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ARTICLE

High school students' preconceptions about the concept of climate change considered from the perspective of visual representation

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Abstract

Preconceptions are an essential foundation for students, serving as a basis for more effective learning. In the context of climate change concepts, many students harbor misconceptions. One method to uncover students' preconceptions is through the use of visual representations. Visual representations can elucidate students' understanding of abstract and complex concepts. This study aims to examine and analyze the extent of high school students' comprehension of climate change. The research employs a descriptive qualitative approach, with a population and sample comprising 63 tenth-grade science students from a high school in Indonesia. Data collection techniques included observation and interviews, with semi-structured interviews being utilized in this study. The results reveal that students have varied understandings of the concept of climate change, with many exhibiting misconceptions. The study identifies three categories of climate change concepts: (1) correct concepts of climate change, representing 37%; (2) climate change concepts based on objects, as depicted in the visualizations provided by the respondents; and (3) incorrect concepts of climate change, representing 63%. Based on empirical evidence, the students' preconceptions of climate change are predominantly at the macroscopic level.

Keywords: Preconceptions, Climate change, Visual representation

1. Introduction

Climate change has become a widely discussed topic and is increasingly drawing global attention. In 2020 alone, almost all land areas experienced more heatwaves and increasingly scorching weather, highlighting the fact that the impacts of climate change are evident in many aspects of human life (Amaliah and Purwaningsih 2021). One of the primary causes of climate change is global warming, driven by the rising levels of greenhouse gases, especially carbon-dioxide in the atmosphere. This climate change negatively impacts human activities on Earth, and if it continues unchecked, it could become a significant threat. Addressing this issue requires the collective effort of the global

community, including Indonesia. One effective strategy is to educate through formal education, which can effectively convey and teach risk management related to climate change impacts.

Raising students' awareness about environmental issues caused by climate change is challenging. Environmental education in Indonesia is still conducted separately and lacks curriculum updates to enhance it. Previous research indicates that students' understanding of climate change concepts remains limited (Arum, Abdurrahman, et al. 2014). One reason for this limited understanding is the way the subject is taught in schools; it is not directly integrated into classroom teaching nor applied to everyday life. Additionally, many students harbor misconceptions about climate change, finding the related physics material abstract, complex, and too general, which often leads to misunderstandings.

Therefore, an initial understanding of a concept is crucial for students, as it serves as a foundation for grasping new and more advanced concepts. An initial understanding of climate change is particularly necessary to provide students with a deeper comprehension of this current issue. Analysis of previous research on the basic skills required by students in the 2013 curriculum for science subjects shows that climate change concepts are not included in the core competencies. This omission is one reason for the low understanding of climate change concepts among students (Scribner 1974). It is known that Indonesian students have low awareness of climate change and do not perceive it as a serious issue (Lopez and Pinto 2017). Consequently, research exploring students' preconceptions about climate change concepts is rare, despite its importance for understanding students' ideas and receptiveness to new material.

Preconceptions are initial understandings students possess before learning specific material. These preconceptions vary among students, deriving from their experiences, knowledge, and information acquired outside of school. Regarding climate change, students already have initial preconceptions that can serve as a starting point for understanding climate change material. Therefore, it is essential to identify students' preconceptions before beginning physics instruction. One way to do this is through the use of visual representations, which can reveal students' preconceptions about abstract and complex concepts.

Visual representations can probe students' understanding of specific concepts, serving as a tool to investigate students' preconceptions about particular physics concepts. The findings from this analysis can help teachers design better instructional strategies using visual representations. Previous research has shown that improper use of visual representations can lead to misunderstandings and difficulties in grasping material (Asenova[1] and Reiss 2011). Nevertheless, visual representations are attracting researchers' interest in physics education, as they are rarely used to explore students' preconceptions about specific physics concepts.

This study aims to examine and analyze the extent of high school students' initial understanding of the current concept of climate change. Understanding students' preconceptions about climate change is crucial, not only for their future but also to meet the demands of the new curriculum. Therefore, the researcher is interested in conducting a study titled "An Analysis of High School Students' Preconceptions About the Concept of Climate Change from the Perspective of Visual Representation.

2. Literature Framework

2.1 Preconceptions

Preconceptions are initial ideas that an individual holds about a concept before formally learning about it. They refer to the initial understandings or intuitive conceptions that a person has prior to formal education on a topic. This aligns with the constructionist educational philosophy, which posits that students' initial preconceptions are transformed through social and physical interactions in the classroom during the learning process. Preconceptions can lead to misunderstandings or difficulties in grasping new concepts. Each student inherently possesses different conceptions due to the influence of personal experiences in daily life, resulting in varied preconceptions about a given

concept. These preconceptions are shaped by everyday experiences, tentative concepts, and prior learning outcomes.

Preconceptions are mental models that individuals have about natural phenomena, based on everyday experiences, tentative concepts, and previous learning outcomes (Asenova[1] and Reiss 2011). Furthermore, preconceptions are the initial understandings or conceptions students have before formally learning a concept (Elkins 2013). For instance, at the beginning of a lesson on Newton's Laws, a teacher might first ask students what they already know about the topic. Each student's response will differ, reflecting their varied experiences with moving objects, stationary objects, objects being pulled, and so forth. Consequently, students already possess initial conceptions that may not align with scientific concepts. Teachers must pay attention to these preconceptions to correct and refine students' understanding during instruction.

2.2 Students' conceptions about climate change

Climate change refers to long-term changes in global atmospheric conditions occurring over several decades or more. This aligns with P the Intergovernmental Panel on Climate Change (IPCC), which defines climate change as a statistically identifiable alteration in climate over a long period, typically estimated over a decade or more (Weber and Stern 2011). A climate change involves changes in global and regional climate characteristics, primarily resulting from human activities such as the use of fossil fuels, deforestation, and air pollution (Whitmarsh 2009). Climate change is often conflated with weather changes and seasonal shifts; however, weather changes refer to short-term atmospheric conditions, typically occurring over a day or week in a specific area. Weather changes represent short-term variations in atmospheric conditions occurring within a few hours or days. Additionally, seasonal changes refer to the transition from one season to another (Zia and Todd 2010).

Formal education does not always influence students' understanding of climate change. Some students have varying levels of understanding, with many associating renewable energies with climate change and lacking knowledge about the phenomenon. Many researchers have conducted studies to identify students' conceptions. For instance, research identified significant misconceptions among high school students about global warming (Alfiyah and IP 2017). Their study, involving 271 students with 20 questions and 40 concepts, found that 26 out of 40 concepts were significantly misunderstood, with a high misconception percentage of 61% and an overall average of 19.14%. Moreover, alternative conceptions occur in the field of physics. Out of 700 studies on alternative conceptions in physics, 300 investigated misconceptions in mechanics; 159 in electricity; 70 in heat, optics, and properties of matter; 35 in earth and space science; and 10 in modern physics. These findings highlight the scarcity of research on climate change, despite its crucial importance (Masud et al. 2015).

Previous research examined students' descriptions of global warming (Pratama and Parinduri 2019). Their results showed that 75.86% of students had misconceptions about global warming, such as believing it is caused by ozone layer depletion, leads to skin cancer, or results in acid rain. Similarly, in the context of climate change, students often think it is merely a weather change due to seasonal transitions, affecting air temperatures. The correct concept of climate change involves the phenomenon of rising average global atmospheric temperatures due to human activities, especially fossil fuel use and deforestation, leading to increased greenhouse gas emissions and subsequent global warming. Consequently, many students experience misconceptions about the concept of climate change.

2.3 Visual representation

Visual representation encompasses anything depicted in images or visualizations across various media, interpret able visually by an observer. Representation is a method used to convey phenomena, objects, concepts, ideas, processes, or systems (Elkins 2009). This method is considered effective in

influencing an individual's knowledge and information, aiding in the interpretation and reasoning of the provided information. Scientists often use representations to explain concepts, ideas, laws, systems, and processes. Visual representation as a mechanism of recognition and perception that transforms visual information into actions and understanding. Representation serves as a mediator supporting human thought processes (Kelly 2012), who state that representation involves effective communicative understanding, the organization of ideas, and the development of concepts and models to explain acquired knowledge. In science, presenting ideas and concepts through verbal explanations, images, diagrams, or mathematical statements enhances comprehension. Scientists also modify and combine existing representations to elucidate events or phenomena.

In textbooks, visual representations can appear as images, diagrams, graphs, maps, and more. These tools directly impact students, especially in shaping perceptions related to concepts and tools, thus playing a crucial role in the learning process (Asenova and Reiss, 2011). From the literature review, it is concluded that there are at least two main purposes for using visual representations in education: first, as a pedagogical tool, and second, as an assessment instrument. Another literature review by Mayer (2005:169–182) indicates that visual representations help students store and recall information more effectively. According to this theory, the visualization process in learning involves three stages: (1) understanding visual information, (2) processing information into cognitive structures, and (3) externalizing information as visual models, such as visual representations. This evidence underscores the importance of visual representations in teaching and learning, as they assist students in better understanding and memorizing information.

One critical factor in using visual representation as an assessment tool, particularly for investigating preconceptions, is that it allows students to connect experiences with specific concepts and visualize abstract ideas, thereby representing complex and unobserved phenomena. This visualization can clarify difficult information, enabling students to devise better learning strategies (Mayer and Pilegard 2005). When students create visual representations, they enhance and reinforce their learning, making visual representation a valuable tool in both teaching and self-directed learning (Weurlander et al. 2012).

2.4 Visual representation as a tool of evalution

One efficient instrument for evaluating learning is the use of images. Concepts can be understood and communicated through images, diagrams, or verbal explanations. Images serve as an evaluative tool capable of elucidating an individual's thoughts and explaining functions and uses, thus helping to be sensitive to specific situations. Physics concepts, in particular, are not solely about memorizing formulas but involve understanding highly abstract and complex material, necessitating a deeper comprehension. Images are a medium that can accurately and intricately combine facts and ideas through the amalgamation of verbal expressions and visual representations (Bustle 2004). Additionally, images are represented as a tool for solving complex and abstract physics problems. One study discussed the creation of physics learning modules based on real-life images in high schools. However, the current use of images as an evaluation tool in physics education remains minimal due to the lack of encouragement from teachers for students to represent physics concepts visually.

Images are an effective means of developing students' thoughts and ideas to explain complex concepts that are difficult to articulate with words. Therefore, using images as an evaluative medium will be a beneficial approach to presenting a concept. Through this medium, teachers can discern students' initial understanding of new material concepts. Evaluation tools in education are crucial for educators to assess each student's capabilities. In this study, images are used as an objective evaluative tool.

The analytical framework in this research is based on using visual representations as an assessment tool, as it can reveal three levels of understanding according to the scale of visual representation produced. These levels are macroscopic (such as representations of everyday experiences like defor-

estation by humans and air pollution due to deforestation, or carbon dioxide concentration in the atmosphere), macroscopic (representations in a narrower context, such as maps of global sea surface temperature anomalies), and microscopic (visual representations such as isotopic spectral analysis in specific environmental contexts like water, soil, and air). This is crucial for enhancing understanding from concrete experiences to related complex concepts. Additionally, it is relevant for highlighting content to determine specific focus areas during the teaching and learning process (Vienot, Durand, and Mahler 2009).

In this study, visual representation is used as a diagnostic tool to identify students' preconceptions about the concept of climate change. Specifically, it examines whether visual representation is an effective tool for identifying students' preconceptions regarding climate change concepts. It aims to develop a methodology for using visual representations to identify students' preconceptions about climate change. This approach is considered beneficial for teachers to understand and characterize students' preconceptions and to develop specific strategies to address conceptual difficulties, scaffolding them toward more advanced and complex conceptions during the learning process.

3. Research Method

3.1 Research design

The research design employed in this study is qualitative descriptive. A qualitative research design aims to understand and explain social phenomena and individual experiences through data analysis in the form of words, texts, images, and cultural objects. Several important reasons justify this research design, including: (a) focusing on discovering the nature of specific events or phenomena under study; (b) the research is conducted in highly factual settings to avoid the Hawthorne effect, where participants alter their behavior knowing they are being studied; (c) the sampling technique is purposive, aimed at obtaining information-rich cases; (d) data analysis is not bound by pre-existing rules; and (e) data presentation involves direct description and summary of the obtained information. This approach aligns with previous literature focused on (1) analyzing students' preconceptions of climate change concepts through the exploration of visual representations; (2) analyzing errors in solving problems related to the visual representation of geometric optics concepts; (3) combining various procedures for data analysis as outlined in existing literature; and (4) implementing visual representation in learning to understand concepts. Therefore, this study's use of qualitative descriptive research is relevant for analyzing phenomena and assessing students' preconceptions of specific concepts.

3.2 Participants and research instruments

The participants in this research include individuals, events, or objects studied to gather data relevant to the research topic. The population consists of tenth-grade students aged 15-16 years from a public high school in one city in Indonesia. The sample comprises 63 students selected through purposive sampling, a technique chosen due to its alignment with the research objectives and predefined criteria.

The instruments used in this research include observation and interview guides. The first instrument, the observation guide, consists of paper sheets, and participants are provided with writing tools to draw objects related to a specific problem. The second instrument is the interview guide for in-depth interviews, featuring open-ended questions that require detailed responses. Interviews are recorded using mobile devices. Of the total 63 students from two classes, 21 students were selected for individual interviews, with 10 students from each class participating. The interviews were conducted in the classroom during lessons. The researcher-maintained neutrality, asking each student to explain their thoughts and ideas reflected in their visual representations. Two questions were posed during the interviews: "What is the meaning of this drawing?" and "From the drawing you made, can this occur or often happen in everyday life? Please explain."

3.3 Data analysis

Thematic analysis is the method used in this study after all data have been collected. Thematic analysis involves identifying and categorizing preconceptions based on generated codes, with a focus on interpretive reliability. Given that the data are visual representations or drawings, the analysis involves two approaches.

The analysis of visual data follows a four-step approach developed (Duncan and Ley 2013): (a) reviewing and annotating visual representations, labeling objects/contexts in the drawings; (b) isolating visual representations based on interpreted meanings, providing detailed descriptions of each visual representation; (c) organizing visual representations into several categories; and (d) synthesizing the visual representations according to different categories. For interview data, thematic analysis is employed, an interpretive method for identifying, analyzing, and reporting themes or patterns within the data. Several key steps are involved in thematic analysis. First, researchers repeatedly read and listen to the audio recordings or interview transcripts to grasp their meaning. Relevant words are highlighted to facilitate understanding. Second, researchers assign codes to identify data potentially aligned with the research questions and provide brief summaries of data segments. Third, themes are established based on the codes related to the research phenomena, and relationships among themes are explored to form a cohesive response from the research data. Any code or theme not fitting the overall research is replaced with a new theme.

4. Result of the research

The data presented were obtained from research using observation sheets and interviews completed by participants. In the observation sheets, participants were instructed to draw according to their preconceptions of visual representations related to the concept of climate change. The research results were processed, yielding several findings: 1) accurate concepts of climate change, 2) object-based concepts of climate change, and 3) incorrect concepts of climate change. These findings were categorized into three groups with the following respective percentages.

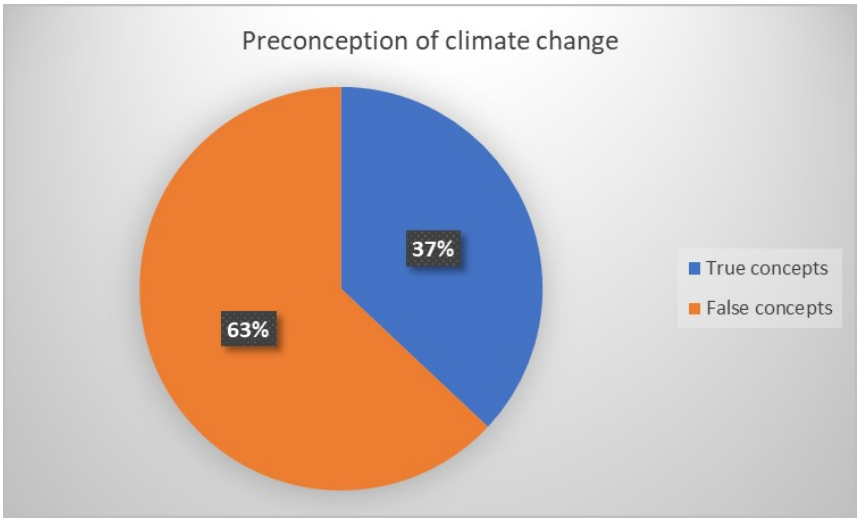

Figure 1. Percentage of preconception of climate change concepts

4.1 Accurate concepts of climate change

The first category from the data analysis is the accurate concepts of climate change. From the observations and interviews conducted with 63 students, it was found that 23 students, or 36.51%,

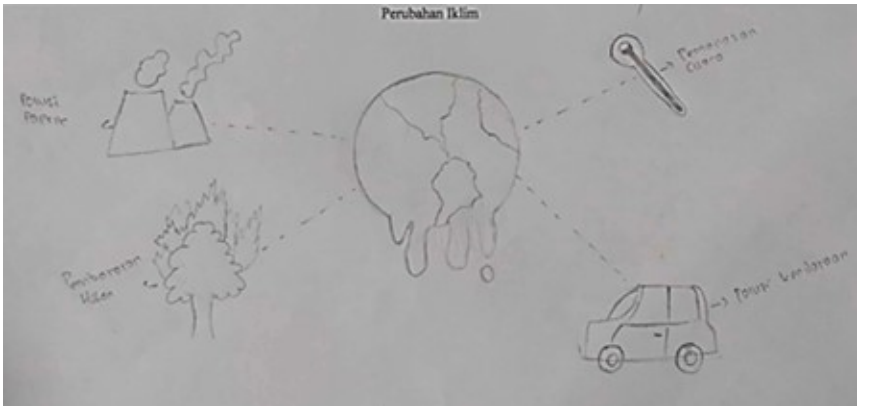

Figure 2. Sample of the appropriate preconcepts of climate change

correctly represented their understanding of climate change through their drawings. This category is based on the definition of climate change, which is understood as a phenomenon of rising average global atmospheric temperatures caused by human activities, particularly the use of fossil fuels and deforestation, resulting in greenhouse gas emissions. Consequently, this leads to extreme weather changes, sea-level rise, and various other environmental issues. Below are some sample data from students who correctly represent

Table 1. Frequency and percentage of preconception of climate change

Objects	Frequency	Percentage
Earth	24	10.17
Cloud	2	0.85
Animal	5	2.12
Factory	10	4.24
Smoke	10	4.24
Ice	4	1.69
Sea	4	1.69
Cloud	37	15.68
Plant	38	16.10
Thermometer	5	2.12
Atmosphere	7	2.97
Sun	33	13.98
Vehicle	2	0.85
Fire	3	1.27
Human	1	0.42
Rain	1	0.42
House	25	10.59
Lake	1	0.42
Drought	1	0.42
Moon	22	9.32
Earth	1	0.42

The visual conception of climate change itself revolves around weather warming affecting climate

change. This closely relates to the physics concept of climate change, explaining that human activities such as forest burning and vehicle pollution can increase the concentration of greenhouse gases like carbon dioxide in the atmosphere. From the visual conception drawn in Figure 2, the respondent shows that climate change can occur due to forest burning, leading to deforestation and a decrease in oxygen levels in the earth, as well as vehicle and factory pollution. If these activities continue unabated, it will result in the earth's temperature rising, as the atmospheric layer, which should act as Earth's protector, gradually thins due to human activities that neglect the environment.

> **Researcher:** According to you, what is the meaning of the drawing? Please explain.
> **Respondent:** Weather warming affects climate change on earth, and factory pollution also has the same effect, um, it affects changing the earth's climate, that is, polluting the air, burning forests also causes air pollution.
> **Researcher:** From the drawing you made, can this occur or often happen in everyday life? Please explain.
> **Respondent:** Sometimes, like vehicle pollution, but not here, I guess.

From the interview results regarding the visual meaning with the statement "Weather warming affects climate change on earth, and factory pollution also changes the earth's climate by polluting the air, burning forests also causes air pollution," the statement is overall correct. In reality, weather warming can occur due to factory pollution, forest burning, and vehicle emissions, as a result of continuous human activities leading to an increase in carbon dioxide levels. Consequently, the atmospheric layer thins, resulting in increased earth temperatures and increasingly hot weather conditions.

4.2 Climate change concepts based on objects

Next, for climate change concepts based on objects, several objects can serve as anchors for understanding the concept of climate change. Some objects that can serve as anchors in the concept of climate change include the earth, atmosphere, ice layers, sea, plants and animals, as well as humans and several other objects. After analyzing the data, it was found that out of the total number of students (63 individuals), most depicted objects that align with the initial description, while some students depicted other objects.

From the analysis of climate change concepts based on objects, it can be seen from Table 1 that essentially, students' conceptions of climate change are well understood from the visual representations drawn by students. The research results obtained objects that serve as anchors and significantly influence the occurrence of climate change. From the data above, some objects that were commonly depicted by respondents include plants with the highest percentage at 16.31%, clouds at 15.68%, house at 10.59%, the sun at 13.98%, and the earth at 38.09%. From these percentages, it can be observed that many students assume that climate change will impact the ongoing processes of life on earth. This is because the objects depicted by students are generally related to the ecosystem of living creatures on earth.

4.3 Incorrect concepts of climate change

Essentially, incorrect concepts of climate change refer to something that does not align with existing scientific data. After conducting observations, the researcher found that 40 out of 63 students depicted incorrect concepts of climate change, accounting for approximately 63.49% of the total respondents. The basis for why the visual representations depicted are incorrect stems from the interview results with the respondents, where the answers from some respondents do not align with relevant theories related to climate change scientists. Below is the table of misconceptions regarding climate change.

Table 2. The frequency and percentage of false conceptions

False preconceptions of climate change	Frequency	Percentage
Climate change from rainy season to dry season.	20	50
The sun shines on the earth, making it hot and causing dried plants to experience the dry season.	7	17.5
Natural changes, originally full of trees, now full of construction, resulting in clean pollution turning dirty.	2	5
Weather changes from clear to cloudy and rainy.	7	17.5
Climate change has its cold and hot moments.	2	5
Weather forecast for one week.	2	5
Total preconception	40	

5. Discussion of research findings

Based on the research conducted, it was found that there are three parts to students' understanding of preconceptions regarding climate change through visual representations. These include (1) Correct concepts of climate change, (2) Concepts of climate change based on objects, and (3) Incorrect concepts of climate change. From these three categories, each has different percentages, with 37% for the correct concept category and 63% for the incorrect concept category. Meanwhile, for the category of climate change concepts based on objects, it was reviewed from the overall images visualized by the respondents. From these percentages, it can be seen that many students still represent misconceptions about climate change, indicating that students' understanding of the concept of climate change is still relatively low. This is consistent with previous research stating that students' understanding of climate change concepts remains low, as many students still consider climate change to be merely seasonal changes. This is also in line with the research, stating that understanding of Newton's Third Law is still low. Most students are disturbed by differences in mass between interacting objects and are also disturbed by initial conditions of one stationary object (Nurutami, Riyadi, and Subanti 2019). Regarding the concept of climate change, students tend to not understand the meaning of climate change itself, thus assuming that climate change is the same as seasonal changes.

In visual representations, students can draw related to the material to be conveyed through their thoughts on the concepts to be taught. From the research conducted, it is evident that with visual representations of preconceptions about climate change, researchers can determine the extent of students' knowledge and understanding of the concept of climate change. Therefore, the use of visual representation tests would be highly beneficial in learning. The research results also show that students' initial understanding through visual representations varies. This is consistent with research which found that students often associate friction with human activities such as rolling and sliding objects on flat surfaces, and are contextual. There are also limited biases demonstrated by non-representation of static friction and non-representation of friction at the mesoscopic and microscopic levels (Canlas 2021). Essentially, humans are equipped with the understanding to develop what is in their minds; this ability can foster a good understanding of concepts, which will eventually affect the students' understanding process in learning materials. As stated by previous research, humans can convey, receive, and interpret meanings through various forms of communication . From the research results, it is proven that through visual representations, students already have an initial understanding of the concept of climate change. Thus, these observation results can be used as

a reference to explain more complex materials on climate change. This is relevant to the opinion stating that representation is a set that can describe, represent, and symbolically represent something in a particular way.

The results of the preconception test with visual representation ability showed that most students still have problems in representing visual concepts of climate change through the drawings they made. Some problems faced by students are: (1) students still do not know what climate change is, (2) students themselves know the impact of climate change, but the concept of climate change itself is still unfamiliar, (3) many students think that climate change is a change in weather from dry season to rainy season and vice versa. This can be evidenced by the results of student drawings, most of which depict climate change from dry season to rainy season. (4) Some students represent that climate change is a weather forecast for several days or even weeks, as evidenced by the results of drawings by students depicting a weather forecast for one week.

From the observations conducted by the researcher through the analysis of students' preconceptions of climate change with visual representation exploration conducted on 63 students, it was found that 63% depicted images that are not quite accurate with the concept of climate change, indicating that many students have misconceptions about climate change. Meanwhile, 23 students depicted the concept of climate change correctly. From this, researchers can see that the use of visual representation to understand students' initial concepts of climate change can be determined. Therefore, based on the research conducted, it can be stated that the ability of visual representation to understand students' initial understanding of climate change can be considered influential.

6. Conclusion

Referring to the problem formulation and based on the results of analysis from the processing of observation and interview data, it can be concluded that students have varying understandings of preconceptions regarding the concept of climate change. This can be seen in the visual representations depicted by students as well as from the interviews conducted with students. From the analysis of visual representations of the concept of climate change, it can be categorized into three categories: 1) correct concepts of climate change; 2) concepts of climate change based on objects; 3) incorrect concepts of climate change. From these three categories, and based on the empirical evidence regarding students' preconceptions of climate change including at the macroscopic level, which means observations are based on students' daily experiences, at this level students more often observe and involve objects in large sizes that can be seen by humans.

Students experience misconceptions in the concept of climate change, which tends to be complex. The infrequent use of visual representations to understand students' understanding is one of the contributing factors. The difficulty students face in explaining and describing the results of visual representations becomes a supporting factor for students' difficulty in understanding the concept of climate change, and the rarity of teachers encouraging students to develop their own visual representations based on their understanding of a concept is another factor that makes students less understand the concepts taught. Therefore, teachers can use visual representations as a tool to identify concept understanding in specific physics topics; Teachers can consider using visual representations as an evaluation tool for students.

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References

Alfiyah, Nur Inna, and S IP. 2017. Perubahan iklim sebagai penyebab terjadinya kekerasan dan migrasi: studi kasus konflik darfur. *DIALEKTIKA Jurnal Ekonomi Dan Ilmu Sosial* 1 (1).

Amaliah, Nur Utami, and Endang Purwaningsih. 2021. Analisis pemahaman konsep, multirepresentasi, dan kosistensi jawaban siswa sma pada konsep hukum iii newton. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)* 9 (4): 671–682.

Arum, Ismi Dwi Mustika, Abdurrahman Abdurrahman, et al. 2014. Pengaruh kemampuan representasi visual terhadap hasil belajar fisika. *Jurnal Pembelajaran Fisika Universitas Lampung* 2 (5): 119018.

Asenova[1], Asya, and Michael Reiss. 2011. The role of visualization of biological knowledge in the formation of sets of educational skills.

Bustle, Lynn Sanders. 2004. The role of visual representation in the assessment of learning. *Journal of Adolescent & Adult Literacy* 47 (5): 416–423.

Canlas, Ian Phil. 2021. Using visual representations in identifying students' preconceptions in friction. *Research in Science & Technological Education* 39 (2): 156–184.

Duncan, James S, and David Ley. 2013. *Place/culture/representation.* Routledge.

Elkins, James. 2009. Introduction: the concept of visual literacy, and its limitations. In *Visual literacy,* 9–18. Routledge.

———. 2013. *Visual studies: a skeptical introduction.* Routledge.

Kelly, Martyn. 2012. The semiotics of slime: visual representation of phytobenthos as an aid to understanding ecological status. *Freshwater Reviews* 5 (2): 105–119.

Lopez, Victor, and Roser Pinto. 2017. Identifying secondary-school students' difficulties when reading visual representations displayed in physics simulations. *International Journal of Science Education* 39 (10): 1353–1380.

Masud, Muhammad Mehedi, Rulia Akhtar, Rafia Afroz, Abul Quasem Al-Amin, and Fatimah Binti Kari. 2015. Pro-environmental behavior and public understanding of climate change. *Mitigation and Adaptation Strategies for Global Change* 20:591–600.

Mayer, Richard E, and Celeste Pilegard. 2005. Principles for managing essential processing in multimedia learning: segmenting, pretraining, and modality principles. *The Cambridge handbook of multimedia learning,* 169–182.

Nurutami, A, R Riyadi, and S Subanti. 2019. Student's mathematical literacy ability on pisa's space and shape task. In *Journal of physics: conference series,* 1188:012060. 1. IOP Publishing.

Pratama, Riza, and Luthfi Parinduri. 2019. Penaggulangan pemanasan global. *Buletin Utama Teknik* 15 (1): 91–95.

Scribner, Michael Cole Sylvia. 1974. *Culture and thought: a psychological introduction.* Wiley.

Vienot, Francoise, Marie-Lucie Durand, and Elodie Mahler. 2009. Kruithof's rule revisited using led illumination. *Journal of Modern Optics* 56 (13): 1433–1446.

Weber, Elke U, and Paul C Stern. 2011. Public understanding of climate change in the united states. *American psychologist* 66 (4): 315.

Weurlander, Maria, Magnus Söderberg, Max Scheja, Håkan Hult, and Annika Wernerson. 2012. Exploring formative assessment as a tool for learning: students' experiences of different methods of formative assessment. *Assessment & Evaluation in Higher Education* 37 (6): 747–760.

Whitmarsh, Lorraine. 2009. What's in a name? commonalities and differences in public understanding of "climate change" and "global warming". *Public understanding of science* 18 (4): 401–420.

Zia, Asim, and Anne Marie Todd. 2010. Evaluating the effects of ideology on public understanding of climate change science: how to improve communication across ideological divides? *Public understanding of science* 19 (6): 743–761.