



Perceptions of Pre-service Science Teachers in Indonesia about the Greenhouse Effect (GHE)

Shelly Efwinda^{1*}, Abdul Hakim², Nadya Meriza³, Aristo Hardinata⁴, Abdul Latip⁵ 

^{1,2} Department of Physics Education, Faculty of Teacher Training and Education, Mulawarman University, Samarinda, Indonesia

² Department of Biology Education, Faculty of Teacher Training and Education, Lampung University, Lampung, Indonesia

³ Department of Science Education, Faculty of Teacher Training and Education, Medan University, Medan, Indonesia

⁴ Department of Science Education, Faculty of Teacher Training and Education, Garut University, Garut, Indonesia

*Corresponding author: shelly.efwinda@fkip.unmul.ac.id

Abstrak

Mengatasi perubahan iklim merupakan salah satu tujuan yang tercakup dalam Sustainable Development Goals (SDGs). Greenhouse Effect (GHE) adalah sumber utama pemanasan global dan perubahan iklim. Penelitian eksploratif ini bertujuan untuk mengeksplorasi persepsi calon guru IPA di Indonesia tentang GHE. Peserta penelitian adalah 265 calon guru IPA di Indonesia. Data penelitian dikumpulkan melalui kuesioner yang terdiri dari tiga pertanyaan terbuka dan 36 pertanyaan pilihan ganda. Pertanyaan-pertanyaan terbuka dianalisis melalui coding dan resume berupa mind map sedangkan pertanyaan lainnya menggunakan statistik deskriptif. Berdasarkan hasil analisis dapat disimpulkan bahwa sebagian besar calon guru belum dapat menguraikan proses terjadinya GHE secara mendetail dan masih terdapat beberapa kesalahan persepsi. Calon guru harus memiliki persepsi yang benar terhadap topik yang akan mereka ajarkan pada siswa mereka di masa depan, maka implikasi penelitian ini adalah rekomendasi untuk lembaga dan dosen pengajar pada pendidikan guru untuk membahas topik GHE secara lebih detail dan memastikan tidak ada kesalahan persepsi.

Kata Kunci: Perubahan iklim, pemanasan global, greenhouse effect, SDGs.

Abstract

Tackling climate change is one of the Sustainable Development Goals (SDGs) and concerns the world community. The greenhouse effect (GHE) is the primary source of global warming and influences climate change. This exploratory research aims to explore the perceptions of pre-service science teachers in Indonesia about the GHE. The study's participants were 265 Indonesian pre-service science teachers. Research data was collected through a questionnaire. The questionnaire consists of three open questions and 36 statements with multiple-choice responses. The open-ended inquiry is coded, and the resume is shown as a mind map. The remaining questionnaire results were examined using descriptive statistics. Based on the analysis results, it can be concluded that most prospective teachers have not been able to describe the process of GHE in detail, and there are still several misperceptions. Prospective teachers must have the correct perception of the topics they will teach their students in the future, so the implications of this research are recommendations for institutions and teaching lecturers in teacher education to discuss GHE topics in more detail and ensure there are no misperceptions.

Keywords: Climate change, global warming, greenhouse effect, SDGs.

History:

Received : October 18, 2023

Accepted : March 20, 2024

Published : April 25, 2024

Publisher: Undiksha Press

Licensed: This work is licensed under a Creative Commons Attribution 4.0 License



1. INTRODUCTION

The Earth's sustainability in the future is the hope of all people worldwide (Uralovich et al., 2023; Vasconcelos & Orion, 2021). The sustainability of the Earth can be maintained with community awareness and action to coexist with the environment wisely, which is a challenge in the 21st Century (Orion, 2019; Vasconcelos & Orion, 2021). Supporting the sustainability of the Earth is the goal of the Sustainable Development Goals (SDGs) Program. One of the main problems that the SDGs focus on is climate change. Human activities that cause climate change are one of the world's most serious issues, both now and in the future (Competente, 2019; Franz et al., 2018; Phun et al., 2020). Climate change induced by global warming is driven mainly by human activities that increase greenhouse gas (GHG) emissions,

such as carbon dioxide (CO₂) and methane (CH₄) (Ateş et al., 2017; Demaidi & Al-Sahili, 2021; Ranney & Velautham, 2021). Transportation equipment and industrial operations using fossil fuels can increase CO₂ GHG emissions and agricultural and animal husbandry activities that generate CH₄ GHG emissions (Mar et al., 2022; Nunes, 2023; Vaghar Seyedin et al., 2022). One SDG is addressing climate change challenges. Climate change knowledge is essential for affecting community behavior or activities to address climate change, particularly among young people (Busch et al., 2019; Kolenatý et al., 2022). Various programs were held to equip the community, especially young people, to deal with climate change (McNeal et al., 2017; Opuni-Frimpong et al., 2022). Plans and actions to promote environmental knowledge through education are urgently required (Suryawati et al., 2020; Wajdi et al., 2022).

In 2015, Indonesia became the world's fourth-largest emitter of GHG (Ahmed et al., 2019; Nihayah et al., 2022). In the following year, in the Nationally Determined Contribution (NDC), Indonesia committed to addressing climate change and reducing total GHG emissions (Cahyono et al., 2022; Siagian et al., 2017). One strategy for dealing with climate change is through mitigation (Nunes, 2023; Vaghar Seyedin et al., 2022). Climate change mitigation can be done by reducing GHG emissions (Bhore, 2016; Budowle et al., 2021). Education can be used to help achieve SDGs (Colmenares-Quintero et al., 2022; Hoque et al., 2022). Mitigation through education can be done by learning and teaching what kind of lifestyle needs to be applied to reduce GHG emissions (Mochizuki & Bryan, 2015; Reid, 2019). Education is considered a key to lowering GHG due to human activities (Dawson, 2015; Kurup et al., 2021). Still, education related to climate change has not yet become a priority for institutions (Hindley, 2022; Molthan-Hill et al., 2019). In education, a teacher must be teaching-ready so that the teaching implementation is carried out successfully (Rusydiyah et al., 2021; Sulaeman et al., 2022). As future teachers, pre-service teachers play an important role as facilitators in improving topic comprehension and shaping students' character. Pre-service science teachers must have strong Pedagogical Content Knowledge (PCK) in the topics taught to students, including issues related to the greenhouse effect (GHE) as part of climate change mitigation efforts. as part of climate change mitigation efforts (Jafer, 2020; Nurmatin & Purwianingsih, 2017).

Many studies have examined perceptions of climate change, global warming, and the greenhouse effect, such as those conducted by other researchers in Ghana, Montenegro, Latin America, and in Bali, Indonesia (Ćeranić et al., 2023; Dewi & Khoirunisa, 2018; Fierros-González & López-Feldman, 2021; Ofori et al., 2023). However, research that focuses on the perceptions of prospective science teachers on the issue of the greenhouse effect (GHE) still does not exist. Thus, the novelty of this study lies in its unique focus in exploring the perceptions of prospective science teachers in Indonesia regarding the greenhouse effect (GHE). This study aims to identify existing understandings and misconceptions among prospective teachers regarding GHE, which is essential for developing more effective and accurate learning strategies in science education. Thus, this study not only adds to the existing literature but also provides significant practical implications for continuing education in Indonesia, particularly in preparing prospective teachers who are able to teach with a correct understanding of crucial environmental issues.

2. METHODS

This research is exploratory. This exploratory research was conducted to explore the perceptions of pre-service science teachers in Indonesia about the GHE. After obtaining an overview of the perceptions of prospective science teachers, it is hoped that this can be the first step in determining what actions need to be taken to contribute to solving the problem of

climate change. Research is carried out to explore a topic about which little is known or possible to investigate, conducting certain research studies as follow-up studies (Swaraj, 2019). The research participants were 265 pre-service teachers from Java, Sumatra, and Borneo (three of the five major islands in Indonesia). The sampling technique used was non-probability sampling using a questionnaire distributed to prospective science teachers. The questionnaire was distributed online using Google Forms. A total of 265 future teachers were willing to participate by filling out the questionnaire. From the regional background, 265 participants came from Java, Sumatra, and Borneo, Indonesia. Details of participants in the study are presented in [Table 1](#).

Table 1. Details of Participants

Gender	Level								Total	
	2 nd		4 th		6 th		8 th		F	%
	F	%	F	%	F	%	F	%		
Male	10	3.8	7	2.6	9	3.4	15	5.7	41	15.5
Female	43	16.2	59	22.3	34	12.8	88	33.2	224	84.5
Total	53	20.0	66	24.9	43	17.2	103	38.9	265	100.0

Research Instrument

The research instrument used was a questionnaire adapted from previous researchers (Boyes et al., 1993; Jafer, 2020). The research instruments are presented in detail in [Table 2](#).

Table 2. Detail Information about the Research Questionnaire

Type of Questionnaire	Aspects	Item Number
Part A: Three open questions	Definition of GHE	1
	The impact of GHE	2
	The causes of GHE	3
Part B: 36 statements with three answer choices: true, false, and no idea	The impact of GHE	1-12
	The causes of GHE	13-24
	Solutions to minimize the GHE	25-36

Research Procedure and Data Analysis

Three experts first validated the questionnaire regarding content and language through Focus Group Discussion (FGD). Validation results from experts stated that several question items in the questionnaire needed to be changed in context to suit the conditions or situation in Indonesia. Details are presented in [Table 3](#).

Table 3. Detailed Information about adapting the questionnaire

Original Statement	Adaptation statement	Item Number	Reasons for adaptation
If the greenhouse effect gets more extensive, some of our tap (drinking) water will become unsafe to drink.	If GHE increases, then sources of drinking water will become unsafe.	6	The use of tap (drinking) water is not yet every day in Indonesia

Original Statement	Adaptation statement	Item Number	Reasons for adaptation
There are no open questions.	Added some open questions	Part A (No. 1,2, dan 3)	To obtain a more in-depth picture regarding the perceptions of prospective science teachers

The validated questionnaire was then completed in the form of a Google form. The link was provided to pre-service science teachers in Indonesia, and 265 of them completed the questionnaire. The completed questionnaire was then processed for description. Data processing for three open statements is done by coding, grouping answers with the same meaning, and then creating a mind map of all responses based on pre-service teachers' perceptions. Data processing for 36 statements was done through descriptive statistics by calculating the percentage of true, false, and no-idea answers for each statement. Then, the results are compared to determine whether they follow the answer key.

3. RESULTS AND DISCUSSION

Result

Perceptions of Pre-service Teachers on the Definition of the GHE

Based on pre-service teachers' perceptions, most pre-service teachers define the GHE as an event where solar radiation is trapped in and by the atmosphere and the trapped reflection of the sun's heat by gases in the atmosphere. In more detail, the answers of pre-service teachers regarding the definition of the GHE are presented in Figure 1.

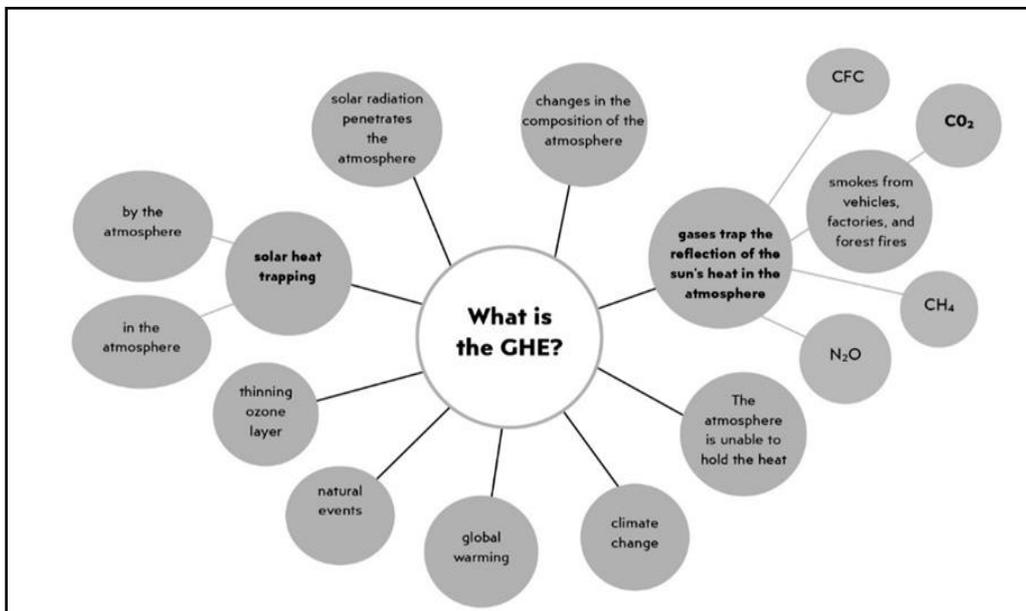


Figure 1. Perceptions of Pre-service Teachers on the Definition of the GHE

Perceptions of Pre-service teachers about the impact of the GHE

Perceptions of pre-service teachers concerning the effects of the GHE are presented in Figure 2 and Table 4.

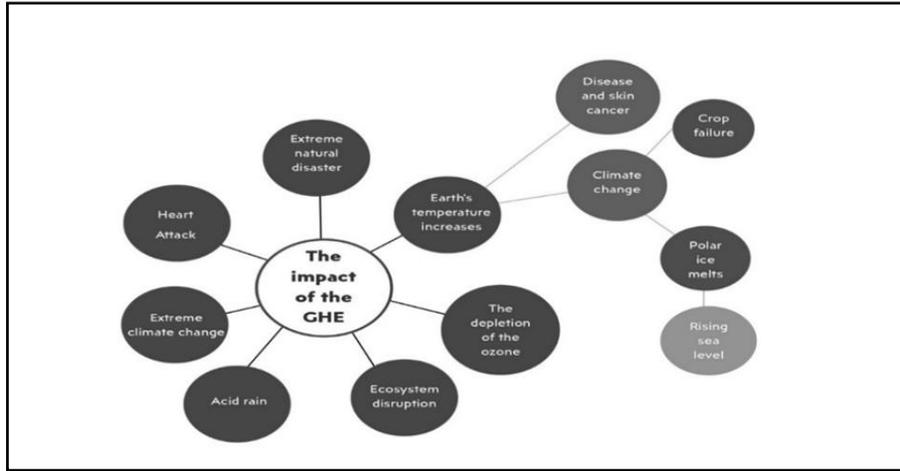


Figure 2. Perceptions of Pre-service Teachers on the Impacts of the GHE

The answers of pre-service teachers to the part B questionnaire on the impact of the GHE are presented in Table 4.

Perceptions of Pre-service teachers about the causes of the GHE

Perceptions of pre-service teachers concerning the grounds of the GHE are presented in Figure 3 and Table 5.

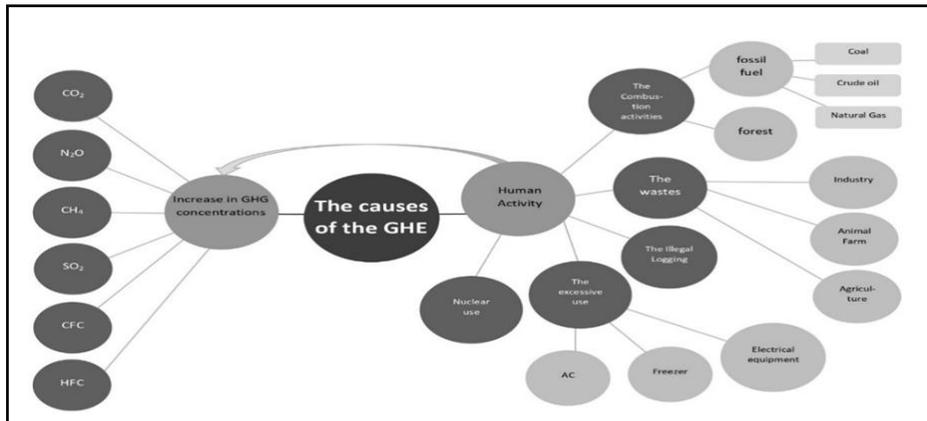


Figure 3. Perceptions of Pre-service Teachers on the Causes of the GHE

Table 4. Perceptions of Pre-service teachers about the impact of the GHE

Statement Number	Perceptions of Pre-service teachers						Answer key
	Σ True	%	Σ False	%	Σ No Idea	%	
1	263	99.2	1	0.4	1	0.4	True
2	138	52.1	77	29.1	50	18.9	False
3	188	70.9	55	20.8	22	8.3	True
4	163	61.5	58	21.9	44	16.6	False
5	230	86.8	12	4.5	23	8.7	False
6	193	72.8	36	13.6	36	13.6	False
7	139	52.5	49	18.5	77	29.1	True
8	257	97.0	0	0.0	8	3.0	True

Statement Number	Perceptions of Pre-service teachers						Answer key
	Σ True	%	Σ False	%	Σ No Idea	%	
9	73	27.5	101	38.1	91	34.3	False
10	154	58.1	57	21.5	54	20.4	True
11	251	94.7	4	1.5	10	3.8	True
12	86	32.5	101	38.1	78	29.4	False

The answers of pre-service teachers to the part B questionnaire on the causes of GHE are presented in [Table 5](#).

Table 5. Perceptions of Pre-service teachers about the causes of the GHE

Statement Number	Perceptions of Pre-service teachers						Answer key
	Σ True	%	Σ False	%	Σ No Idea	%	
13	171	64.5%	61	23.0%	33	12.5%	True
14	192	72.5%	53	20.0%	20	7.5%	False
15	212	80.0%	24	9.1%	29	10.9%	True
16	153	57.7%	61	23.0%	51	19.2%	False
17	140	52.8%	95	35.8%	30	11.3%	False
18	191	72.1%	45	17.0%	29	10.9%	True
19	207	78.1%	18	6.8%	40	15.1%	False
20	190	71.7%	44	16.6%	31	11.7%	False
21	212	80.0%	13	4.9%	40	15.1%	True
22	146	55.1%	69	26.0%	50	18.9%	True
23	219	82.6%	20	7.5%	26	9.8%	False
24	198	74.7%	30	11.3%	37	14.0%	False

Perceptions of Pre-service teachers about the solutions to minimize the GHE [Table 6](#) shows pre-service teachers' perspectives on the solutions to minimize the GHE.

Table 6. Perceptions of Pre-service teachers about the solutions to minimize the GHE

Statement Number	Perceptions of Pre-service teachers						Answer key
	Σ True	%	Σ False	%	Σ No Idea	%	
25	135	50.9%	45	17.0%	85	32.1%	True
26	116	43.8%	102	38.5%	47	17.7%	False
27	169	63.8%	54	20.4%	42	15.8%	False
28	169	63.8%	28	10.6%	68	25.7%	False
29	174	65.7%	23	8.7%	68	25.7%	False
30	252	95.1%	4	1.5%	9	3.4%	True
31	195	73.6%	19	7.2%	51	19.2%	True
32	201	75.8%	26	9.8%	38	14.3%	True
33	168	63.4%	57	21.5%	40	15.1%	False
34	210	79.2%	28	10.6%	27	10.2%	True
35	72	27.2%	134	50.6%	59	22.3%	False
36	226	85.3%	20	7.5%	19	7.2%	True

Discussions

Overall, there are still many misperceptions that pre-service teachers have and need to be straightened out. This research aligns with similar research, who show that undergraduate students still have insufficient knowledge and a wrong conceptual understanding regarding GHE and climate change (Damayanti et al., 2023; Geiger et al., 2017). Climate change, global warming, and GHE are serious problems, but many global misconceptions exist (Hannula, 2022; Mochizuki & Bryan, 2015). The misperceptions of pre-service teachers must be a concern for educators in teacher education institutions. As future teachers, pre-service teachers must correctly perceive the topics they teach their students. Figure 1 shows that some pre-service teachers can define the basic understanding of the GHE that GHE occurs due to the presence of gases that absorb the reflection of solar heat radiation in the atmosphere. The GHE is a natural process that describes the absorption of long-wave radiation (infrared) by GHGs so that they are trapped in the Earth's atmosphere and cause the Earth to be warm and livable (Etobro, 2020; Jafer, 2020). An increase in GHG can lead to increased absorbed long-wave radiation, which causes global warming. However, some pre-service teachers still have misperceptions; for example, pre-service teacher number 13 (PT-13) stated that the GHE is an event where the atmosphere cannot retain heat.

Figure 2 shows that based on pre-service teachers' perceptions, the impacts caused by increased GHE include increasing the Earth's temperature, extreme climate change, natural disasters, and ecosystem disruption; this corresponds to (Asimakopoulou et al., 2021; Handayani & Triyanto, 2022). However, some have the wrong perception that an increase in the GHE can lead to a rise in heart disease, skin cancer, and acid rain. The understanding that an increase in the GHE can lead to an increased risk of skin cancer is a misconception (Etobro, 2020; Jafer, 2020). This research follows the results of previous study, which show that students have insufficient knowledge, and there are still misconceptions among students regarding the causes and impacts of climate change (Fierros-González & López-Feldman, 2021; Ofori et al., 2023).

Table 4 shows that statements 1, 8, and 11 are statements that most pre-service teachers correctly perceive that the increase in the GHE causes the Earth to warm up, climate change in the world, and melting polar ice (Asimakopoulou et al., 2021; Demaidi & Al-Sahili, 2021). Statements number 5 and 6 are statements that most pre-service teachers have the wrong perception that an increase in the GHE causes an increase in the possibility of having skin cancer and an increase in the GHE can make drinking water sources unsafe. Statement number 9 is that most pre-service teachers choose the answer option with 'no idea.' This statement states that an increase in the GHE can lead to an increased risk of heart disease. Figure 3 shows that pre-service teachers already know that some human activities can cause an increase in GHG, so the GHE also increases. For example, PT-30 states that human activities that can cause an increase in GHE are using fossil fuels and burning forests.

PT-30: *"The increase in the GHE can be caused by human activities such as burning fossil fuels, the high use of motorized vehicles, chemical fertilizers in agriculture, illegal logging, and forest burning."*

However, the answers given by pre-service teachers have not explained in depth how these human activities can increase GHE. Several misperceptions were also pointed out by some pre-service teachers, for example, PT-33's answer, which stated that the use of nuclear was one of the causes of an increase in the GHE.

PT-33: *"Increased GHE caused by burning fuel, deforestation, forest fires, coal burning, nuclear use, etc."*

Another misperception was also pointed out by PT-76, which stated that sulfur dioxide (SO₂) is a greenhouse gas. SO₂ is one of the gases that cause acid rain and is not included as a GHG. GHG include CO₂, CH₄, nitrous oxide (N₂O), ozone (O₃), chlorofluorocarbons (CFC), water vapor (H₂O), and hydrofluorocarbon (HFC) (Franz et al., 2018; Kurup et al., 2021; Peyyala & Sudheer, 2017; Thacker & Sinatra, 2019). Table 5 shows that statements 15 and 21 are statements that most pre-service teachers have the correct perception that the increase in the GHE is exacerbated by increasing carbon dioxide and CFC gases. CO₂ and CFC are GHG, so their atmospheric growth can increase GHE. Statements number 19 and 23 are statements that most pre-service teachers wrongly perceive that the increase in the GHE is exacerbated by the rise in radioactive waste from nuclear power plants and is exacerbated by holes in the ozone layer. The depletion of the ozone layer is not a cause of the GHE but rather an impact of the GHE, CFC can damage the ozone layer. Statement number 22 states that most pre-service teachers choose the answer option with 'no idea.' This statement says that the GHE increase is exacerbated by gas from artificial fertilizers. The rise in GHE can be caused by increased CO₂ in the air and synthetic fertilizers (Boyes et al., 1993; Jafer, 2020).

Reduced greenhouse gas emissions are one mitigation strategy for combating climate change (IPCC, 2021; Reid, 2019). Table 6 shows that statements 30, 34, and 36 are the statements that most pre-service teachers correctly perceive that the GHE can be reduced by planting more trees worldwide, not wasting electricity, and not using vehicles powered by fossil fuels too often. The results of this research align with similar research, which shows that students believe that fighting global warming can be done by reducing the use of fossil energy (Ćeranić et al., 2023; Dewi & Khoirunisa, 2018). Statements 27, 28, and 29 are statements that most pre-service teachers wrongly perceive that the GHE can be reduced by keeping beaches clean, using unleaded gasoline, and reducing the number of nuclear bombs worldwide. Statements 25 and 35 are the statements in which most pre-service teachers choose the answer option with 'no idea.' These statements are that the GHE can be reduced by having a nuclear power plant instead of a coal-fired power plant and reducing world hunger. The use of nuclear is a misperception that appears in aspects that cause GHE and solutions to minimize the increase in GHE. Some pre-service teachers believe that using nuclear energy can cause an increase in GHE, so the key to reducing the rise in GHE is to minimize the use of atomic energy. However, using nuclear can be one way to reduce fossil fuels. Atomic energy is touted as an alternative to clean energy, supporting the SDGs (Jin & Kim, 2018; Yue et al., 2022).

The advantage of this research is that it has a broader range of research participants, namely prospective science teachers from several regions in Indonesia, so that it can complement the results of previous research, which identified future teachers' perceptions of the greenhouse effect issue in only one region in Indonesia (Damayanti et al., 2023; Geiger et al., 2017). This research can contribute to educational institutions for prospective teachers, especially prospective science teachers, to increase attention to education about climate change, global warming, and GHE, for example, by integrating education related to these topics into the lecture curriculum because there are still many prospective teachers who have misperceptions regarding this issue. The limitation of this research is that it has not identified further whether there are differences in the perceptions of prospective teachers in different gender groups. Apart from that, the results of this research are only limited to describing perceptions; currently, no action has been taken to increase students' knowledge regarding the issue of the greenhouse effect. So, further research needs to be carried out to find the best strategies that can be used to increase students' knowledge regarding the problem of the GHE

4. CONCLUSION

According to the findings, most pre-service teachers have a broad comprehension of the description of the GHE but cannot articulate how the process works in depth. Pre-service teachers have misperceptions about the influence of the GHE; for example, an increase in the GHE can raise the risk of skin cancer, heart disease, and other diseases. Misperceptions held by pre-service teachers concerning the causes of GHE include claims that the ozone layer is depleted and nuclear weapons are used to induce GHE. Educators must address pre-service teachers' misperceptions in teacher education institutions to develop suitable content delivery methodologies so that pre-service teachers no longer misbehave.

5. ACKNOWLEDGMENT

The authors would like to thank the Faculty of Teacher Training and Education, Mulawarman University, for the financial support provided for this research activity. We would also like to thank the research participants who were willing to participate in this research to obtain an overview of the perceptions of prospective science teachers in Indonesia regarding the GHE issue.

6. REFERENCES

- Ahmed, Z., Wang, Z., & Ali, S. (2019). Investigating the non-linear relationship between urbanization and CO₂ emissions: An empirical analysis. *Air Quality, Atmosphere & Health*, 12, 945–953. <https://doi.org/10.1007/s11869-019-00711-x>.
- Asimakopoulou, P., Nastos, P., Vassilakis, E., Hatzaki, M., & Antonarakou, A. (2021). Earth observation as a facilitator of climate change education in schools: The teachers' perspectives. *Remote Sensing*, 13(8), 1587. <https://doi.org/10.3390/rs13081587>.
- Ateş, D., Teksöz, G., & Ertepinar, H. (2017). Exploring the Role of Future Perspective in Predicting Turkish University Students' Beliefs About Global Climate Change. *Discourse and Communication for Sustainable Education*, 8(1), 32–52. <https://doi.org/10.1515/dcse-2017-0003>.
- Bhore, S. J. (2016). Paris agreement on climate change: A booster to enable sustainable global development and beyond. *International Journal of Environmental Research and Public Health*, 13(11), 1134. <https://doi.org/10.3390/ijerph13111134>.
- Boyes, E., Chuckran, D., & Stanisstreet, M. (1993). How do high school students perceive global climatic change: What are its manifestations? What are its origins? What corrective action can be taken? *Journal of Science Education and Technology*, 2(4), 541–557. <https://doi.org/10.1007/BF00695323>.
- Budowle, R., Krszjzaniek, E., & Taylor, C. (2021). Students as change agents for community–university sustainability transition partnerships. *Sustainability*, 13(11), 1–26. <https://doi.org/10.3390/su13116036>.
- Busch, K. C., Ardoin, N., Gruehn, D., & Stevenson, K. (2019). Exploring a theoretical model of climate change action for youth. *International Journal of Science Education*, 41(17), 2389–2409. <https://doi.org/10.1080/09500693.2019.1680903>.
- Cahyono, W. E., Joy, B., Setyawati, W., & Mahdi, R. (2022). Projection of CO₂ emissions in Indonesia. *Materials Today: Proceedings*, 63, S438–S444. <https://doi.org/10.1016/j.matpr.2022.04.091>.
- Ćeranić, G., Krivokapić, N., Šarović, R., & Živković, P. (2023). Perception of Climate Change and Assessment of the Importance of Sustainable Behavior for Their Mitigation: The Example of Montenegro. *Sustainability (Switzerland)*, 15(13), 10165. <https://doi.org/10.3390/su151310165>.

- Colmenares-Quintero, R. F., Barbosa-Granados, S., Rojas, N., Stansfield, K. E., Colmenares-Quintero, J. C., Ruiz-Candamil, M., & Cano-Perdomo, P. (2022). Learning and teaching styles in a public school with a focus on renewable energies. *Sustainability*, *14*(23), 15545. <https://doi.org/10.3390/su142315545>.
- Competente, R. J. T. (2019). Pre-service teachers' inclusion of climate change education. *International Journal of Evaluation and Research in Education*, *8*(1), 119–126. <https://doi.org/10.11591/ijere.v8i1.16923>.
- Damayanti, P., Efwinda, S., & Junus, M. (2023). Perceptions of Pre-Service Science Teachers in Nusantara Capital City About The Greenhouse Effect. *Jurnal Pendidikan Sains (JPS)*, *11*(1), 9–20. <https://doi.org/10.26714/jps.11.1.2023.9-20>.
- Dawson, V. (2015). Western Australian High School Students' Understandings about the Socioscientific Issue of Climate Change. *International Journal of Science Education*, *37*(7), 1024–1043. <https://doi.org/10.1080/09500693.2015.1015181>.
- Demaidi, M. N., & Al-Sahili, K. (2021). Integrating sdgs in higher education—case of climate change awareness and gender equality in a developing country according to rmei-target strategy. *Sustainability*, *13*(6), 3101. <https://doi.org/10.3390/su13063101>.
- Dewi, R. P., & Khoirunisa, N. (2018). Middle school student's perception of climate change at Boyolali District, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *200*(1). <https://doi.org/10.1088/1755-1315/200/1/012061>.
- Etobro, B. A. (2020). Pre-service biology teachers' perception of global warming, greenhouse effect and ozone layer depletion in Lagos state university. *Global Journal of Educational Research*, *19*(1), 9–14. <https://doi.org/10.4314/gjedr.v19i1.3>.
- Fierros-González, I., & López-Feldman, A. (2021). Farmers' Perception of Climate Change: A Review of the Literature for Latin America. *Frontiers in Environmental Science*, *9*, 1–7. <https://doi.org/10.3389/fenvs.2021.672399>.
- Franz, D., Acosta, M., Altimir, N., Arriga, N., Arrouays, D., Aubinet, M., Aurela, M., Ayres, E., López-Ballesteros, A., Barbaste, M., Berveiller, D., Biraud, S., Boukir, H., Brown, T., Brömmer, C., Buchmann, N., Burba, G., Carrara, A., Cescatti, A., ... Vesala, T. (2018). Towards long-Term standardised carbon and greenhouse gas observations for monitoring Europe's terrestrial ecosystems: A review. *International Agrophysics*, *32*(4), 439–455. <https://doi.org/10.1515/intag-2017-0039>.
- Geiger, N., Swim, J. K., & Fraser, J. (2017). Creating a climate for change: Interventions, efficacy and public discussion about climate change. *Journal of Environmental Psychology*, *51*, 104–116. <https://doi.org/10.1016/j.jenvp.2017.03.010>.
- Handayani, R. A. D., & Triyanto, T. (2022). Seventh-grade students' conceptions of climate change, global warming, and the greenhouse effect. *Journal of Geoscience Education*, *70*(4), 490–500. <https://doi.org/10.1080/10899995.2021.1989941>.
- Hannula, K. A. (2022). Education about climate change. *Journal of Geoscience Education*, *70*(4), 423. <https://doi.org/10.1080/10899995.2022.2115763>.
- Hindley, A. (2022). Understanding the Gap between University Ambitions to Teach and Deliver Climate Change Education. *Sustainability*, *14*(21), 13823. <https://doi.org/10.3390/su142113823>.
- Hoque, F., Yasin, R. M., & Sopian, K. (2022). Revisiting Education for Sustainable Development: Methods to Inspire Secondary School Students toward Renewable Energy. *Sustainability*, *14*(14), 8296. <https://doi.org/10.3390/su14148296>.
- IPCC. (2021). Climate Change 2021 The Physical Science Basis WGI. In *Bulletin of the Chinese Academy of Sciences* (Vol. 34, Issue 2)..
- Jafer, Y. J. (2020). Assessing Kuwaiti Pre-service Science Teachers' Greenhouse Effect Perceptions and Misconceptions. *International Journal of Science and Mathematics Education*, *18*(4), 657–667. <https://doi.org/10.1007/s10763-019-09992-1>.

- Jin, T., & Kim, J. (2018). What is better for mitigating carbon emissions – Renewable energy or nuclear energy? A panel data analysis. *Renewable and Sustainable Energy Reviews*, *91*, 464–471. <https://doi.org/10.1016/j.rser.2018.04.022>.
- Kolenatý, M., Kroufek, R., & Činčera, J. (2022). What Triggers Climate Action: The Impact of a Climate Change Education Program on Students' Climate Literacy and Their Willingness to Act. *Sustainability*, *14*(16). <https://doi.org/10.3390/su141610365>.
- Kurup, P. M., Levinson, R., & Li, X. (2021). Informed-Decision Regarding Global Warming and Climate Change Among High School Students in the United Kingdom. *Canadian Journal of Science, Mathematics and Technology Education*, *21*(1), 166–185. <https://doi.org/10.1007/s42330-020-00123-5>.
- Mar, K. A., Unger, C., Walderdorff, L., & Butler, T. (2022). Beyond CO2 equivalence: The impacts of methane on climate, ecosystems, and health. *Environmental Science and Policy*, *134*, 127–136. <https://doi.org/10.1016/j.envsci.2022.03.027>.
- McNeal, P., Petcovic, H., & Reeves, P. (2017). What is motivating middle-school science teachers to teach climate change? *International Journal of Science Education*, *39*(8), 1069–1088. <https://doi.org/10.1080/09500693.2017.1315466>.
- Mochizuki, Y., & Bryan, A. (2015). Climate Change Education in the Context of Education for Sustainable Development: Rationale and Principles. *Journal of Education for Sustainable Development*, *9*(1), 4–26. <https://doi.org/10.1177/0973408215569109>.
- Molthan-Hill, P., Worsfold, N., Nagy, G. J., Leal Filho, W., & Mifsud, M. (2019). Climate change education for universities: A conceptual framework from an international study. *Journal of Cleaner Production*, *226*, 1092–1101. <https://doi.org/10.1016/j.jclepro.2019.04.053>.
- Nihayah, D. M., Mafruhah, I., Hakim, L., & Suryanto, S. (2022). CO2 Emissions in Indonesia: The Role of Urbanization and Economic Activities towards Net Zero Carbon. *Economies*, *10*(4). <https://doi.org/10.3390/economies10040072>.
- Nunes, L. J. R. (2023). The Rising Threat of Atmospheric CO2: A Review on the Causes, Impacts, and Mitigation Strategies. *Environments - MDPI*, *10*(4), 66. <https://doi.org/10.3390/environments10040066>.
- Nurmatin, S., & Purwianingsih, W. (2017). Capturing the PCK ability of prospective science teachers using core and PaP-Er. *Jurnal Pendidikan IPA Indonesia*, *6*(2), 271–276. <https://doi.org/10.15294/jpii.v6i2.9507>.
- Ofori, B. Y., Ameade, E. P. K., Ohemeng, F., Musah, Y., Quartey, J. K., & Owusu, E. H. (2023). Climate change knowledge, attitude and perception of undergraduate students in Ghana. *PLOS Climate*, *2*(6). <https://doi.org/10.1371/journal.pclm.0000215>.
- Opuni-Frimpong, N. Y., Essel, H. B., Opuni-Frimpong, E., & Obeng, E. A. (2022). Sustainable Development Goal for Education: Teachers' Perspectives on Climate Change Education in Senior High Schools (SHS). *Sustainability*, *14*(13). <https://doi.org/10.3390/su14138086>.
- Orion, N. (2019). The future challenge of Earth science education research. *Disciplinary and Interdisciplinary Science Education Research*, *1*(1), 1–8. <https://doi.org/10.1186/s43031-019-0003-z>.
- Peyyala, A., & Sudheer, N. V. V. S. (2017). Experimental Investigation of COP Using Hydro Carbon Refrigerant in a Domestic Refrigerator. *IOP Conference Series: Materials Science and Engineering*, *225*(1). <https://doi.org/10.1088/1757-899X/225/1/012236>.
- Phun, Y., Chauca, M., Curro, O., Chauca, C., Yallico, R., & Quispe, V. (2020). Disruptive education based on action characterizing ecoenvironmental variables to mitigate global warming. *Procedia Computer Science*, *172*(2019), 979–984. <https://doi.org/10.1016/j.procs.2020.05.142>.
- Ranney, M. A., & Velautham, L. (2021). Climate change cognition and education: given no

- silver bullet for denial, diverse information-hunks increase global warming acceptance. *Current Opinion in Behavioral Sciences*, 42, 139–146. <https://doi.org/10.1016/j.cobeha.2021.08.001>.
- Reid, A. (2019). Climate change education and research: possibilities and potentials versus problems and perils? *Environmental Education Research*, 25(6), 767–790. <https://doi.org/10.1080/13504622.2019.1664075>.
- Rusdiyati, E. F., Indarwati, D., Jazil, S., Susilawati, S., & Gusniwati, G. (2021). Stem learning environment: Perceptions and implementation skills in prospective science teachers. *Jurnal Pendidikan IPA Indonesia*, 10(1), 138–148. <https://doi.org/10.15294/jpii.v10i1.28303>.
- Siagian, U. W., Yuwono, B. B., Fujimori, S., & Masui, T. (2017). Low-carbon energy development in Indonesia in alignment with Intended Nationally Determined Contribution (INDC) by 2030. *Energies*, 10(1), 1–15. <https://doi.org/10.3390/en10010052>.
- Sulaeman, N. F., Efwinda, S., & Putra, P. D. A. (2022). Teacher readiness in STEM education: Voices of Indonesian physics teachers. *Journal of Technology and Science Education*, 12(1), 68–82. <https://doi.org/10.3926/jotse.1191>.
- Suryawati, E., Suzanti, F., Zulfarina, Z., Putriana, A. R., & Febrianti, L. (2020). The implementation of local environmental problem-based learning student worksheets to strengthen environmental literacy. *Jurnal Pendidikan IPA Indonesia*, 9(2), 169–178. <https://doi.org/10.15294/jpii.v9i2.22892>.
- Swaraj, A. (2019). Exploratory Research: Purpose And Process. *Parisheelan Journal*, 15(2), 666–670.
- Thacker, I., & Sinatra, G. M. (2019). Visualizing the greenhouse effect: Restructuring mental models of climate change through a guided online simulation. *Education Sciences*, 9(1), 14. <https://doi.org/10.3390/educsci9010014>.
- Uralovich, K. S., Toshmamatovich, T. U., Kubayevich, K. F., Sapaev, I. B., Saylaubaevna, S. S., Beknazarova, Z. F., & Khurramov, A. (2023). A primary factor in sustainable development and environmental sustainability is environmental education. *Caspian Journal of Environmental Sciences*, 21(4), 965–975. <https://doi.org/10.22124/CJES.2023.7155>.
- Vaghar Seyedin, S. M., Zeidi, A., Chamanehpour, E., Nasri, M. H. F., & Vargas-Bello-Pérez, E. (2022). Methane Emission: Strategies to Reduce Global Warming in Relation to Animal Husbandry Units with Emphasis on Ruminants. *Sustainability*, 14(24). <https://doi.org/10.3390/su142416897>.
- Vasconcelos, C., & Orion, N. (2021). Earth science education as a key component of education for sustainability. *Sustainability*, 13(3), 1–11. <https://doi.org/10.3390/su13031316>.
- Wajdi, M., Jamaluddin, A. B., Nurdianti, N., & Maghfirah, N. (2022). The effectiveness of problem-based learning with environmental-based comic in enhancing students environmental literacy. *International Journal of Evaluation and Research in Education*, 11(3), 1049–1057. <https://doi.org/10.11591/ijere.v11i3.22140>.
- Yue, X., Yao-Ping Peng, Michael Anser, M. K., Nassani, A. A., Haffar, M., & Zaman, K. (2022). The role of carbon taxes, clean fuels, and renewable energy in promoting sustainable development: How green is nuclear energy?, *Renewable Energy*. *Renewable Energy*, 193, 167–178. <https://doi.org/10.1016/j.renene.2022.05.017>.