

Knowledge of ozone depletion and climate change: An empirical research from Russian pre-service teachers

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Abstract

Pre-service teachers' (PTs) knowledge about climate change issues is essential to a greater willingness to act on environmental problems. However, existing studies have not addressed knowledge of ozone layer depletion (OLD) and climate change among Russian PTs. To address this gap in the literature, this study examined Russian PTs' knowledge of OLD and climate change. The results showed that most participants correctly had scientific knowledge about OLD and climate change. However, the results also showed that participants had misunderstood and inaccurate knowledge about the relationship between acid rain and the ozone layer, the role of carbon dioxide in ozone depletion, the impact of acid on the greenhouse effect (GE), and the impact of the GE on ultraviolet radiation, skin cancer risk, and radioactive waste. Furthermore, the findings revealed no significant differences in gender and major areas in knowledge of OLD and climate change. The results also showed that the media and the Internet were the primary sources of participants and significant differences between major and non-major science participants' knowledge sources.

Keywords: climate change, climate change education, ozone layer depletion, pre-service teachers, Russia

INTRODUCTION

The climate system contains the atmosphere, the land, the marine biosphere, and the oceans as parts of life in the world. These elements are essential for all lives and continuing life in the world within an interaction among them to shape the world's climate. Variations in temperature and precipitation are referred to as climate change. Human activities that modify atmospheric composition primarily contribute to climate change (Akerlof et al., 2010). Industrial advancement and human endeavors are the primary contributors to climate change. First, the Industrial Revolution led to increased use of fossil fuels, misallocating agricultural land, and the onset of deforestation (Liu & Li, 2023).

Secondly, significant changes in people's daily routines and working environments affect climate change's impacts (González-García et al., 2018; Wynes & Nicholas, 2017). Third, the global decline in biodiversity significantly contributes to climate change by altering the composition of the earth's atmosphere (Newbold et al., 2020; Weiskopf et al., 2024).

Hence, knowledge of climate change is critical to promoting the sustainable development of society and environmental literacy persons (Janney et al., 2024). To encourage people's willingness to take mitigation and adaptation actions to support sustainability science principles, knowledge is essential to promote actions (Thapa et al., 2024; Vukelić et al., 2022) and teachers' environmental literacy. Furthermore, research has

Contribution to the literature

- The lack of studies on these topics in the Russian context signifies a research gap in the literature.
- Most of the existing studies have been conducted in the context of the United States, European countries and other contexts.
- The results showed that our participants had incorrect and inaccurate knowledge about the relationship between acid rain and the ozone layer and that there were no significant differences in knowledge between genders and major domains.

indicated that pre-service teachers' (PTs) knowledge about environmental problems can positively influence their students' attitudes, behaviors, and perspectives toward environmental issues (Said et al., 2003; Tuncer et al., 2007; Zhdanov et al., 2023). Moreover, previous research has indicated that knowledge of climate change is essential to prepare PT as environmental literacy people to have an increased knowledge to engage in actions that mitigate its impacts and to incorporate these subjects into their future curricula (Dorji et al., 2021; Hubert et al., 2024; Kitagawa, 2023). Researchers contend that a good knowledge of climate change can yield positive results when teaching these subjects in schools (Stevenson et al., 2016).

To date, researchers have investigated the knowledge levels of prospective teachers on climate change issues because they are expected to instruct these topics in schools. Also, prospective teachers' knowledge of climate change issues can lead to developing essential teaching strategies on climate change issues (Thapa et al., 2024). Research has shown that knowledge is essential in understanding climate change risks, human contributions to climate change, and barriers to climate action (Fielding et al., 2014). Therefore, the study of knowledge is a necessary research focus to understand how the knowledge of people from different backgrounds differs. In addition, researchers have indicated that knowledge can be influenced by a variety of factors such as age, gender, and educational background that can affect knowledge towards climate change, and they have pointed out the need for further research on different demographic variables (Ayalon & Roy, 2023; Huber et al., 2020; Pan et al., 2022; Salehi et al., 2016). Further research is required to investigate the extent of understanding regarding climate change and ozone depletion across various contexts.

Moreover, research has shown that prospective teachers have limited knowledge about ozone depletion and climate change, which could be due to misconceptions, alternative concepts, and insufficient understanding. This limited knowledge of these issues is critical to effectively implementing school climate change education. Research findings indicate that while knowledge of ozone depletion and climate change among PT has been studied, there is a research gap for Russian PT because existing studies have focused on participants in developed countries. No studies on the

PTs' knowledge of ozone depletion and climate change have been conducted among Russian PTs. In light of this rationality, this study examined the PT's knowledge in a different context to fill this gap and improve their understanding of these critical issues.

PREVIOUS STUDIES

Prospective teachers must understand ozone depletion and climate change well, as this understanding will significantly impact how they teach these topics. To date, many researchers have studied the knowledge of ozone depletion and climate change among prospective teachers in different countries. For example, Haq and Ahmed (2020) examined university students' perceptions regarding climate change. Most respondents pointed out climate change to human activities, including deforestation, river dredging, sand extraction from rivers, industrial development, and vehicle carbon emissions. Abasto et al. (2023) investigated the level of knowledge and alternative ideas about climate change of PT science teachers and non-science teachers. Their findings indicated that the PT moderately understood climate change and some alternative concepts regarding climate change issues. Also, they found no knowledge differences between science and non-science majors.

Ballegeer et al. (2024) investigated the indirect effect of subject knowledge on PTs' willingness to take harm-reduction measures. They found that subject matter knowledge indirectly affects PTs' preparedness and is mediated by emotions and attitudes. Majid et al. (2023) investigated PTs' subject knowledge of climate change. Their results showed that PTs lack essential subject knowledge about climate change and sustainable education.

Liu et al. (2022) investigated the effect of distance education on climate change on prospective science teachers' knowledge of climate change in an undergraduate chemistry course. Their results showed a significant increase in PT's knowledge of climate change. In addition, they concluded that online climate change education programs positively impacted participants' knowledge. Nyarko and Petcovic (2021) examined the knowledge of prospective teachers regarding climate change and ozone layer depletion (OLD). Their findings indicated that prospective educators could articulate that stratospheric ozone constitutes a gaseous layer in

the atmosphere and confused climate change with variations in weather. Nonetheless, they could elucidate anthropogenic activities such as deforestation and the combustion of fossil fuels. Over 88% believed climate change and ozone depletion were causally linked, with textbooks, educators, and media being the most essential sources. They also found that participants cited textbooks (80%), educators (64%), and the media (62%) as the most essential sources.

Salehi et al. (2016) found that Iranian university students' understanding of climate change was moderate, and social factors, environmental attitudes, trust, and personal efficiency impacted their knowledge. Lounis et al. (2023) indicated that Algerian students' knowledge about climate change was significantly related to age, and non-science major participants had a lower knowledge level. In addition, they found that participants had a medium level of knowledge about climate change. In a recent research, Cornejo et al. (2024) examined agronomy students' perceptions and knowledge about climate change and found that most students had a medium level of knowledge (54.25%).

The results of these studies show that PT had moderate knowledge of climate change and alternative ideas. However, the existing studies have not sufficiently expanded researchers' knowledge of Russian PT. The lack of research on this topic in the Russian context means a research gap in the literature. Moreover, given that most of the existing research studies were conducted in the context of the United States (Liu et al., 2022), European countries (e.g., Ballegeer et al., 2024; Majid et al., 2023), and other contexts (e.g., Cornejo et al., 2024; Lounis et al., 2023). Hence, this research is essential and aims to examine the knowledge about ozone depletion and climate change among PT within a Russian context.

METHOD

In this study, the researchers used quantitative research methods. Quantitative research methods were essential for ascertaining participants' knowledge of ozone depletion and climate change. This methodology allowed researchers to examine data from a substantial sample of PT to identify participants' knowledge determinants.

Participants

This research involved prospective teachers studying at Almetyevsk State Technological University, Kazan Federal University, and Kazan State Technological University in Russia. The snowball method was used to involve the participants. The PT from the classes taught by the researchers were invited to participate. A total of 318 PTs participated voluntarily in the study. Of the participants, 232 were female, 86 were male, and 175

were enrolled in a science major program. The remaining participants (n = 143) were non-science majors.

Data Collection Instrument

This study used a data collection tool Nyarko and Petcovic (2021) developed. They developed the instrument in the form of Likert-type items. Their instrument consisted of 42 Likert items, a knowledge source item, and demographic questions. They individually examined 22 items about ozone depletion and the 20 associated with climate change concepts. The Likert items included both scientifically accurate and inaccurate statements. Each item was evaluated based on the accuracy of PTs' knowledge and confidence, utilizing a four-point scale from 'I am sure this is incorrect' to 'I am sure this is correct.' The absence of a neutral or 'I do not know' option was intended to limit the choices and drive participants to express an opinion on every item.

The questionnaire was translated into the participants' mother tongues. Initially, the researchers translated the questionnaire into Russian during a meeting with two Russian-speaking English education specialists with expertise in science education. The researchers revised the entire questionnaire to ensure its accuracy and readability for the participants involved in the study. Furthermore, the translated questionnaire was subjected to feedback from three experts. These individuals possessed a doctorate in scientific education. The researcher revised the final version of the questionnaire based on the experts' suggestions.

Data Collection

We made data collection tools available to classroom and online participants through a Google Forms survey. The survey took between 20 and 40 minutes to complete. On average, the researchers observed that participants in this study completed the questionnaire in twenty-five minutes. The data collection began in April 2024 and was completed in May 2024.

Data Analysis

We used SPSS 24.0 for the data analysis. First, we entered all responses into an Excel file and then imported the data into the SPSS program. In the first step of the data analysis, we analyzed the frequency, percentages, mean scores, and standard deviations. In addition, we performed a two-way-ANOVA analysis to check whether there were differences in gender and major area. Furthermore, we conducted a Kruskal-Wallis analysis to detect differences among knowledge sources according to major areas. The Cronbach's alpha (α) coefficient for the 42 items was $\alpha = 0.91$, indicating that the data collection instrument is reliable for this study.

Table 1. Knowledge about OLD

Statements	N (%)				M	SD
	ISTW	ITTW	ITTR	ISTR		
If OLD is made worse, the weather will become hotter.	14 (4)	36 (11)	126 (40)	142 (45)	3.25	0.82
If OLD is made worse, the risk of skin cancer will be higher.	9 (3)	24 (8)	103 (32)	182 (57)	3.44	0.75
The ozone layer protects the earth from UV rays from the sun.	8 (3)	13 (4)	65 (20)	232 (73)	3.64	0.68
If OLD is made worse, more UV will reach the earth's surface.	17 (5)	20 (6)	96 (30)	185 (59)	3.41	0.83
The ozone layer is up in the atmosphere.	51 (16)	60 (19)	129 (41)	78 (24)	2.74	1.00
OLD is made worse by acid rain.	40 (13)	90 (28)	121 (38)	67 (21)	2.68	0.95
The ozone layer is a layer of gas.	23 (7)	78 (25)	127 (40)	90 (28)	2.89	0.90
OLD is made worse by CO ₂ entering the atmosphere.	35 (11)	87 (27)	120 (38)	76 (24)	2.75	0.94
OLD can be reduced by stopping the emission of CO ₂ gases.	22 (7)	70 (22)	133 (42)	93 (29)	2.93	0.89
OLD can be reduced by stopping the use of CFC gases.	10 (3)	74 (23)	162 (51)	72 (23)	2.93	0.76
OLD is made worse by CFC gases entering the atmosphere.	8 (2)	73 (23)	158 (50)	79 (25)	2.97	0.76
OLD is made worse by fumes from car exhaust.	7 (2)	53 (17)	129 (41)	129 (40)	3.19	0.79
OLD can be reduced by planting more trees on a large scale.	20 (6)	71 (22)	124 (39)	103 (33)	2.97	0.89
OLD is made worse by deforestation.	16 (5)	67 (21)	120 (38)	115 (36)	3.05	0.88
OLD can be reduced by increasing the use of nuclear power stations.	47 (15)	94 (29)	114 (36)	63 (20)	2.61	0.97
OLD can be reduced by reducing the use of coal power stations.	22 (7)	68 (21)	145 (46)	83 (26)	2.91	0.86
OLD can be reduced by using lead free petrol.	21 (7)	106 (33)	153 (48)	38 (12)	2.65	0.77
OLD is made worse by smoke from factories.	8 (2)	47 (15)	144 (45)	119 (38)	3.18	0.77
If OLD is made worse, there will be more pollution at the ground in the air we breathe.	24 (8)	76 (24)	118 (36)	100 (31)	2.92	0.92
If OLD is made worse, there will be more flooding in the world.	42 (13)	119 (38)	101 (32)	56 (17)	2.54	0.93

Note. ISTW: I am sure this is wrong; ITTW: I think this is wrong; ITTR: I think this is right; & ISTR: I am sure this is right

RESULTS

Knowledge About Ozone Layer Depletion

Table 1 shows the knowledge about OLD.

Features and functions of the ozone layer depletion

Most teachers who participated in our study had correct and coherent knowledge about the ozone layer's characteristics and functions (Table 1). More than 80% of the participants correctly recognized that the depletion of the ozone layer makes the weather hotter. 90% of females recognized this, and 96% of males accepted it as accurate. Men were slightly more confident that increasing depletion of the ozone layer would make the weather hotter. Regarding skin cancer risk, 91% of participants agreed that the risk of skin cancer is increasing due to OLD, while 87.2% of females accepted this as accurate. This time, both genders showed a high level of agreement, with females slightly more confident of the increased risk of skin cancer.

More than 90% of participants (93%) agreed that the ozone layer safeguards the earth from ultraviolet (UV) by diminishing the quantity of UV radiation reaching earth's surface. 93% of females agreed with this statement, while 94.1% of men recognized this fact as accurate. The certainty that the ozone layer protects the earth from UV radiation is higher among males. As for UV reaching the earth's surface, 88.4% of participants correctly identified that the ozone layer protects the earth from UV rays. 89% of females stated this was correct, and 88% of male participants also stated this was

correct. 64% of participants thought this was true. However, 35% stated that this was not the case. 62.9% of females correctly identified this item, and 71% of males correctly identified it.

For an item on acid rain, 59% of all participants stated that this was correct for them. However, over 40 of the participants (41%) correctly stated that acid rain is not responsible for the depletion of the ozone layer. Over 60% of female participants agreed that acid rain is responsible for the depletion of the ozone layer, and 44% of male participants agreed with this statement. This result means that females are more likely than males to think that acid rain exacerbates the depletion of the ozone layer. In another item about the composition of the ozone layer, 68% of all participants agreed that the ozone layer is a gas layer. However, 33% of participants disagreed. 68% of female participants agreed that the ozone layer is a gas layer, and 70% of male participants agreed. This result indicates a knowledge gap among the participants.

Causes and containment of ozone layer depletion

Only 76% of participants (78% of females and 66% of males) accurately understood that ozone depletion is attributable to releasing chlorofluorocarbon (CFC) gases into the atmosphere. 73% of participants (75% of females and 68% of males) knew that reducing and phasing out the emission of CFC gasses would reduce ozone depletion (see Table 1). Of the participants, 81% (81% of females and 80% of males) agreed that car emissions worsen ozone depletion.

62% of PT also agreed that the depletion of the ozone layer is exacerbated by carbon dioxide (CO₂) entering the atmosphere (**Table 1**). 62% of female and 61% of male participants had this idea about the contribution of CO₂ to the depletion of the ozone layer. Similarly, over 70% of the participants (70% of females and 73% of males) incorrectly stated that the depletion of the ozone layer can be reduced by stopping the emission of CO₂. 74% of participants (75% of females and 71% of males) and approximately 71% (74% of females and 64% of males) concurred that large-scale tree planting would mitigate OLD.

Most PTs agreed that CFC and CO₂ gasses cause ozone depletion. This perspective is erroneous, as CO₂ does not contribute to ozone depletion, and trees do not mitigate emissions of CFC gases in the atmosphere. Many PTs knew that utilizing clean energy sources, such as nuclear power plants and unleaded gasoline, can diminish CO₂ emissions and mitigate ozone depletion. Specifically, 56% of participants (54% of females and 60% of males) knew that using nuclear power stations was helping to reduce the OLD. Also, 72% of participants (74% of females and 66% of males) knew about reducing the use of coal-fired power stations. In addition, 60% of participants (65% of females and 47% of males) agreed with the idea of reducing by using lead-free petrol. These results show that nearly 30% to 40% of PT lack adequate knowledge regarding clean energy sources, including nuclear power plants and unleaded gasoline. This suggests that PT has a combination of scientific and inaccurate knowledge about clean energy sources and OLD.

Consequences of ozone layer depletion

About 72% of participants contended that ozone depletion does not result in heightened flooding (**Table 1**). 83% of participants (84% females and 78% males) contended that factory emissions aggravate ozone depletion. 68% of participants (71% of females and 60% of males) thought that ozone depletion is worsened because the air we breathe becomes more polluted at ground level. 49% of participants (46% of females and 58% of males) believe that there will be more flooding in the world if ozone depletion worsens

Knowledge About Climate Change

Consequences of climate change

Three-quarters of PT (73%) erroneously believed that an intensified greenhouse effect (GE) would lead to a more significant influx of UV reaching the earth's surface. 76% of female and 65% of male participants felt this was scientifically correct. Similarly, participants incorrectly assumed that a stronger GE would increase the risk of skin cancer (76% agreed, 78% of females and 63% of males). Similarly, around 69% of PT (76% of

females and 52% of males) believed that radioactive waste from nuclear power plants would increase the GE. In addition, a more substantial ratio (over 80%) thought that the GE would lead to a hotter climate and increased glacier melting (69% agreement).

In addition, a more substantial considered GE would lead to more ground and air pollution (73% agreement, 77% of females and 61% of males). The results showed that our participants were confused about the relationship between the GE and the function of the ozone layer. Incorrectly, 73% of PT believed that an enhanced GE would increase UV radiation despite scientific evidence to the contrary. They believed that an intensified GE would elevate the risk of skin cancer and exacerbate radioactive waste from nuclear power plants.

Human-induced pollution and climate change

Table 2 shows the results of human-induced activities in climate change. The participants agreed that cutting down trees (65% agreed, 65% of females and 53% of males), exhaust fumes from cars (84% agreed, 87% of females and 77% of males), and smoke from factories (82% agreed, 83% of females and 79% of males) increase the GE. Similarly, 64% of participants (67% females and 56% males) believed acid rain would increase the GE.

Similarly, extensive tree planting (76% agreement, 78% of females and 71% of males), using lead-free petrol (60%, 66% of females and 44% of males), and using nuclear power (52%, 53% of females and 49% of males) will reduce the GE. Over seventy-five percent of the participants accurately identified that CO₂ (75% agreement) and CFC gases (70% agreement) exacerbate GE. Over fifty percent of the participants acknowledged that diminishing CO₂ (75% concurrence) and CFCs (66% concurrence) in the atmosphere will mitigate the GE. The data indicates that our PT accurately and rationally associates the causes of climate change with the necessary actions for its mitigation.

Effects of demographic factors on knowledge

To examine differences in the knowledge level of participants according to gender and major area, we conducted a two-way ANOVA analysis. This analysis helped to determine whether differences between gender and major areas are statistically significant. The results in **Table 3** suggest that neither gender ($F[1, 314] = .412, p = .521$), major area ($F[1, 314] = 1.510, p = .220$), nor their interaction ($F[1, 314] = 2.428, p = .120$) has a statistically significant effect on the knowledge of climate change and ozone depletion. In addition, the model itself does not explain much of the variance in knowledge, as indicated by the low R-squared value (see **Table 3**). Therefore, it can be concluded that knowledge does not significantly differ based on gender, major area, or the interaction between these two factors.

Table 2. Distribution of PT's response climate change statements

Statements	N (%)				M	SD
	ISTW	ITTW	ITTR	ISTR		
If the GE is made stronger, it will cause more UV to reach the earth's surface.	16 (5)	69 (22)	134 (42)	99 (31)	2.99	0.86
If the GE is made stronger, it will cause the risk of skin cancer to be higher.	17 (5)	67 (21)	131 (41)	103 (33)	3.01	0.87
If the GE is made stronger, it will cause the climate to become hotter.	8 (3)	36 (11)	122 (38)	152 (48)	3.31	0.77
If the GE is made stronger, it will cause more pollution at the ground in the air we breathe.	15 (5)	71 (22)	140 (44)	92 (29)	2.97	0.84
If the GE is made stronger, it will cause more glaciers to melt.	10 (3)	29 (9)	125 (40)	154 (48)	3.33	0.77
The GE is made stronger by radioactive waste from nuclear power plants.	26 (8)	71 (22)	141 (45)	80 (25)	2.86	0.89
The GE is made stronger by cutting down of trees.	23 (7)	88 (28)	122 (38)	85 (27)	2.85	0.90
The GE is made stronger by fumes from car exhaust.	9 (3)	42 (13)	146 (46)	121 (38)	3.19	0.77
The GE is made stronger by smoke from factories.	13 (4)	44 (14)	142 (45)	119 (37)	3.15	0.81
The GE is made stronger by acid rain.	33 (10)	81 (25)	145 (46)	59 (19)	2.72	0.88
The GE can be reduced by increasing the use of nuclear power stations.	45 (14)	108 (34)	114 (36)	51 (16)	2.54	0.92
The GE can be reduced by planting more trees.	16 (5)	60 (19)	162 (51)	80 (25)	2.96	0.80
The GE can be reduced by using lead free petrol.	32 (10)	95 (30)	143 (45)	48 (15)	2.65	0.86
The GE can be reduced by stopping the emission of carbon dioxide gases.	19 (6)	61 (19)	147 (46)	91 (29)	2.97	0.85
The GE can be reduced by stopping the use of CFC gases.	18 (5)	76 (24)	152 (48)	72 (23)	2.87	0.82
The GE is made stronger by carbon dioxide gases entering the atmosphere.	17 (5)	62 (20)	153 (48)	86 (27)	2.97	0.82
The GE is made stronger by CFC gases entering the atmosphere.	21 (7)	86 (27)	146 (46)	65 (20)	2.80	0.84

Note. ISTW: I am sure this is wrong; ITTW: I think this is wrong; ITTR: I think this is right; & ISTR: I am sure this is right

Table 3. Results of two-way ANOVA analysis

Source	Type III sum of squares	df	Mean square	F	Significance
Corrected model	.751 ^a	3	.250	1.497	.215
Intercept	1,879.563	1	1,879.563	11,237.283	.000
Gender	.069	1	.069	.412	.521
Major area	.253	1	.253	1.510	.220
Gender * Major area	.406	1	.406	2.428	.120
Error	52.520	314	.167		
Total	2,854.462	318			
Corrected total	53.271	317			

Note. ^aR squared = .014 (adjusted R squared = .005)

Knowledge sources about ozone depletion and climate change

The results regarding their sources of knowledge on ozone and climate show that our participants chose from various options, encompassing formal sources of knowledge, including textbooks and educators, as well as informal sources such as media, the Internet, climate experts, and religious and political discussions. **Figure 1** shows the results in terms of knowledge sources. Accordingly, the results show that the media and the Internet were the most important sources. Another source is textbooks. Lecturers and climate experts were a source of knowledge for a small proportion of participants.

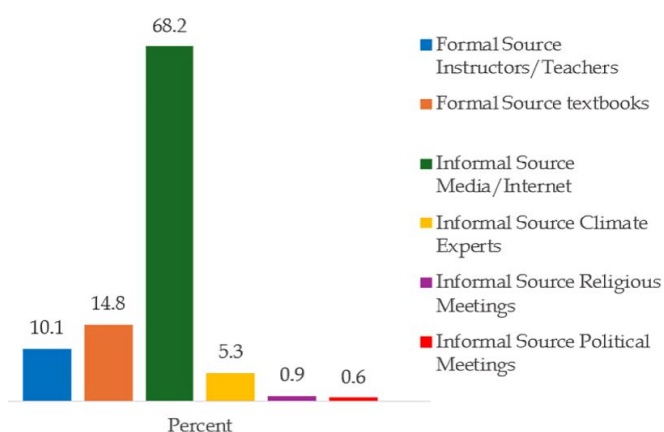


Figure 1. Knowledge sources (Source: Authors' own elaboration)

Knowledge sources according to major area

We conducted additional analyses to determine whether differences in knowledge sources according to major areas. **Table 4** shows the descriptive results about information sources of knowledge. Accordingly, over half of science majors use the media/the Internet as a

knowledge source. Of them, 17% relied on textbooks, and 14% indicated instructors/teachers. A minimal number (7%) indicated climate experts. The ratio of religious meetings and political meetings was 2% and 1%, respectively. Concerning non-majors in science, a big ratio (79%) indicated the media/the Internet as a

Table 4. Results regarding distribution of knowledge sources according to major area

Major area	Frequency & ratio	Media/the Internet	Textbooks	Instructors/ teachers	Climate experts	Religious meetings	Political meetings	Total
Major in science	N %	104 59	30 17	24 14	12 7	3 2	2 1	175
Non-major in science	N %	113 79	17 12	8 6	5 3	0 0	0 0	143
Total	N %	217 68	47 15	32 10	17 5	3 1	2 1	318

knowledge source. Of them, 12% relied on textbooks, and 6% indicated instructors/teachers. A minimal number (3%) indicated climate experts. In addition, none of them indicated religious or political meetings as a knowledge source. In addition, we conducted a Chi-square analysis to determine the differences between participants' knowledge sources and major areas. This analysis showed a significant difference between participants' knowledge sources and major areas ($\chi^2[5] = 16.801, p = .005$).

DISCUSSION

This study examined PT's knowledge of ozone depletion and climate change. Our results showed that most participants understood the ozone layer's properties and functions, with over 80% aware of its depletion, increasing heat and skin cancer risks. The ozone layer protects us from UV rays. 88% of respondents correctly recognized the OLD. However, 64.1% believed the ozone layer is at the top of the atmosphere, and over 40 correctly stated that acid rain is not responsible for its depletion. This result is very similar to that of Nyarko and Petcovic (2021), as they found that three-quarters of their participants misperceived the ozone layer and acid rain. Our results show that the participants did not correctly understand the relationship between acid rain and the ozone layer. In addition, 68% of participants agreed that the ozone layer is a layer of gas, while 33% disagreed, indicating a knowledge gap.

Participants indicated that over 70% knew that CFC gasses cause OLD and that reducing and phasing out CFC emissions would reduce. However, 62% believed that ozone depletion is exacerbated by CO₂. Over 70 participants erroneously thought that reducing CO₂ emissions could mitigate ozone depletion. Moreover, 71% concurred that large-scale tree planting would mitigate OLD. However, this statement is factually incorrect, as CO₂ does not contribute to the depletion of the ozone layer, and trees do not mitigate emissions of CFC gases in the atmosphere. Many PTs thought reducing the number of coal-fired power plants and utilizing clean energy sources, such as nuclear power plants and unleaded gasoline, may mitigate CO₂ emissions and ozone depletion. However, this finding suggests that PT has a combination of scientific and inaccurate knowledge about clean energy sources and

OLD. Furthermore, this finding implies that 30% to 40% of participants need more scientific information about clean energy sources and OLD (Abasto et al., 2023).

Regarding the consequences of ozone depletion, over 70% of PT believed that ozone depletion does not contribute to heightened flooding, whereas 83% asserted that industrial emissions exacerbate it. 68% believe that ground-level air pollution worsens ozone depletion, and 49% predict more global flooding if ozone depletion worsens. However, this idea of more flooding as the ozone layer worsens is not scientifically correct. This finding demonstrates that PT may have misunderstandings and misconceptions about climate change and OLD. PT misunderstandings or misconceptions about understanding ozone depletion and climate change are evidenced by previous research (Abasto et al., 2023; Herman et al., 2017; Nyarko & Petcovic, 2021). Furthermore, research has shown that PST has different levels of knowledge about OLD and climate change issues. However, the variations in knowledge regarding ozone depletion and climate change may stem from the training provided in teacher education programs.

Concerning the consequences of climate change, over 70% of PT incorrectly believed that a more potent GE would increase UV radiation, skin cancer risk, and radioactive waste from nuclear power plants. 69% of PT believed that radioactive waste from nuclear power plants would increase the GE. 70% agreed that an intensified GE would result in elevated temperatures, accelerated glacial melting, and increased soil and air pollution. Despite the scientific evidence, these misconceptions persist. Over 70% of PT wrongly believed that a stronger GE would increase UV radiation, the risk of skin cancer, and radioactive waste from nuclear power plants, despite scientific evidence to the contrary. In addition, over 70% thought the GE would lead to increased soil and air pollution. This result aligns with previous studies (Abasto et al., 2023; Arslan et al., 2012; Boon, 2010; Nyarko & Petcovic, 2021).

The results on knowledge about human-induced pollution and climate change showed that participants concurred on the necessity of deforestation (65% agree), exhaust fumes from cars (84% agree), smoke from factories (82% agree), and acid rain (64% agree) increase the GE. However, the ideas about acid rain are not correct. This result is similar to that of Abasto et al.

(2023), who found incorrect answers from PT about what a greenhouse gas is. The PT's misconceptions and lack of knowledge can explain this result about acid rain (Arslan et al., 2012; Nyarko & Petcovic, 2021; Turajlić et al., 2022). Similarly, Nyarko and Petcovic's (2021) findings showed that PT was confused about climate change due to the changes in weather and seasons. In addition, participants believed that large-scale tree planting (76% agreement), the use of unleaded gasoline (60% agreement), and the use of nuclear energy (52% agreement) would reduce the GE. These results parallel the findings of Haq and Ahmed (2020), who found that university students believe climate change is due to human activity.

More than seventy-five percent of the participants accurately identified that CO₂ and CFC gases exacerbate the GE. Over fifty percent of the participants acknowledged that decreasing CO₂ and CFC emissions in the atmosphere mitigate the GE. The data indicates that our PT accurately and rationally associates the causes of climate change with the necessary actions for its mitigation. However, participants do not have sufficient scientific knowledge and need more information on these topics. This finding supports the findings described in previous research (Bhattacharya et al., 2021; Cornejo et al. (2024; Lounis et al., 2023; Majid et al., 2023; Salehi et al., 2016). For example, Bhattacharya et al. (2021) found preconceptions and the need for more knowledge about the GE among PT. Furthermore, the reason for these findings could be due to the weaknesses and deficiencies in deepening knowledge about climate change in teacher education programs (Abasto et al., 2023; Colston & Ivey, 2015; Majid et al., 2023; Nyarko & Petcovic, 2021; Plutzer et al., 2016; Salehi et al., 2016).

Our findings about the effects of gender and major areas on knowledge revealed no statistically significant differences. This finding is similar to previous research (e. g., Nyarko & Petcovic, 2021). Finally, our results about sources of knowledge showed that our participants benefited from media and the Internet. This finding is contrary to previous research (Nyarko & Petcovic, 2021), which found that textbooks (80%), educators (64%), and the media (62%) were the most knowledgeable sources. In addition, our results revealed that over half of science majors utilized media/the Internet for knowledge, and 79% of non-science majors cited media/the Internet as their knowledge source. Furthermore, our findings showed a significant difference between participants' knowledge sources and major areas. This finding shows the importance of using appropriate knowledge sources to inform PT scientifically in out-of-school learning environments.

CONCLUSION

This study examined PT's knowledge about ozone depletion and climate change. The results show that PT

generally understands OLD's functions and characteristics. However, participants lack knowledge about the ozone layer and its role in acid rain, location, tree planting, clean energy sources, flooding, and the relationship between CFC gases and ozone depletion. Based on these findings, our results show that PT has ideas about ozone depletion that are not scientifically accurate. Regarding climate change, our results showed that over 70% of PT believe an intensified GE would elevate UV radiation, heighten the risk of skin cancer, and augment radioactive waste from nuclear power facilities, resulting in a warmer climate, accelerated glacial melting, and exacerbated soil and air pollution. However, over 60% of PT thought of acid rain, which is false. This finding suggests that the PT needs a correct scientific understanding of climate change.

Thus, our results show a need to develop appropriate climate change education strategies for PT. This study provides a deeper understanding of ozone depletion and climate change knowledge in a different context. The findings suggest that climate change education should include knowledge and understanding of PT in regional and cultural contexts to develop teaching strategies on climate change issues. Climate change is becoming increasingly serious around the world. Therefore, educators and policymakers should understand the PT to develop strategies and teaching methods about climate change. It is also necessary to examine PT's knowledge of climate change in other countries. Our study has several strengths. As far as we know, our results provide unique insights into the level of knowledge about OLD and climate change among PTs in Russia. In addition, we provided results on the level of knowledge of PT with and without majors in the natural sciences to understand if and how it varies by major. Future studies can be conducted to understand better climate change perceptions among pre- and in-service teachers from different backgrounds and subject areas.

Recommendations

This study shows that our participants need education about climate change and OLD. Understanding ozone depletion and climate change can help improve prospective teachers' level of knowledge about the importance of environmental phenomena such as climate change. Therefore, to improve students' understanding of the phenomenon of ozone depletion and climate change and sustainable development, it is essential to include environmental education in university teacher education. Moreover, the effectiveness of environmental policy in higher education depends on the quality of teaching about environmental issues and problems. Hence, researchers should focus on the impact and quality of teaching about environmental issues and problems to promote environmental literacy. Finally, we advocate for future

research to encompass a more diverse participant group to investigate ozone depletion and climate change concepts comprehensively and over an extended period.

Limitations

This study has limitations. First, we had a limited number of participants. Because of this, we cannot generalize our results to all PTs in the country where the study was conducted. Another limitation is that we did not study all participants' perceptions of OLD and climate change in this research. We recommend that future research include a broader group of participants to explore ideas in depth and longitudinally.

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