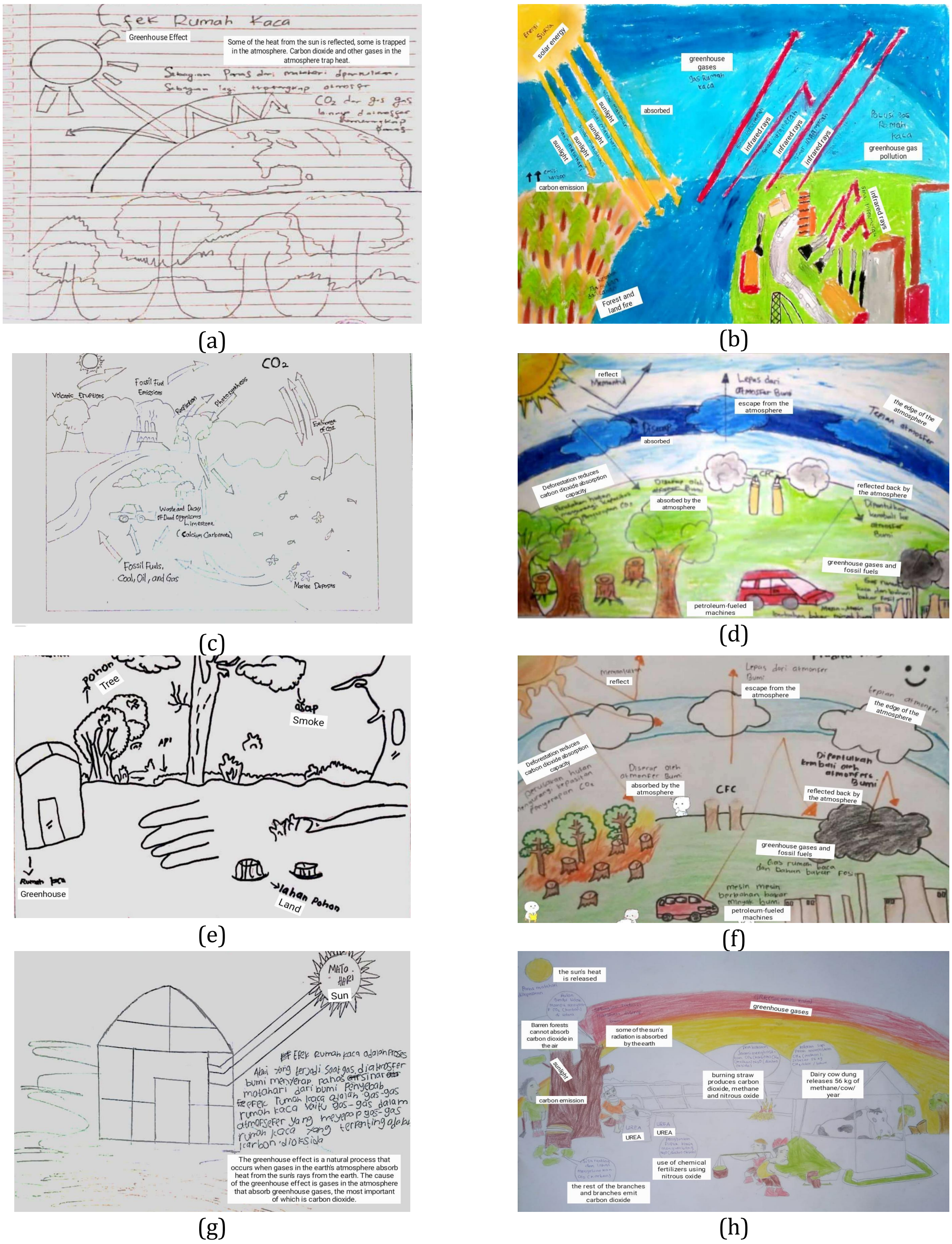


Figure 11. Comparison of answers to drawing of the relationship between forest and peatland fires on students' conceptions. (a, b) In the pretest responses, students were unable to analyze the relationship between forest and peatland fires and the greenhouse effect (GHE). Students depicted forest and peatland fires and GHE as separate phenomena. After instruction, students acquired the correct conception. (c, d) The pretest responses indicate that students held a scientific understanding of global warming, but their drawings lacked the depiction of greenhouse gas layers in the atmosphere. After learning, students were able to accurately illustrate the GHE layers and the relationship between forest and peatland fires and GHE. (e, f) In the pretest, students misunderstood the greenhouse effect, depicting it as a glass house. After the learning activity, students were able to define the greenhouse effect correctly. (g, h) Students' pretest responses revealed initial misconceptions, with the greenhouse effect illustrated as glass buildings. After instruction, students corrected their understanding, depicting the greenhouse effect with an accurate scientific conception.

The study investigated changes in students' conceptions across various models related to earth sciences and environmental phenomena, revealing several key findings. In the Earth's Surface Model, students in Group 1 initially used a basic semicircle representation but progressed to a more detailed depiction that included urban buildings, forests, and rivers. Group 2 maintained their initial conception throughout, while Group 3 expanded their view from a forest-centric perspective to include urban areas. Group 4 shifted from a linear representation to incorporating rural areas with visible human activity.

In the Forest and Peatland Fire Model, most groups initially depicted fires in forests and showed little change after the learning intervention. However, Group 3 enhanced their drawings by adding burnt trees, while Group 4 incorporated the concept of human-induced deforestation. For the Greenhouse Gas Layer Model, Groups 1, 2, and 3 improved their illustrations by depicting a thicker greenhouse gas layer after the learning process, whereas Group 4 began to recognize the existence of atmospheric layers, though they lacked detailed descriptions. Changes were also observed in the Sun Model and Ray Reflection. Group 1 adjusted their understanding of sunlight reflection to include both atmospheric and surface reflections. Groups 2 and 3 started to consider sunlight reflection only after the learning intervention, while Group 4 showed no change in understanding. In the Forest and Peatland Fire Emission Model, all groups initially omitted emissions in their drawings, but post-learning, they added arrows and examples of carbon dioxide to represent emissions. For the Overall Model of Forest/Peatland Fires and the Greenhouse Effect, students initially held misconceptions about the greenhouse effect, with some associating it with glass buildings. After learning, however, most students recognized forest and peatland fires as contributors to the greenhouse effect, along with other factors.

These changes are attributed to effective learning processes, including teacher explanations and student discussions. Overall, students' conceptions evolved towards a more comprehensive understanding of earth sciences and environmental phenomena (Shepardson et al., 2011). Initially, students exhibited confusion about the greenhouse effect; some described it as a "glass house," others viewed forest and peatland fires as the sole cause, and some did not recognize the greenhouse effect as an atmospheric layer. After instruction, students' conceptions improved, as they were able to describe the relationship between forest and peatland fires and the greenhouse effect using various representations while maintaining a consistent conceptual understanding. Some students provided complete and proportional explanations of phenomena that contribute to the greenhouse effect (Gilbert, 2004; Paulos, 2017), while others illustrated tools contributing to greenhouse gas emissions.

Overall, students understood that forest and peatland fires are just one of several causes of the greenhouse effect. They also recognized the presence of a greenhouse layer that reflects some solar heat back to Earth and some to the atmosphere. Students' conceptual changes were influenced by several factors, particularly a well-executed learning process, which aligned with observations of lesson plan implementation and student engagement.

CONCLUSION

The study showed that, although students were already aware of the direct effects of forest and peatland fires on their daily lives, understanding the connection between these fires and broader environmental impacts was challenging. Modeling-based learning enhanced their understanding, enabling students to accurately depict the relationship between forest and peatland fires and the greenhouse effect in their drawings. The results revealed students' conceptual changes before and after modeling, categorized into five groups: (1) scientific conception from the beginning (37%), (2) static (20%), (3) disorientation (17%), (4) revision or reconstruction (8%), and (5) construction (18%). Overall, 26% of students showed positive conceptual change, reflecting an improved understanding.

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