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Investigating Knowledge of Indonesian Pre-service Science Teachers on the Greenhouse Effect Issue

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Abstract

Teacher education institutions must pay attention so that future teachers have a strong and correct concept to teach actual knowledge to their students. This study explores Indonesian pre-service science teachers' (PSTs') knowledge of the Greenhouse Effect (GHE). The research participants were 187 Indonesian PSTs. The sampling technique used in this study was purposive sampling. The research instrument used was a questionnaire survey of 24 knowledge questions with three answer choices (true, wrong, or do not know) and two open questions. The PSTs' knowledge data were analyzed through statistics and the Mann-Whitney test. The results of the data analysis showed that PSTs' knowledge was in a low category, with an average score of 66.82. There was no significant difference between the knowledge of junior (2nd and 4th semester) and senior (6th and 8th semester) PSTs shown by a significance value of 0.445 > 0.005. Our findings also show that their knowledge of this issue is only superficial; for example, most of them mentioned that they had learned about the GHE process, but their explanations of how the GHE occurs were not detailed. Therefore, Institutions must strengthen their curriculum to equip PSTs with accurate and actionable knowledge of the GHE.

Keywords: climate change; global warming; greenhouse effect; pre-service teachers; science

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INTRODUCTION

The scientific community has found that human activities that produce greenhouse gas (GHG) emissions are the leading cause of the greenhouse effect (GHE), global warming (Freije et al., 2017; IPCC, 2021), and climate change (Aksoy & Erten, 2022; Mazzalai et al., 2022; Oh & Jeon, 2017). Global warming and climate change are serious issues currently faced by the worldwide community (Hestness et al., 2019; Kurup et al., 2021; Urbańska et al., 2022). In response to these global issues, climate change adaptation and mitigation have become a top priority (Nayan et al., 2020) and are included in one of the SDGs, SDG 13.

One of the efforts communities can undertake to mitigate climate change is education (Hannah & Rhubart, 2020). Such efforts have already begun, for example, through sustainable programmes organized by schools (Arto-Blanco et al., 2017). However, teaching topics related to climate change remains challenging due to their complex underlying principles (Breslyn & McGinnis, 2019; Lombardi et al., 2017; Oh & Jeon, 2017). Even classrooms can become places of misinformation (Hannah & Rhubart, 2020). Preparing teachers to teach this issue in the school is a current need (González, 2021). Therefore, pre-service science teachers (PSTs) as

future teachers require a strong understanding of climate change-related topics to teach about these issues effectively.

Knowledge is the meaning we give to reality arising from our daily contact between our minds and the environment (Nyarko & Petcovic, 2021). Knowledge about climate change plays a vital role in how a person acts in combating climate change (Higuchi et al., 2018). Mastering knowledge about climate change issues can affect one's skepticism toward this issue (Trémolière & Djeriouat, 2021) and make someone more interested in discussing this issue (Cooper et al., 2019).

Increasing scientific literacy is an educational practice believed to reduce activities that can increase GHG (Tobin & Alexakos, 2021). This aligns with one of the learning objectives of SDG 13, which is for students to understand GHE as a natural phenomenon caused by GHG isolation (UNESCO, 2017). To achieve SDG 13, teachers play an essential role as implementers of climate change education. How teachers understand the topic will affect what they teach their students (Nyarko & Petcovic, 2021). Teachers need to have a strong knowledge of the content (Gunamantha & Dantes, 2019) and appropriate teaching methods to create learning that can increase students' awareness and interest in protecting the environment (Hoque et al., 2022; Meilinda et al., 2017).

Research related to climate change, especially young people's knowledge of climate change, must be intensified. Several studies related to the issue of climate change education have been carried out, for example, by, which shows that the knowledge of pre-service teachers in Malaysia about climate change is in the high category (Nayan et al., 2020). According to research by (Powers et al., 2021) in the USA, Senior students have a higher average knowledge than their juniors.

Several studies related to this issue have also been carried out in Indonesia. For example, in Bali, Indonesia, elementary school students in the village of Buleleng, Bali, have misconceptions about basic knowledge about climate change (Gunamantha & Dantes, 2019). Junior high school students in urban areas better understand climate change than those in rural areas (Dewi & Khoirunisa, 2018). A study by (Laliyo et al., 2020) shows that most high school seniors are not worried about the effects of global warming. The results of these studies indicate that the knowledge and attention of Indonesian students regarding this issue are still lacking, and may be due to teachers' limited knowledge when teaching.

Research on Indonesian teachers shows that teachers' understanding of climate change is still lacking (Sofiyan et al., 2019). Research on pre-service teachers as participants shows they still have misconceptions about global warming (Winarno et al., 2019). Although some research has been conducted, the knowledge gap regarding PST remains under-explored, and comparative analyses between juniors and seniors in Indonesia are still lacking. Prospective science teachers need to have a strong knowledge of concepts related to environmental issues, including GHE, as they can play a role in solving environmental problems, especially through education.

Therefore, it is essential to explore PSTs' knowledge regarding the issue of climate change, especially related to GHE, which is one of the primary roots of climate change. In addition, several years ago, attention to environmental issues was not as high as it is today, so it can be assumed that prospective senior teachers do not yet have sufficient knowledge about this issue. If this is proven to be the case, then additional information related to environmental issues and potential solutions needs to be provided.

As a guide in conducting research, the questions in this research include:

a. What is the Indonesian PSTs' knowledge about the causes and effects of the GHE?
b. Are there significant differences in knowledge about the GHE between Indonesian juniors (2nd and 4th-semester students) and seniors PSTs (6th and 8th-semester students)?

This study aims to explore Indonesian PSTs' knowledge regarding the issue of GHE.

METHOD

Design and Participants

This survey research design aims to explore Indonesian PSTs' knowledge of the causes and effects of GHE. The research participants were 187 students of science, physics, chemistry, and biology education study programs as PSTs from several public and privat universities in Indonesia. The number of PSTs in their area is presented graphically in Figure 1.

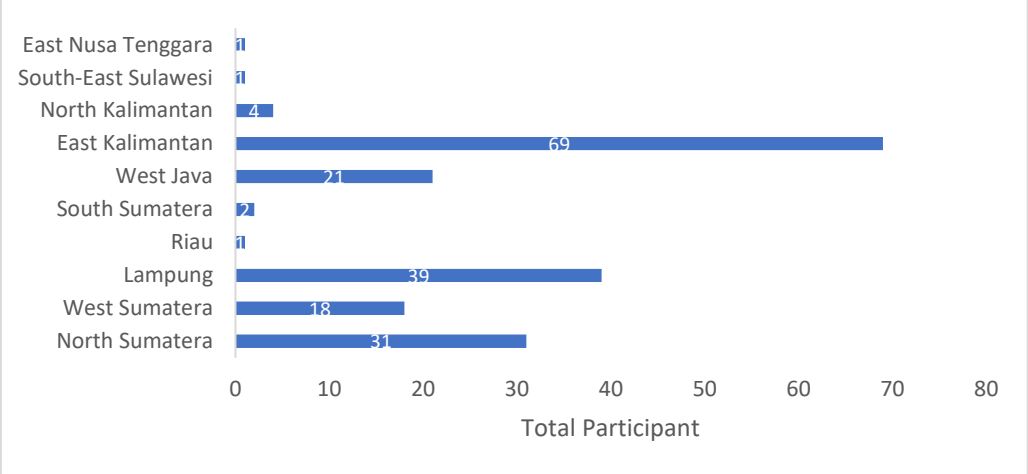

Figure 1. Number of participants based on their province

The sampling technique used in this study was purposive sampling, and considerations for selecting the sample included PSTs from different provinces and study levels. The number of participants by gender and level of study is presented in detail in Table 1.

Table 1. Details of participants based on the level and gender of PSTs

Level of study	Semester	Gender				Total	
		Female		Male			
		total	percentage	total	percentage	total	percentage
Junior	2nd semester	37	20	10	5	47	25
	4th semester	34	18	15	8	49	26
Senior	6th semester	38	20	10	5	48	26
	8th semester	40	21	3	2	43	23
Total		149	80	38	20	187	100

Instrument Development and Validation

The research instruments used in this study were 24 knowledge questions adapted from (Jafer, 2020), with the instrument's reliability measured using Cronbach's alpha coefficient and found to be 0.922. 24 The questions in the questionnaire consist of two aspects: the causes of GHE (numbers 1-12) and the impacts if GHE increases (numbers 13-24). In addition to 24 multiple-choice questions, the questionnaire included two open-ended questions. Two open-ended questions that experts verified as additional questions are related to what PSTs have learned and what they would like to know more about GHE.

Data collection

Research instruments validated and rewritten on the Google form have been distributed to potential participants. The data collection process began from March 9 to July 2, 2022. There was no compulsion in the data collection process, and data were collected from 187 pre-service teachers who met the requirements and were willing to fill out the questionnaire.

Data analysis techniques

To answer research question number 1, the data analysis of the multiple-choice questions includes descriptive statistics to calculate the average value and categorise the pre-service teachers' knowledge of the GHE topic. If the PSTs' answers are correct, they are given a score of 1, while incorrect or unknown answers are given a score of 0. The PSTs' knowledge scores are calculated by summing the scores obtained and dividing them by the maximum score (24), then multiplying the result by 100. Scores are calculated for each PST and then averaged. The categories of knowledge adapted from (Hakim et al., 2023) are presented in Table 2.

Table 2. Category of Knowledge of Pre-service Teachers about the GHE

Average Value	Category
$90 \leq x \leq 100$	Very High
$80 \leq x < 90$	High
$70 \leq x < 80$	Moderate
$60 \leq x < 70$	Low
< 60	Very Low

Data analysis for open-ended questions was conducted by coding the PSTs' responses. Responses with similar meanings were then grouped, and their percentage of occurrence was calculated. Apart from using descriptive statistics, the data were also analyzed using the Mann-Whitney U test. The purpose of the Mann-Whitney U test is to determine whether there is a difference between two independent samples. This study compares the GHE knowledge of two groups, including junior and senior PSTs (to answer research question 2). This non-parametric test is an alternative to the independent t-test when the data is not normally distributed. In addition to the data not being normally distributed, the selection of the Mann-Whitney U test is because this study does not use covariates, does not measure or consider other variables that may influence the variables measured in this study, such as learning interest, self-study time, etc.

The hypothesis used in this study (H_a) is that there is a significant difference between the GHE knowledge of junior and senior PSTs, while the null hypothesis (H_0) is that there is no significant difference between the GHE knowledge of junior and senior PSTs. The decision is that if $p \leq 0.05$, then H_0 is rejected and H_a is accepted.

A flow chart showing data collection and analysis is presented in Figure 2.

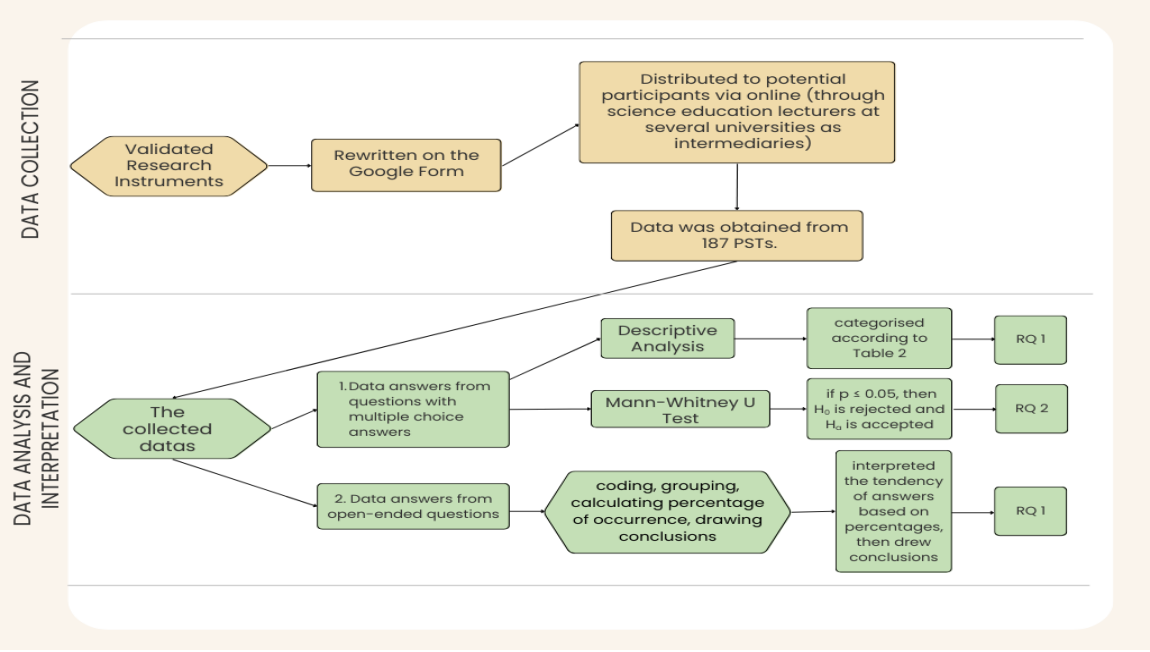

Figure 2. Flowchart of data collection and analysis

RESULTS AND DISCUSSION

In this section, the research results will be described, including 1) PSTs Knowledge Level (Quantitative Results); 2) Open Responses Analysis (Qualitative Insights); 3) Junior vs Senior PST Comparison, and 4) Interpretation whether or not there is a significant difference between Junior and Senior PST related to their level of knowledge.

Findings

PSTs' Knowledge Level (Quantitative Results)

Descriptive data analysis of PSTs' knowledge of GHE includes Mean, Median, Variance, Std. Deviation, Minimum, Maximum, and Range values are presented in Table 3.

Table 3. Results of Descriptive Data Analysis of PSTs' Knowledge of GHE

Descriptive Data	Value
Mean	66.82
Median	66.67
Variance	300.26
Std. Deviation	17.33
Minimum	33.33
Maximum	100.00
Range	66.82

Table 3 shows that overall, the average value of PST knowledge regarding the GHE issue is 66.82, which is in the low category. The data distribution is quite significant from the average value, with a standard deviation of 17.33. The minimum knowledge value of prospective teachers regarding GHE is 33.33, which is in the very low category, and the maximum value of 100 is in the very high category, indicating a significant knowledge gap among prospective teachers.

The minimum, maximum, and average knowledge scores of prospective teachers regarding GHE were also analysed by grouping them based on the aspects of GHE that were asked, namely the causal and impact aspects of GHE. The average value for the causal aspect is 65.06, and for the impact aspect is 68.58; both are in the low category, as shown in Figure 3.

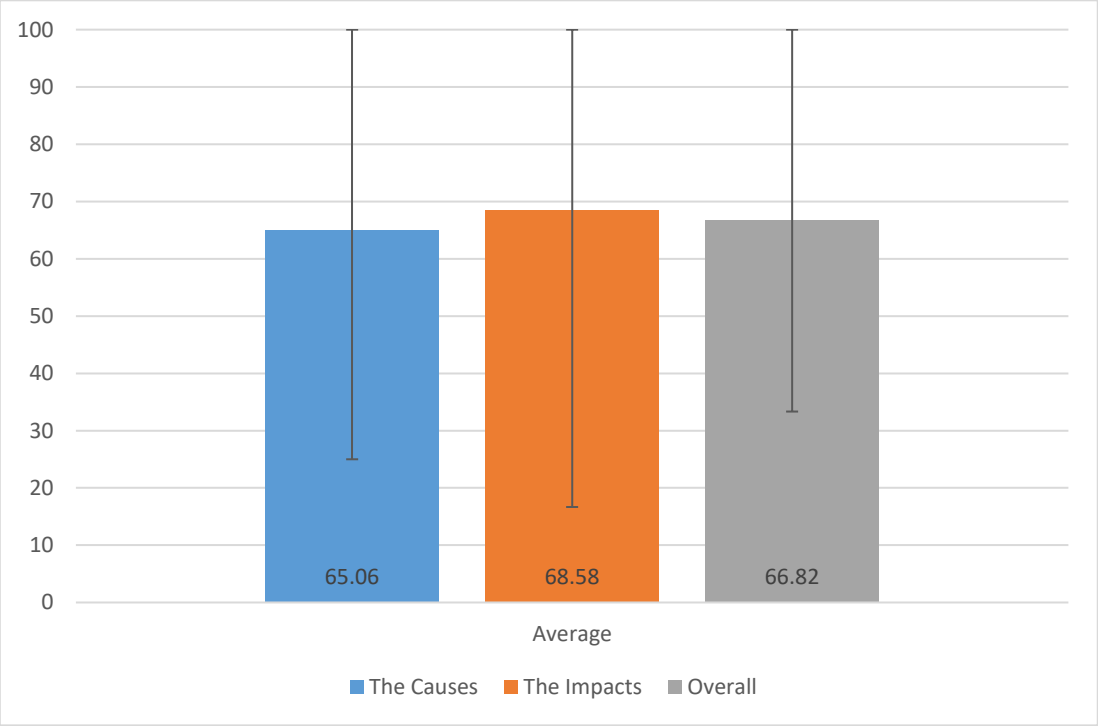

Figure 3. Average Value with Min–Max Range

Open Responses Analysis (Qualitative Insights)

PST's answers to open questions were analyzed descriptively. The answers given by the PSTs for the number 1 question can be coded into 13 aspects, while the number 2 question has 10 aspects. Table 4 presents the percentage of each code.

Table 4. Percentage of each code that is the PST's answer

No	Number 1 What have you learned in college about the GHE?		Number 2 What would you like to learn more about the GHE?	
	The answers	**Percentage**	**The answers**	**Percentage**
1	The negative impacts	59.89	The most effective solutions	45.99
2	The definition and process	45.99	The profound negative impacts	24.06
3	The causes	42.24	The more specific process	21.39
4	The solutions	25.67	The causes	5.34
5	Have not studied	6.95	The prevention	5.34
6	Relate to global warming	5.88	The relationship with technology development	2.14
7	The GHG	4.81	The characteristics of GHG	2.14
8	The positive impacts	3.74	The relationship with global warming and climate change	1.60
9	The preventive	2.14	How to raise public awareness	1.60
10	One of the SDGs	1.60	The positive impacts	1.60
11	Relate to climate change	1.07		
12	Efficiency and energy conservation	1.07		
13	Practicum and Field Lecture	1.07		

Regarding the open-ended question 1, Table 4 shows that the "negative impacts, definitions, processes, and causes of GHE" are information learned by most PSTs in college, as stated by PST 10 and PST 55.

PST 10 (Junior PST from Science Education Field of Study):

"The disadvantage of the GHE increase is that, if the amount is too large, the temperature on Earth will be very high, and the ice at the north and south poles will melt."

PST 20 (Senior PST from Science Education Field of Study):

"*Related to the process, causes, impacts, mitigation or prevention, and efforts we can make to reduce the GHE."*

The topic of the GHE related to climate change, energy conservation, and practicum or field activities was also obtained by several PSTs with the smallest percentage compared to other subtopics of the GHE. An example is PST 29 and 109:

PST 29 (Senior PST from Biology Education Field of Study):

"Regarding how the GHE influences climate change and temperature."

PST 109 (Junior PST from Science Education Field of Study):

"In the Environmental Knowledge course, we conducted a field study to plant mangrove trees, which had a significant impact on reducing the greenhouse effect."

Regarding the open-ended question number 2, Table 4 shows that the "most effective solution" is the thing that PSTs most want to know more about, for example, PST 43, as follows:

PST 43 (Junior PST from Science Education Field of Study):

"I want to know if we will continue to allow this increase in GHE, what the impact and potential disasters will be, and is there any other way to overcome the impact caused by this increase in the greenhouse effect? "

Even though they have studied GHE's processes, impacts, and causes, PSTs want to learn it more deeply and in detail, for example, by PSTs 17, 169, and 130.

PST 17 (Junior PST from Science Education Field of Study):

"I want to know more about the process when the GHE occurs in detail."

PST 169 (Senior PST from Physics Education Field of Study):

"I want to know more about the process when the GHE occurs in depth."

PST 130 (Senior PST from Biology Education Field of Study):

"Usually, it is only taught in theory, but I want to learn more about it in practice or through direct explanations in the field, because it will be easier to understand and provide a deeper understanding."

Junior vs Senior PST Comparison

The percentage of PST in each category of knowledge is presented in Table 5 that shows in all three aspects, most of the PSTs are in a low category; there are even several students whose knowledge about the GHE is very low.

Table 5. Percentage of PST in each category of knowledge

Level of study	Category	Aspect of GHE		
		The Causes	The Impact	Overall
Junior	Very high	15.6%	21.9%	12.5%
	High	15.6%	13.5%	19.8%
	Moderate	7.3%	15.6%	16.7%
	Low	17.7%	13.5%	15.6%
	Very low	43.8%	35.4%	35.4%
Senior	Very high	13.2%	19.8%	12.1%
	High	12.1%	7.7%	17.6%
	Moderate	13.2%	17.6%	8.8%
	Low	8.8%	17.6%	19.8%
	Very low	52.7%	37.4%	41.8%

To determine whether there is a significant difference in knowledge about the GHE between Junior and Senior PST, normality and homogeneity tests are carried out as prerequisite tests. The results of the Normality, Homogeneity, and Mann-Whitney U Test are presented in Table 6.

Table 6. Statistical Summary Table

Tests of Normality

Knowledge of pre-service teachers	Level of pre-service teachers	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
	Junior	.067	96	.200	.975	96	.064
	Senior	.101	91	.022	.966	91	.017

a. Lilliefors Significance Correction

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.

Value	Based on Mean	.158	1	185	.691
	Based on Median	.201	1	185	.654
	Based on Median and with adjusted df	.201	1	184.843	.654
	Based on trimmed mean	.163	1	185	.686

Test Statistics

	Knowledge of pre-service teachers
Mann-Whitney U	4086.000
Wilcoxon W	8272.000
Z	-.764
Asymp. Sig. (2-tailed)	.445

a. Grouping Variable: Level of pre-service teachers

Based on Table 6, on the normality test, a significance value of $p<0.05$ was obtained, so it can be stated that the data is not normally distributed. Based on the homogeneity test, a significance value of $p > 0.05$ is received, so that it can be stated that the data is homogeneous. Because the normality test results showed that the data are not normally distributed, the difference test is a non-parametric statistical test using the Mann-Whitney test. On the Mann-Whitney U Test, the significance value is $p > 0.005$, so it can be concluded that H_0 is accepted, which means there is no significant difference in knowledge about the GHE between Junior and Senior PST.

Interpretation

The increase in the GHE is caused by the rise in GHG emissions due to human activities, which ultimately causes global warming (González, 2021), such as emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) (Mazzalai et al., 2022). This global warming will impact ecosystems; if this is allowed to continue without any adaptation and mitigation efforts, then this will threaten the sustainability of planet Earth, where we live. Adaptation and mitigation efforts related to this issue can be made through education (UNESCO, 2017) and are urgent at this time (Sultan, 2020).

In education, teachers have an essential role in the achievement of learning by students. Therefore, to correct the learning concepts received by students, the teacher must have mastery of the knowledge to teach the topic so that there are no mistakes in mastering the concept by students. Knowledge has a solid relationship to the willingness to take action (Kolenatý et al., 2022)and can help someone prepare the necessary strategic actions (Ratinen, 2021). The teacher's correct and in-depth knowledge regarding the GHE is something that the teacher must possess. However, the results of this study indicate that Indonesian PSTs' knowledge related to the GHE issue is in the low category, as shown in Table 3 and Figure 3. The results of this study contradict research on climate literacy among prospective teachers in Malaysia (Nayan et al., 2020). The research found that prospective teachers' knowledge of climate change adaptation and mitigation was high. The results of our study show that PSTs' knowledge of GHE is low and needs serious attention from education stakeholders because these prospective teachers are future science teachers who will play an essential role in imparting knowledge to their students. If prospective teachers do not have good knowledge, how can they convey the

correct concepts to their students. The result of our study is also a worrying situation because it has the potential for students to develop misconceptions about GHE if they receive inaccurate knowledge from their teachers.

Although this study contradicts (Nayan et al., 2020)'s research, its results align with (Jafer, 2020)'s research on prospective teachers at Kuwait University. (Jafer, 2020)'s research found that most prospective science teachers from Kuwait University had misconceptions about the GHE. Another study showing similar results is research on prospective teachers from the University of Eastern Finland (Tolppanen et al., 2021). The findings indicate that prospective teachers have very little knowledge about the impacts of various climate change mitigation actions. Other relevant research, for example, (Huxster et al., 2015) surveyed undergraduate students in the US, and the results showed that most did not understand climate change following the scientific model. We also observe the maximum score obtained by students; in the causes aspect, a student has scores in the very high category. These results are, of course, expected to be received by all students because knowledge of causal aspects is relevant to global efforts related to global warming (Oumarou & HongXia, 2022).

Many aspects have been learned by PSTs related to the GHE issues, but not in detail, as shown in Table 4. There are also many aspects that they want to study in more detail and depth regarding the greenhouse effect. Research by (Mazzalai et al., 2022) found that compared to universities, television is the primary source of knowledge related to climate change issues, even though a lot of unreliable information is displayed on television. Universities play an essential role in educating college students regarding matters related to climate change (Prasad & Mkumbachi, 2021), including those related to the GHE.

Table 5 shows that in all aspects of GHE, most PSTs are in a low category, both junior and senior PSTs; there are even several students whose knowledge about the GHE is very low. Only a few students have high and very high knowledge related to the GHE, whereas knowledge is the primary key to taking action(Kolenatý et al., 2022). These results indicate an emergency that needs to be followed up on so that the knowledge of PSTs can increase. Educators need to have a good mastery of knowledge regarding this issue because they will convey it to students (Prasad & Mkumbachi, 2021), who are the future generations who can contribute to fighting global warming. Professional teachers are needed who can integrate pedagogical and content knowledge related to the topics to be taught (Efwinda & Mannan, 2020). Therefore, lecturers at teacher education institutions need to pay more attention to designing learning strategies that can increase the knowledge of PSTs on GHE and global warming topics.

Table 6 shows no significant difference between the knowledge of junior and senior teacher candidates. This is thought to be because no courses in the Indonesian science education curriculum specifically discuss the greenhouse effect, global warming, and climate change. These topics are only integrated into specific courses during certain lectures, such as Environmental Science, Environmental Physics, Earth and Space, and others. However, the material on GHE, global warming, and climate change is complex and requires more lectures to discuss thoroughly. Therefore, we recommend that the integration of climate change education be further expanded into the science teacher education curriculum so that prospective teachers do not merely learn the surface level but delve deeply into the subject, as suggested, for example, by PST 17 and 169.

Additionally, topics on climate change should be taught theoretically and through practical lectures, as suggested, for example, by PST 130. These results also indicate that the knowledge transfer strategy received by PSTs in institutions regarding the issue of the GHE is not optimal because the knowledge of junior and senior PSTs is relatively the same, which, unfortunately, is both in the low category. There is an urgency for teacher education institutions to prepare PSTs as future science teachers with good content knowledge related to the GHE issue; because knowledge of the content of the topic to be taught is one of the knowledge that

teachers need to have (Efwinda & Mannan, 2021; Kula & Güler, 2021). Based on the results of this study, we also recommend the need for pedagogical training as a mediating factor in knowledge acquisition. Educators need to be trained in various strategies for planning, teaching, and evaluating learning related to climate change, particularly regarding GHE, which effectively improves prospective teachers' mastery of knowledge on this topic.

CONCLUSION

Based on the research results, it can be concluded that PSTs' knowledge of the GHE is in a low category. In college, PSTs have learned about the impacts and causes of increasing the GHE, solutions, and the relation to global warming, climate change, and energy conservation, but not in detail, so they still want to learn more about the most effective solutions to issues related to the increase of the GHE. Teacher education institutions need to review the curriculum and its implementation in preparing future science teachers who can teach this subject with correct and in-depth knowledge.

RECOMMENDATION

These results indicate the need for content reform covering environmental issues such as increasing GHE, global warming, and climate change in depth to be integrated into the curriculum for prospective science teachers. Teacher education institutions should re-evaluate lecture curricula that are effective in preparing future science teachers with adequate mastery of knowledge in teaching related to the problem of increasing the GHE, climate change, and environmental literacy. This is in line with (Arto-Blanco et al., 2017), who recommended the importance of integrating climate change education into the higher education curriculum. In addition, curriculum modules and training workshops for teachers and prospective teachers are also needed to strengthen their knowledge of these global issues. Recommendations for broader and deeper integration of climate change education into the curriculum align with national and global policies to support the achievement of SDG 13 on climate action.

This research is limited to exploring pre-service teachers' knowledge regarding the GHE phenomenon. Further research should examine aspects of attitudes and behavior, not only knowledge, and investigate the relationship between these aspects. The other recommendations for further research are to explore what learning strategies can increase knowledge, attitudes, and behavior regarding the GHE.

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Author Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Muhammad Nur Mannan	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓	✓
Shelly Efwinda	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Lambang Subagiyo		✓		✓	✓		✓	✓		✓		✓	✓	✓

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Siti Qusnul Khotimah			✓		✓						✓		✓	✓
Ricky Andrian			✓		✓						✓		✓	✓

Conflict of Interest Statement

Authors state no conflict of interest.

Data Availability

The data that support the findings of this study are available from the corresponding author, upon reasonable request, SE.

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