

The SUNY Journal of the Scholarship of Engagement: JoSE

Volume 3 | Issue 1

Article 1

October 2023

Concerned but Confused: University students' knowledge and perceptions of climate change, and how they plan to address it in their future personal and professional lives.

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Recommended Citation

Kistner, Miranda and Jiménez, Jeremy (2023) "Concerned but Confused: University students' knowledge and perceptions of climate change, and how they plan to address it in their future personal and professional lives.," *The SUNY Journal of the Scholarship of Engagement: JoSE*: Vol. 3: Iss. 1, Article 1. Available at: <https://digitalcommons.cortland.edu/jose/vol3/iss1/1>

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INTRODUCTION

Human-induced climate change has already caused “widespread adverse impacts,” losses, and damages to people and nature (IPCC, 2022, p. 9). Though actions can still be taken to greatly reduce the projected impacts of climate change, even near-term action cannot eliminate all of the consequences (IPCC, 2022, p. 13).¹ The Intergovernmental Panel on Climate Change concludes: “Climate change is a threat to human well-being and planetary health. Any further delay in concerted anticipatory global action on adaptation and mitigation will miss a brief and rapidly closing window of opportunity to secure a livable and sustainable future for all” (IPCC, 2022, p. 33).

One constraint to climate action may be a lack of climate literacy, which is defined as an awareness of the causes of human-induced climate change and its myriad impacts (IPCC, 2022). Research has pointed to the key role that education can have in increasing people’s ability to mitigate and adapt to climate change (A. Anderson, 2012; Lutz et al., 2014). However, most higher education institutions in the United States are arguably failing their students to address climate change in their present-day lives and futures. For instance, some studies (Hiser & Lynch, 2021) have found university students to have low levels of climate literacy and self-confidence in climate change knowledge. As summarized by Hiser and Lynch (2021):

Universities are effective producers of climate knowledge through research enterprise, but the higher education sector provides no assurance that college graduates have been formally exposed to basic information about the science, scope, and scale of global warming and climate change, nor to a realistic understanding of the anticipated localized impacts that will impact their futures. What is the function of college in preparing for such an uncertain future, and how will the higher education sector meet the rising concerns of the next generation? (p. 96)

The pre-service teachers of today are of particular interest within the educational context because they are both current students and future teachers. They are living in a world increasingly impacted by climate change, soon to be tasked with educating a generation whose future depends on the adaptation and mitigation efforts undertaken by those before them (IPCC, 2022). Despite their unique position within the educational context, however, recent studies of pre-

¹ Of course, it is important to recognize that climate change is not the only threat to sustainable well-being for humanity. Climate change is unfolding while the world also experiences global trends of biodiversity loss, depletion of natural resources, land/ecosystem degradation, and social and economic inequalities (IPCC, 2022, p. 5).

service teachers' knowledge and perceptions of climate change in the United States are quite limited.

Thus, this study aimed to provide a preliminary understanding of what pre-service teachers in the United States know and believe about climate change by conducting a survey of 135 college students at a regional public university (SUNY Cortland) with a significant emphasis on teacher preparation programs. This sample included both pre-service teachers as well as students not majoring in education. Surveying both groups allowed researchers to compare each group's responses to assess the extent to which pre-service teachers' thoughts and perceptions of climate change resemble those of their non-Education major peers. That is, we wished to tease out whether our Education students' knowledge was more reflective of students broadly in this university setting and analyze the extent to which these Education students may have diverged in their climate change literacy. If we found minimal differences, this might suggest similar climate change education exposure (or lack thereof) to our participants outside of their college program; on the contrary, if we found notable differences this might suggest key differences in either populations' higher education exposure to the topics or differences in their inclination to learn more about climate change by their own initiative.

The results of this survey are important because understanding what pre-service teachers already know and believe about climate change is a first step in assisting universities to design and implement effective climate change education efforts for pre-service teachers. Efforts by universities to educate pre-service teachers in climate change could potentially have multiplier effects for future generations, given that these pre-service teachers can go on to incorporate climate change education into their lessons for their future students.

Previous research concerning in-service teachers in the United States and internationally has shown that both groups have high levels of concern for the impacts that climate change could have on future generations, albeit more often seeing the problem as more of a long-term threat than an immediate one (Seroussi et al., 2019; Liu et al., 2015; Trendell Nation, 2017).

In addition to misconceptions about the timeline of climate change, pre-service teachers have been found to have a "vague understanding" of the impact of various actions related to climate change (Tolppanen et al., 2020). It is important to note that there are two types of broad responses to climate change—mitigation and adaptation. Mitigation efforts aim to reduce the amount of future greenhouse gases (GHGs) added to our atmosphere, such as curtailing industrial (and other) activities that emit these GHGs. Adaptation efforts are those which help humans adjust to the current or anticipated climate effects and reduce harm, such as planting more heat-resistant crops. While mitigation efforts are necessary to prevent further harm, adaptation is crucial to prepare individuals and communities for the damage that has occurred/will inevitably occur because of the greenhouse gases already

released.² A combination of climate change mitigation and adaptation efforts are imperative for securing a livable future for humanity (IPCC, 2022, p. 33).

Previous research has shown that pre-service teachers do not have a clear understanding of mitigative actions that can slow down the rate of global warming (Tolppanen et al., 2020). The idea that any positive environmental action (related to climate change or not) can be a mitigative action has been observed among pre-service teacher populations (Boon, 2016; Ikonomidis et al., 2012). Additionally, pre-service teachers tend to underestimate the impact of high-impact actions and overestimate the impact of low-impact actions, and are more willing to discuss and adopt these low-impact actions (Tolppanen et al., 2020).

Recycling is one example of a low-impact action that pre-service teachers consider a primary means of mitigating climate change. Wynes and Nicholas (2017) found that recycling has only a modest impact on emissions mitigation. Even if a household recycles all of its recyclable waste for many years, the impact on climate change would be less than the emission reduction potential of taking one less transatlantic flight (Wynes & Nicholas, 2017). This is because recycling is a process that requires energy, and energy often comes from the burning of fossil fuels and release of CO₂ into the atmosphere (Ewijk et al., 2021; Hillman et al., 2015). Even if recycling produces less emissions than the original production of the material, the production of new material will always be required to make up for the material that is degraded and lost through the recycling process (Ewijk et al., 2021). Thus, recycling is not a meaningful response to climate change, but rather a low-impact action that only minimally reduces emissions (Wynes & Nicholas, 2017). Despite its relatively low impact, pre-service teachers around the world have been found to frequently cite recycling as a way to mitigate climate change, as well as overestimating its positive impact on climate change (Ambusaidi et al., 2012; Boon, 2010; Ikonomidis et al., 2012; Tolppanen et al., 2020; Tolppanen & Kärkkäinen, 2021). They are also more willing to take action related to recycling in order to reduce their carbon footprint (Ambusaidi et al., 2012; Tolppanen et al., 2020).

Some of the highest-impact actions to mitigate climate change are rarely mentioned by pre-service teachers. For instance, Wynes and Nicholas (2017) found that the most impactful action to reducing emissions that a household can take (especially those living in high income countries) is to have one less child than otherwise planned. In a study of Finnish pre-service teachers, only 5% of responses mentioned limiting the global human population (Tolppanen & Kärkkäinen, 2021). In other research concerning pre-service teachers and climate change in various countries, having fewer children is not mentioned at all.

² Given that there is a lag in the emission of GHGs and their concomitant warming, it takes at least 10 years, and possibly several decades, for the full consequences of GHGs emitted today to impact global temperatures (Ricke & Caldeira, 2014)

The general lack of discourse about overpopulation in studies of pre-service teachers may be due to the fact that it is absent from discourse surrounding climate change as a whole. In an analysis of Canadian textbooks and government documents from the United States, Canada, Australia, and the United Kingdom that recommended actions to reduce an individual's greenhouse gas emissions, Wynes and Nicholas (2017) found that there were no mentions of having one less child. Instead, these resources focused on moderate-impact actions, such as recycling.

An exception to this lack of discourse about overpopulation appears in a study of students in two K-12 International Baccalaureate schools in Singapore (Jimenez et al., 2020). The issue of overpopulation was completely absent in participant questionnaire responses; yet, population reduction was brought up frequently by students in focus-group interviews (Jimenez et al., 2020). Jimenez et al. (2020) suggests that these students may be more likely to raise overpopulation as an issue for multiple reasons: (1) the students live in a region where population control measures have been part of public policy; (2) they "have not yet been exposed to academic norms discouraging overpopulation discourse;" and (3) they may be more apt to consider "unorthodox" methods to mitigate climate change, given the bleak outlook provided by recent environmental reporting.

One mitigative action that pre-service teachers have demonstrated an accurate perception of is changing their driving habits (Tolppanen & Kärkkäinen, 2021). Pre-service teachers see changing driving habits as having a high impact on carbon emissions; and, according to Wynes and Nicholas (2017), living car free is the second most impactful action that an individual can take to reduce their carbon emissions. Buying a more efficient car also has a high impact on carbon emissions (Wynes & Nicholas, 2017). Pre-service teachers also have been found to view changes in food consumption as an impactful mitigative action (Tolppanen et al., 2020; Tolppanen & Kärkkäinen, 2021). Switching to an entirely plant-based diet for a year is also classified as a high-impact action, according to Wynes and Nicholas (2017). While such studies have frequently addressed potential mitigation strategies, these studies seldom if ever addressed pre-service teachers' knowledge of climate adaptation strategies, and thus in our survey we were keen to also inquire about the climate adaptation literacy of our participants.

METHODS

Participants and Setting

Participants in this study were undergraduate students enrolled in at least one class at SUNY Cortland. Both pre-service teachers and non-education majors participated in the study and data collection was approved by SUNY Cortland's Institutional Review Board (IRB) (Protocol #222,304); data collection took place

during the Spring semester (2023). Data was collected from both pre-service teachers and non-education majors to increase the number of participants and for potential comparative purposes. By asking participants to answer yes or no to the question “Are you an education major?”, the survey divided participants into two sub-groups: pre-service teachers and non-education majors. Information on participants' exact majors within those categories was not collected. This means that the pre-service teacher participants could have been majoring in any of SUNY Cortland's 17 undergraduate majors in education, including adolescence education in core subjects, early childhood and childhood education, health education, inclusive childhood and early childhood education, physical education, and teaching English as a second language (SUNY Cortland, n.d.-a). The non-education-major participants were those with any other major offered by SUNY Cortland.

SUNY Cortland is a state university in New York with an undergraduate population of nearly 6,000 (SUNY Cortland, 2022). It has the largest teacher education program in New York State and the 10th largest teacher education program among all public institutions in the United States (SUNY Cortland, n.d.-b). SUNY Cortland has taken action to mitigate its own contribution to climate change by using 100% renewable electric energy (SUNY Cortland, 2013). The university has also implemented programs to promote sustainability on campus, including a recycling program and a “Green Rep” program that hires and trains student educators to promote “a more sustainable lifestyle across campus” (SUNY Cortland, n.d.-c) as well as plans to develop a food forest on campus (SUNY Cortland, 2021). Concerning formal coursework, there is no requirement for students to take any course that specifically addresses climate change, sustainability, or the environment. Students may be exposed to this content through electives, specific requirements for their major (such as Adolescence Education: Biology), or courses that fulfill general education requirements; still, it is possible that students complete their degree without ever having received college-level instruction on climate change and/or other environmental issues. Arguably, the climate change and sustainability-related initiatives remain largely separate from the teacher preparation program itself.

Survey

The survey questions were designed around three main research inquiries: (1) What do pre-service teachers know about climate change, its causes, and its impacts? (2) How severe of a threat do pre-service teachers perceive climate change and its impacts, and what actions do they prioritize to address how it could impact their lives? and (3) What roles, if any, do pre-service teachers consider themselves to fulfill as future educators in a world that will be impacted by human-induced

climate change? The survey contained Likert scale, multiple choice, and open-ended questions, thus providing a mix of quantitative and qualitative data. Some multiple choice questions required participants to choose one option; others allowed for the selection of multiple options or allowed participants to write in their own answer. Open-ended questions allowed participants to raise issues that may not have been included in pre-selected response options. The survey was the same for all participants, with the exception of the final three questions. If a participant indicated that they were an education major at the beginning of the survey, they were prompted with three additional questions that asked about their plans to address climate change/other environmental issues in their future classrooms.

Numerous survey questions were based on questions used in a 2020 survey of K-12 students in Singapore, which had previously been piloted among pre-service teachers at U.S. institutions (Jimenez et al., 2020). The survey used in this study was also piloted in six individual interviews of SUNY Cortland undergraduate students, three of which were pre-service teachers and three of which were not. After the pilot interviews, it was decided to eliminate two questions that asked participants to identify the estimated temperature and sea level rise by 2050, as participants were unable to provide any estimates. A question about knowledge of other planetary boundaries (Steffen et al., 2015) was also eliminated since participants provided little detailed information about each boundary and overall had little to no awareness of most of these additional environmental issues; such a finding was unsurprising given the disproportionate emphasis that higher education institutions place on climate change (which is already quite limited) compared to these other planetary boundaries (Jimenez and Kabachnik, 2023).

Data collection

135 students participated in the survey. Participants were recruited by emailing professors from various departments (such as Modern Languages, Foundations and Social Advocacy, and English) who teach classes taken by both pre-service teachers and non-education majors. Willing professors set aside 15 minutes of in-class time for students to complete the online survey. Students had the option of saving and finishing the survey at a future time if they did not finish within 15 minutes or if they did not have access to an electronic device in class. 73% (98 participants) were education majors and 27% (37 participants) were not. The number of participants that responded to each question varies; as per our IRB consent documents, participants could choose to skip any questions or withdraw their participation at any point. Data from open-ended questions was analyzed using an open-coding approach. After reading through the responses, the primary researcher developed themes that appeared in responses to each question. The number of responses that exhibited each theme were tallied and expressed in a percentage according to how

many responses there were for each question. Responses were also broken down into three groups for comparison purposes: pre-service teachers, non-pre-service teachers, and the total sample overall.

RESULTS

Research Question #1: What do pre-service teachers know about climate change, its causes, and its impacts?

Pre-service teachers demonstrated some knowledge of climate change, its causes, and its impacts, but still hold many misconceptions. The human-induced nature of our changing climate was widely acknowledged and understood, and pre-service teachers identified various climate-related changes they have noticed occur since they were younger. In this section, survey questions will be shared with accompanying analyses.

In your own words, in 1-2 sentences, what is climate change?

The most common description of climate change among pre-service teachers referenced the changing of weather/weather patterns (34% of responses). The second most common response mentioned changes in temperature (29% of responses). Pre-service teachers were more likely to describe it as a gradual, long-term change (23% of responses) as opposed to a rapid or drastic change (4% of responses).

Have human activities contributed to climate change? If so, how?

Almost all pre-service teachers (97%) indicated that humans contribute to climate change. The most popular response included a reference to pollution of air and/or water (28% of responses). Pre-service teachers also indicated that humans contribute to climate change by burning fossil fuels (23% of responses), by emitting gases (CO₂, methane, unspecified) into the atmosphere (23% of responses), and through technology, machines, and industry/corporations (23% of responses). Additionally, 15% of pre-service teachers identified waste creation and management as a human cause of climate change; example responses from this category are “not recycling” and “littering.” 14% of responses identified deforestation as a contributor to climate change. Only 2 (3% of total) identified overpopulation as a contributor to climate change.

What significant impacts (if any) does climate change have? Please list up to 5.

Among pre-service teachers, the most common response referenced one or more weather event changes, including more frequent/severe storms, natural disasters, and abnormal weather events. The second most common impact mentioned one or more wildlife impacts, such as habitat destruction, killing animals, and dying coral reefs. The next most common responses were temperature impacts, weather changes, pollution, sea level rise, glaciers/ice caps melting, and agricultural/food production problems. Similar to the definitions they provided, pre-service teachers were much more likely to use distancing language to describe impacts rather than using words that might suggest emotion or human impacts. For instance, it was much more popular to state “sea level rise” than “displacement of people in coastal cities.”

Figure I: PSTs’ reported impacts of climate change	
Most Common Themes	Percentage of PSTs’ responses that included that theme
Weather event changes	37%
Wildlife impacts	34%
Temperature impacts	29%
Weather changes	29%
Pollution	25%
Sea level rise	20%
Glaciers/ice caps melting	20%
Agricultural/food production problems	15%

What climate-change-related changes have you noticed in the world (if any) compared to when you were younger?

The most popular change mentioned by pre-service teachers was related to weather (22% of responses), specifically changes in snow patterns (18% of responses). Many of these pre-service teachers indicated that they have been seeing less snow in recent years. One pre-service teacher stated: “It used to snow all the time at home;

now it never really does.” It is important to note that only one pre-service teacher (1% of responses) identified a snow-related change as an impact of climate change when asked to list impacts of climate change.

Interestingly, the second most common theme appearing among pre-service teachers was not a change in the climate itself, but rather a change in human response to it. 21% of responses expressed that they have seen more climate change awareness and/or advocating, including international agreements, laws, protests, and news coverage. The third most popular theme was changes in the seasons, followed by temperature-related changes. While not directly related to climate change, 17% of pre-service teachers' responses cited recycling/plastic use changes as a climate-related change they have noticed. Other changes mentioned were energy-related changes (more renewable energy, electric cars), impacts on non-human entities (glaciers, polar bears, coral reefs, rainforests), natural disasters, and pollution.

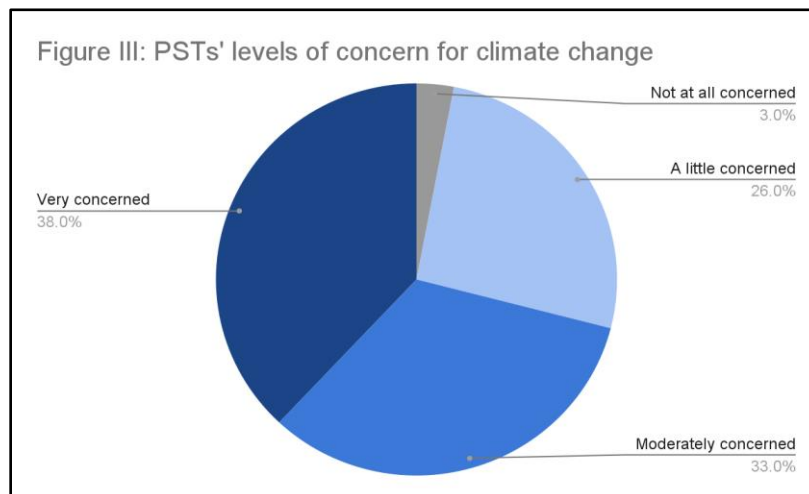
Figure II: PSTs' observed climate-change-related changes since younger	
Most Common Themes (Changes in...)	Percentage of PSTs' responses that included that theme
Weather	22%
Human response to climate change	21%
Seasons	19%
Temperature	17%
Recycling/plastic use	17%
Energy	13%
Non-human entities	9%
Natural disasters	8%
Pollution	6%

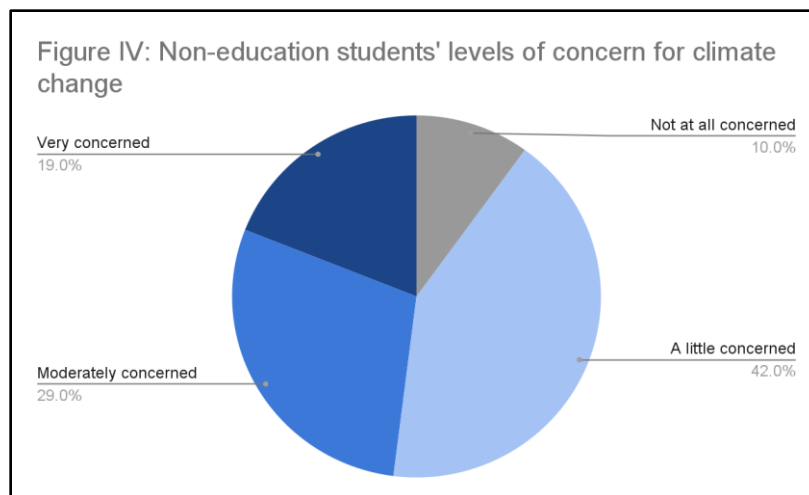
Research Question #2: How severe of a threat do pre-service teachers perceive climate change and its impacts, and what actions do they prioritize to address how it could impact their lives?

Despite being highly concerned for the effects of climate change, the actions that pre-service teachers prioritize to respond to it were some of the least impactful. Additionally, pre-service teachers focused almost entirely on mitigation actions, leaving out another key component to climate change responses, namely, adaptation.

How concerned are you about climate change impacting your life in the future?

97% of pre-service teachers reported some level of concern for climate change impacting their life in the future. On a scale of “Not at all concerned” to “Very concerned,” the most common response was “Very concerned” (38% of responses). Pre-service teachers also demonstrated a higher level of concern for climate change than their peers who were not education majors. Among students who were not education majors, the most common response was “A little concerned” (42% of responses).





In what ways (if any) are you concerned that climate change will impact you in the future?

The most common theme appearing in response to this question was concern for future generations (33% of responses). Many of these responses expressed explicit anxiety or fear for future generations. One pre-service teacher explained:

While I do not know if it will change anything in the immediate future for myself, I fear for the safety of my future students and any children I may have one day. You see all these predictions as to what will cause the end of the world and while there is no way to be certain, I am concerned that the quality of life that future generations will experience will decrease rapidly.

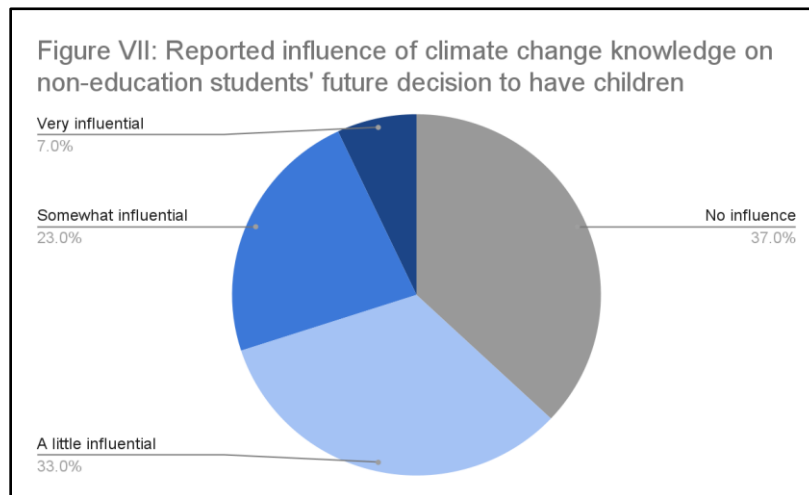
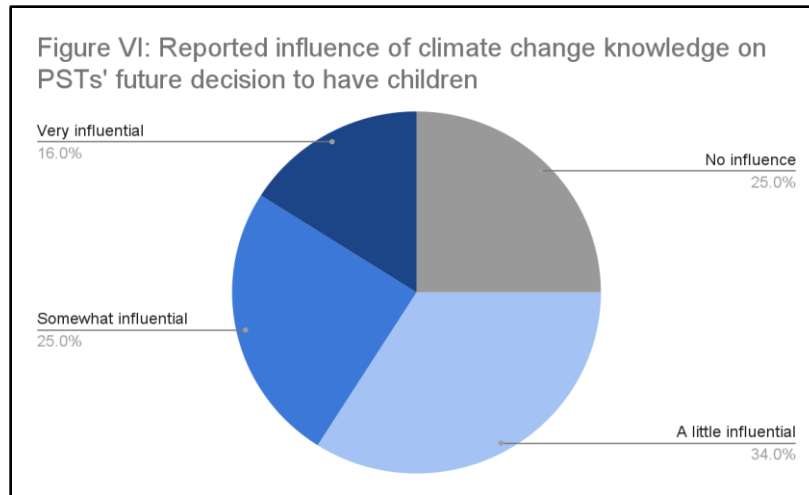
The second most common concern cited among pre-service teachers was experiencing direct impacts during their lives. Some responses demonstrating this sentiment included: “The life span of humans will begin to shrink,” “The extremities showing the breakdown of society,” and “I am concerned for how it will affect my current lifestyle.” Some pre-service teachers explicitly expressed anxiety and fear about how climate change will impact their own lives: “I get anxious thinking about how the Earth will be when I'm in my later years of life.”

Following this, the next most frequently mentioned themes were resource scarcity (food, water, land), harm to wildlife (plant/animal extinction), weather-related changes, natural disasters, areas becoming uninhabitable, and temperature-related changes.

Figure V: Ways that PST are concerned climate change will impact them	
Most Common Themes	Percentage of PSTs' responses that included that theme
Future generations	33%
Direct impacts during their lives	21%
Resource scarcity	14%
Harm to wildlife	14%
Weather-related changes	12%
Natural disasters	11%
Areas becoming uninhabitable	11%
Temperature-related changes	10%

To what extent do you think your knowledge of climate change might influence your future decision to have children?

75% of responding pre-service teachers indicated that climate change might have some influence on their future decision to have children, while 25% said that it will have no influence. The most common response was “A little influential.” Pre-service teachers reported a generally higher influence than non-pre-service teachers. For non-pre-service teachers, it was most common to report that knowledge of climate change would have no influence on their future decision to have children.



What preparations (if any) do you prioritize to address how climate change can impact your life?

The two most common responses from pre-service teachers concerning preparations to address climate change were recycling (35% of responses) and changing transportation habits (35% of responses). Changing transportation habits included actions such as carpooling, using public transport, buying an electric or hybrid vehicle, driving less, and walking more. The third most common preparation mentioned by pre-service teachers was changing consumption/waste habits. Example responses in this category included: “Reducing the use of plastic like water bottles,” “Use less paper products,” and “Cleaning up garbage.” Other actions pre-service teachers reported prioritizing were reducing the amount of meat eaten, educating themselves/others on climate change, and reusing items.

Only 4 pre-service teachers who responded to this question (8% of total) reported practicing some form of self-sufficiency, such as growing their own food or preserving their produce. One participant explained: “Learning to grow my own food at home so that I do not have to rely on a grocery store that may no longer sell what I need anymore.”

Many pre-service teachers also expressed that they do not take any action to prepare, and/or they do not know what to do to prepare (13% of responses). For instance, one pre-service teacher reported:

I honestly have no clue. While it concerns me on a larger scale, I have things in my immediate life that are pressing for right now, which is obviously a problem. I personally do not know an adequate way to prepare.

Figure VIII: PSTs’ reported preparations to address climate change	
Most Common Themes	Percentage of PSTs’ responses that included that theme
Recycling	35%
Changing transportation habits	35%
Changing consumption/waste habits	27%
Reducing amount of meat in diet	13%
Educating themselves/others	13%
Reusing items	10%
Practicing self-sufficiency	8%

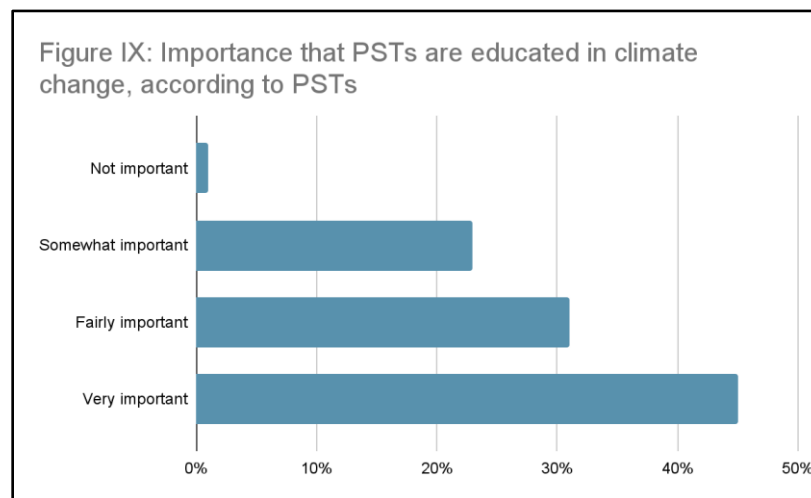
In terms of mitigation and adaptation actions, it was much more common for a pre-service teacher to prioritize a mitigation action rather than an adaptation one. 73% of responses from pre-service teachers named at least one mitigation action (such as driving less, recycling, and eating less meat) while only 10% named an adaptation action (such as planning future places to live, composting, and growing food). It is important to note that this question was worded in such a way that it did not require participants to respond with only mitigation actions or only adaptation actions.

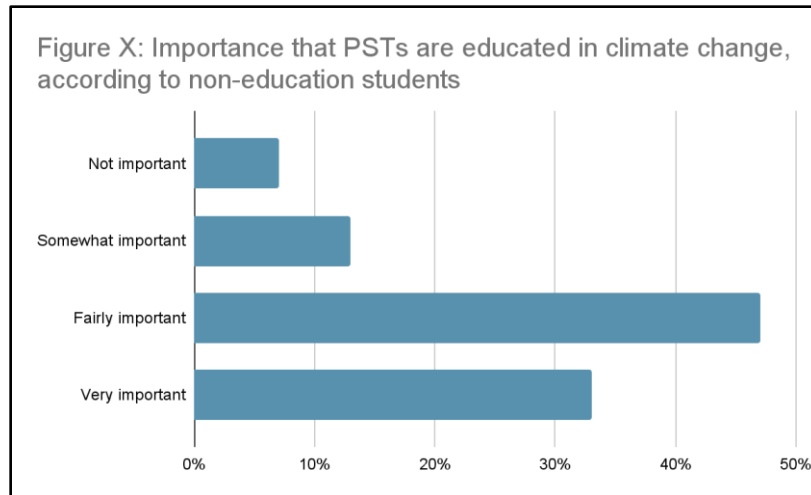
Research Question #3: What roles, if any, do pre-service teachers consider themselves to fulfill as future educators in a world that will be impacted by human-induced climate change?

Pre-service teachers shared a strong belief that it is important for them to be educated in climate change and important for them to address it in the classroom, regardless of the subject or grade level they planned to teach. A vast majority said they plan to address it in their classroom, but fewer participants shared a specific way that they planned to do this. The most common role that they consider themselves to fulfill as educators is a person who transfers information to students about climate change.

How important do you think it is for pre-service teachers, regardless of subject/grade level, to be educated in climate change?

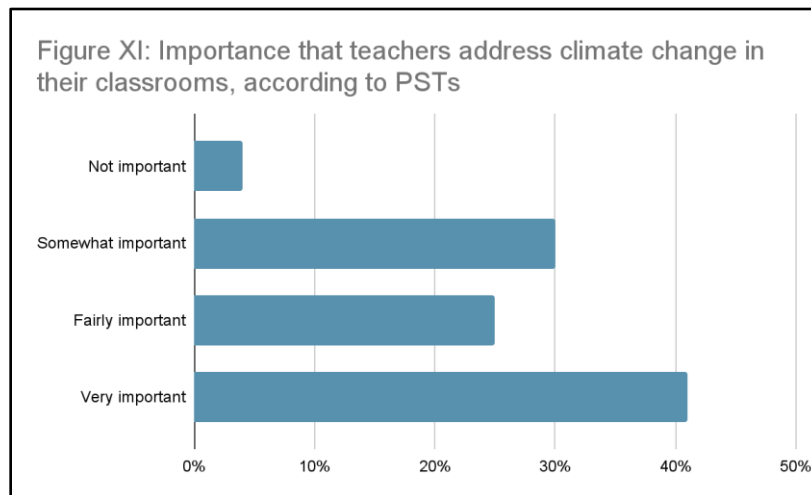
All but one of the 71 pre-service teachers who responded to this question expressed some level of importance for pre-service teachers to be educated in climate change. The most common response was “very important” (45% of responses). Of the non-pre-service teachers who responded, “fairly important” was the most common response (47%). Thus, both groups think it is important for pre-service teachers to be educated in climate change.

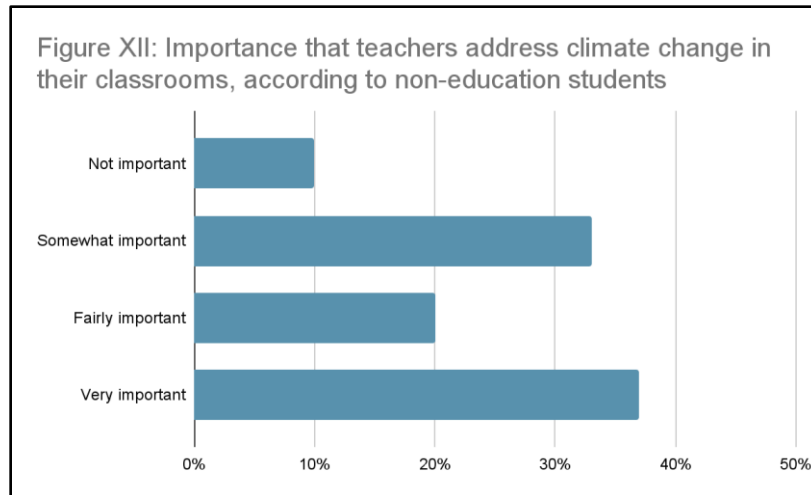




How important do you think it is for teachers, regardless of subject/grade level, to address climate change in their classrooms?

96% of the pre-service teachers who responded to this question indicated some level of importance for addressing climate change in the classroom. Again, the most common response was “very important” (41% of responses). The distribution for non-pre-service teachers was very similar, and the most common response was also “very important” (37% of responses).

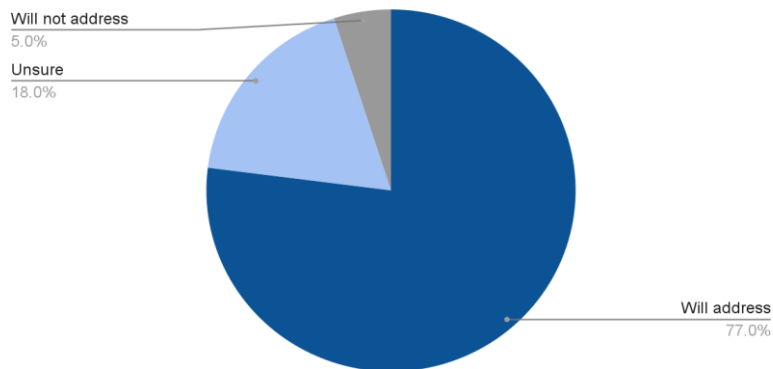




Do you plan to address climate change in your future classroom? If so, how? If not, why not?

In this open-ended question, the vast majority of pre-service teachers (77%) reported that they plan to address climate change in their future classrooms. 18% reported that they were unsure, and 5% reported that they would not.

Figure XIII: PSTs' reported plans to address climate change in their future classrooms



Of the pre-service teachers who plan to address it, a common purpose cited for doing so was to make students aware of the issue and help them understand what is happening in the world (20% of responses).

Even though most plan to address it, a minority (41% of responses) included a specific idea/method to address climate change in the classroom. The most common approach mentioned was to teach students what they can do to help (15%

of responses). Other ideas included teaching about climate change through literature (8%), discussions (6%) and by addressing the news on climate change (5%). Some pre-service teachers expressed they were unsure about addressing it because they lacked the knowledge to do so: “I would like to after taking this survey, but I am not sure how to go about it and I don’t feel I have enough knowledge on the subject.”

What role (if any) do you see yourself having as an educator in a future impacted by climate change and/or other environmental issues?

Of the 31 pre-service teachers who responded to this question, 14 (45%) expressed that they see themselves as people who transfer information to students about climate change in some capacity. Common action words used in this category were “inform,” “make aware,” “educate,” and “provide knowledge.” For instance, one pre-service teacher explained:

I could see myself having to educate students in the issues of climate change, what it is, how we impact it, and how humans can help climate change slow down, as well as provide resources for students to further learn more about the topic.

The second most common role mentioned was a person who teaches students how to decrease the impacts of climate change (16% of responses). For example, one pre-service teacher explained: “As an educator I would be informing and teaching about different ways we can ease the impact in global warming, even though the damage is already done.” Another said they would “teach students the significance of recycling” and “let students know that they are important and can help fix this problem.”

Only 2 of the 31 pre-service teachers (7%) saw themselves as people who teach students skills to survive in a changing world. One of these respondents said that they will try to give students “tools about how to deal with it [climate change] emotionally.” The other pre-service teacher stated:

For me, I think the language classroom is especially important when we are going to see the world change so much in the coming decade, like any time period of course. But for me, the emphasis of my role would be to make my students prepared to interact with other people and being able to properly communicate with others in a world where we are going to have to work together in order to survive.

Figure XIV: PSTs' reported roles as educators in climate change/other environmental issues	
Most Common Themes	Percentage of PSTs' responses that included that theme
Transfer information	45%
Teach ways to decrease impacts	16%
Teach ways to survive in a changing world	7%

DISCUSSION:

In this section, we outline various themes that emerged from our analysis of our participants' responses.

Accuracy of Knowledge

Pre-service teachers have been found to attribute climate change to pollution, both in this study and in previous research (Boon, 2010; Ikonomidis et al., 2012). In reality, climate change and pollution are closely related, but different phenomena. Zhao (2019) explains: "Environment pollution is the introduction of pollutants into the natural environment, and causes adverse effects. Climate change refers to a change in average weather conditions, or in the time variation of weather in the context of longer-term average conditions." Thus, they may be confusing the two because some of their causes are similar. For instance, burning fossil fuels contributes to both air pollution and climate change. However, their impacts are quite different. In fact, some industrial pollutants like the sulfur that used to be emitted from transoceanic barges actually serve as planetary coolants by deflecting sunlight back to space in what some refer to as the aerosol dimming effect (Levy et al., 2013).

Pre-service teachers in this study also attributed climate change to creation/management of waste by humans. It is unclear if this conflation is what led pre-service teachers to suggest waste management solutions (such as recycling and reducing paper and plastic use) as solutions to climate change, or if they believe that these actions would mitigate climate change itself. Either way, not being able to clearly distinguish between the two issues could inhibit pre-service teachers from addressing either effectively in their own lives and/or in the lives of their students.

Some pre-service teachers were also found to share in-service teachers' perceptions that climate change will not significantly impact them directly, but rather future generations (Seroussi et al., 2019; Liu et al., 2015; Trendell Nation, 2017). While it is true that climate change will more significantly impact future generations, the perception that climate change will only be a threat in the future is a misconception. Human-induced warming has already caused heat-induced human deaths, adverse physical and mental health impacts, mass mortality of land and sea life, increased food and water-borne illnesses, human displacement, and food insecurity, with the most vulnerable populations of people being disproportionately affected (IPCC, 2022). Thus, to only consider climate change a problem for the future is arguably a form of climate denialism itself. Pre-service teachers need to understand how immediate a threat climate change is to themselves and their future students. By failing to recognize its severity in the present, pre-service teachers may feel less urgency to address it in their future classrooms, arguably robbing their students of the preparation opportunities they deserve as the inheritors of a climate disaster caused by previous generations. Though it should be noted that, in general, the pre-service teacher candidates were more likely to view climate change as impacting their own lives (such as their plans to have children) compared to the non-Education students, and in a few of their open responses they showed they are aware of our changing climate's looming severity, such as when one student mentioned needing to help their students "survive" in a climate changing future, as another student was resigned to "the (climate) damage (that) is already done".

Interestingly, a tendency to confuse ozone depletion and climate change was not as prevalent in this study as it has been observed in past studies of pre-service and in-service teachers (Arslan et al., 2012; Herman et al., 2017; Ikonomidis et al., 2012). While the survey did not ask pre-service teachers directly about how ozone depletion and climate change are related, only 3 pre-service teachers (4% of responses) identified harm to the ozone layer as an anthropogenic cause of climate change. The relationship between ozone depletion and climate change is complex, with recent research showing that storms, made more severe by climate change, may be causing increased ozone depletion by injecting water vapor into the atmosphere (J. G. Anderson et al., 2017). In this way, ozone depletion is not a cause of climate change, but rather an impact. However, given pre-service teachers' confusion of various other environmental issues with climate change, it raises the question of why they did not appear to confuse it with ozone depletion. Perhaps, it is because the pre-service teachers of today have not been exposed to the concept of ozone depletion as frequently or saliently as previous generations have. Laws that limited ozone-harming substances were put in place before they were born or when they were very young, and by the time they entered middle school, the most egregious ozone-harming substances were generally phased out of production in the United States (United States EPA, 2022). Thus, without a significant awareness

of the issue, there was little opportunity to confuse it with climate change. Instead, the environmental issues that they are most aware of and exposed to (such as trash pollution and plastic usage) are the ones that they conflated with climate change.

Concern Level and Eco-Anxiety

The worry that people feel about climate change and its perceived negative impacts has been referred to as eco-anxiety and/or climate change anxiety (Coffey et al., 2021). Young people, including those represented in this study, have demonstrated high levels of concern in regard to climate change and how it could impact their lives. In one study of young people aged 16-25, 89% of participants living in the U.S. reported some level of worry for climate change, with over a quarter of participants revealing that this worry impacts their daily lives (Hickman et al., 2021). However, the fact that our participants were considerably more likely to envision climate change as impacting future generations rather than themselves suggests that this deflection may actually be a coping mechanism; that is, by convincing themselves it's more an issue for people in the future, they can reduce the eco-anxiety they experience in the midst of the plethora of recent headlines suggesting it may be "too late" to prevent the Amazon from becoming a savannah or losing practically all of the multi-year ice from the Arctic.

However, it is likely that these headlines do not just reflect discrete weather events. A cursory examination of recent data from sea surface temperatures and Antarctic ice extent suggest that we may currently be experiencing not just particular outlier weather but, in fact, what Scheffer and Carpenter (2003) refer to as a "regime shift" in our climate system, namely, when dramatic changes herald a likely irreversible transition to a an entirely new, and potentially much less stable, system (see Appendix Figures X and Y). Furthermore, recent analysis of growing methane levels (see Appendix Figure Z) has led some to similarly speculate the Earth may be experiencing a rapid and dramatic transition to a new climate state similar to past transitions from ice ages to interglacial warm periods (Nisbet et al., 2023).

Mitigating Climate Change

Recycling was a popular action pre-service teachers report taking to address climate change; yet as previously mentioned, it is one of the least impactful actions that a person can take to reduce their own emissions (Wynes & Nicholas, 2017). Pre-service teachers citing recycling as a way to mitigate climate change is a pattern observed in international research (Ambusaidi et al., 2012; Boon, 2010; Ikonomidis et al., 2012; Tolppanen et al., 2020; Tolppanen & Kärkkäinen, 2021). Trendell Nation (2017) suggests that the popularity of recycling in response to climate

change (observed in both student populations and the general population) can be attributed to its accessibility and low-cost; people are willing to recycle because there are few barriers to do so. Its popularity as a mitigative action could also be due to its presence in textbooks and government documents (Wynes & Nicholas, 2017) from which pre-service teachers have learned about climate change.

Another influence could be the multimillion-dollar plastic recycling advertisement campaign mounted by plastic companies beginning in the 1990s (Sullivan, 2020). It is likely that the pre-service teachers of today were inundated with messages of “reduce, reuse, recycle” in their youth, seeing bright blue recycling bins in their classrooms and out on the street corner for garbage day. Given that pre-service teachers have been found to link any positive environmental action to reducing global warming (Boon, 2016; Ikonomidis et al., 2012), pre-service teachers may be associating the general environmental action of recycling as a solution to the very different and much larger problem of climate change. Pre-service teachers should be aware of the relatively low impact that recycling has on climate change, so as to not conflate a classroom recycling program as a satisfactory “climate change education” for their future students.

Some of the most impactful mitigative actions were absent from pre-service teachers’ responses. Having one fewer child is the most impactful mitigative action Wynes and Nicholas (2017) found that one can take to reduce their carbon emissions; however, it was not mentioned at all in pre-service teachers’ responses. Another impactful mitigation action absent from responses was reducing air travel (Wynes & Nicholas, 2017). The absence of these two actions was also observed in a study of pre-service teachers in Finland (Tolppanen & Kärkkäinen, 2021). This could suggest that pre-service teachers do not know the most impactful actions to reduce climate change. Having fewer children likely does not appear as a recommendation in government documents or textbooks, and reducing air travel is not mentioned frequently in these sources either (Wynes & Nicholas, 2017). Academic and social norms surrounding overpopulation discussions, along with the racist framing inherent in some of this discourse, may also limit pre-service teachers’ exposure to this idea as well as hinder them from suggesting having fewer children as a response (Jimenez et al., 2020). Furthermore, perhaps pre-service teachers are conflating the frequency and saliency with which they encounter potential responses to climate change with their effectiveness. This could explain why recycling was such a popular response and having one fewer child was not; recycling is hyper-present in their daily lives and overpopulation is hardly mentioned. Alternatively, pre-service teachers may understand that these actions have a low impact, but still take them because there are few barriers to doing so. There are arguably more barriers for certain high-impact actions, which decreases their willingness to act.

Adapting to Climate Change

Adaptation actions were also largely absent from what pre-service teachers report doing to address climate change, with the vast majority prioritizing mitigating actions. There could be several possible explanations for this prominence of discussions about mitigating actions. First, perhaps some pre-service teachers conceptualize climate change as a problem that can still be avoided through mitigating actions such as recycling and driving less. One survey found that 36% of Americans believe this (Tyson et al., 2022). This idea would be a misconception because climate-related changes have already started to take place (IPCC, 2022). Moreover, climate-related changes would continue to take place even if all emissions stopped due to a phenomenon labeled the “lag effect,” in which the warming impact of a carbon dioxide emission can take more than 10 years to reach its maximum. Thus, if all carbon emissions stopped on a particular day, the planet would likely continue warming more than a decade into the future (Ricke & Caldeira, 2014). This makes adaptation efforts necessary to cope with the inevitable future warming already set to take place.

A second possible reason for the omission of adaptation responses is that pre-service teachers simply are not aware of adaptation as an option, nor of the different actions they can take to adapt. They are likely not exposed to adaptation efforts in their daily lives, given that most current actions are “fragmented [and] small in scale” (IPCC, 2022). In either case, it is true that an essential piece of climate change response was left out of what pre-service teachers do to prepare, since adaptation will be a key way to minimize harm as climate-related changes continue occurring (IPCC, 2022). For instance, learning to grow your own food could supplement one’s diet when food shortages are caused by changing temperatures or natural disasters (increasingly worse with global warming), and moving away from the coastline would reduce one’s risk of losing their home to floods and/or rising sea levels (IPCC, 2022).

The lack of adaptation measures in pre-service teachers’ responses raises questions about how prepared they will be to face some of the unavoidable consequences of climate change and help their students face them in the future. For this reason, pre-service teachers should have a stronger understanding of what mitigating and adaptation measures are, the differences between the two, and why they are both necessary in addressing the climate crisis. Pre-service teachers also need to know the most effective mitigating and adaptation actions that individuals can take, which they can then adapt and teach their students using their knowledge of developmentally appropriate pedagogy. For instance, a teacher and their elementary school class growing their own fruits and vegetables in a school garden would be an example of a meaningful adaptation strategy (and if using natural

fertilizer such as locally sourced compost rather than artificial fertilizers, it would be a mitigating action as well).

Roles in climate change as pre-service teachers

If pre-service teachers see themselves as people who transfer information to students about climate change, yet they hold various misconceptions about it, the question arises of how accurately they will be teaching students about it. Additionally, it raises the question as to what is the most important role for a teacher to play in a climate crisis. Previous research shows that educational efforts can contribute to pro-environmental behavior change in adolescent and university students alike (Cordero et al., 2020; Flora et al., 2014). However, transferring data or other factual information to people about climate change is less effective for promoting behavior change than other strategies (Bergquist et al., 2023; Jickling and Wals, 2008). Climate change education is most effective when students participate in active learning activities which integrate climate science into multiple subject areas (A. Anderson, 2012, p. 198). This suggests that teachers may be able to inspire their students to take mitigative and adaptation actions towards climate change, given they are designed appropriately. However, if pre-service teachers' understanding of climate change education is limited to transferring information about some of the least impactful mitigative actions, at best, they will be encouraging students to take those minimally impactful actions. By only teaching mitigative actions, they may also pass on to students the misconception that climate change can be "solved." The problem of climate change is already too complex, far along, and deeply interconnected with global industrial society to ever be "solved," especially when considering the carbon lag effect, numerous positive feedbacks, and temperature records worldwide being routinely broken at rates 'much faster than previously expected'.

This role of transferring information to students about climate change also reflects a transmissive model of education rather than a transformational one, which inherently limits teachers' ability to prepare students to live in an uncertain climate future. In a transmissive education, teachers transfer "facts, skills, and values" to students, and learning objectives are "predetermined and prescribed by a small group of experts" (Jickling & Wals, 2008). This type of approach limits students' learning outcomes to those deemed appropriate by the teacher, government, group, or industry that designs the curriculum. On the other hand, in a transformative model of education, knowledge is co-created amongst teachers and learners, drawing on prior knowledge, curriculum, and different cultural perspectives. As Jickling and Wals (2008) explain: "In this sense, a function of environmental education is to enable students to become critically aware of how they perceive the world with a view to fostering citizen engagement with social and environmental

issues and participation in decision-making processes.” Arguably, this transformative model is better suited for the needs of today’s students, since the future of the climate and its concurrent impacts on the world remain highly uncertain. However, the responses from our participants were almost exclusively advocating this less desirable “transmissive” pedagogical style; this should come as no surprise, given the likely general lack of exposure to transformative environmental pedagogy throughout their educational experience.

Thus, a key role missing from pre-service teachers’ responses was teaching students skills to adapt to and survive in a world impacted by climate change. Without knowledge of adaptation actions themselves, pre-service teachers will not be able to educate their students in this essential piece of climate change response. Arguably, adaptation will be even more important for future generations of students, given that they have limited control over how much warming has already occurred but will experience the full impact of a continuously warming planet.

Teachers could play a vital role in teaching students individual adaptation strategies that reduce their risk of harm from climate-change induced impacts. These strategies could include activities such as gardening, composting, food preservation, and natural disaster responses. Additionally, as two pre-service teachers mentioned in the survey, communication and emotional regulation skills will be important to adjusting to a world where the impacts of climate change become increasingly severe. However, in order to fulfill this role in their future students’ lives, pre-service teachers need to greatly expand their conceptualizations of both climate change and climate change education. First and foremost, pre-service teachers should have a thorough understanding of the causes, consequences, urgency, and most impactful mitigating and adaptation responses to climate change. This foundation is necessary for pre-service teachers to feel confident enough to address climate change in their classrooms, and to do so accurately. Then, to actually educate their future students, pre-service teachers need to know how to design and implement effective lessons on climate change; that is, using multidisciplinary, hands-on learning activities in which the teacher and students co-construct their understandings of climate change and responses to it. Conveniently, many of the adaptation strategies mentioned above lend themselves to this educational model. Teachers could, for instance, prepare a project where students and the teacher create a composting bin and add their food scraps to it throughout the year. By the end of the year, both students and teachers will have learned the skill of composting, a skill they can use to cultivate a successful garden and adapt to potential future food shortages.³

³ See Badurek and Jimenez (2022) for excerpts of a children’s composting book that SUNY Cortland Education students created as part of a service learning project. The authors will happily share this digital book upon request.

It is also important to recognize that higher education institutions have the potential and responsibility to model effective climate change education to their pre-service teachers by providing this education to them. Addressing the severity of our growing ecological emergencies calls for a complete overhaul of how higher education institutions approach the issues. Rather than piecemeal additions such as incorporating a required climate/environmental course or occasional related lectures and events, higher education institutions should holistically restructure their missions so that ecological thinking and actions are infused into every aspect of their students' undergraduate experience. For instance, many scholars have discussed the importance of "decolonizing higher education"; in other words, recognizing the role that modernity and its concomitant lifestyles play in contributing to "unsustainability" (Misiaszek & Rodrigues, 2023). As such, one approach could be to highlight the experiences and perspectives of indigenous communities worldwide in successfully modeling long-term sustainable living, and infuse "Indigenous sustainabilities" (Jimenez & Kabachnik, 2023) into all aspects of university life. Such an approach can also infuse an emotional component to learning beyond disembodied "climate facts and figures" that is prevalent in much of climate change communication; students might learn how Indigenous communities have long used storytelling techniques that emphasize relationships as a method to inculcate effective land stewardship and concern for our wider community of life in their communities. Overall, the importance that our participants (pre-service teachers and non-education majors alike) attributed to climate change education for pre-service teachers suggests some support for the aforementioned restructuring of climate change education at the university level.

CONCLUSION

This study has helped reveal university students and pre-service teachers' misconceptions and gaps in knowledge concerning climate change. Further research is needed to investigate pre-service teachers' knowledge of adaptation efforts to climate change. Since this survey did not ask explicitly inquire about how participants considered climate adaptation, it remains unclear if pre-service teachers know about adaptation but did not prioritize it in their responses (or prioritize it in their lives), if they do not know much about adaptation, or if they do not consider adaptation essential because they believe climate change can still be "solved" through mitigation.

Given the urgency of climate change and other ecological threats to humanity, it is imperative that institutions of higher education begin to center broader, ecological thinking in their students' experience, especially when educating pre-service teachers. Of course, this calls for greater commitment on the part of university faculty to prioritize learning both the content and pedagogy

around these issues. These future educators have shown a high level of concern for and eagerness to address climate change in their classrooms, as well as a willingness to learn more when they feel uninformed. Higher education institutions, and especially teacher preparation programs, have the potential to harness this concern and eagerness for action, provided they are committed to radically transforming their existing curriculum and pedagogy into a more well-rounded and systemic ecological education that can better prepare their students for the myriad challenges, both personally and professionally, that climate change and other environmental issues will pose for them throughout their lives, as well as the lives of all the future generations bestowed in their care.

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APPENDIX

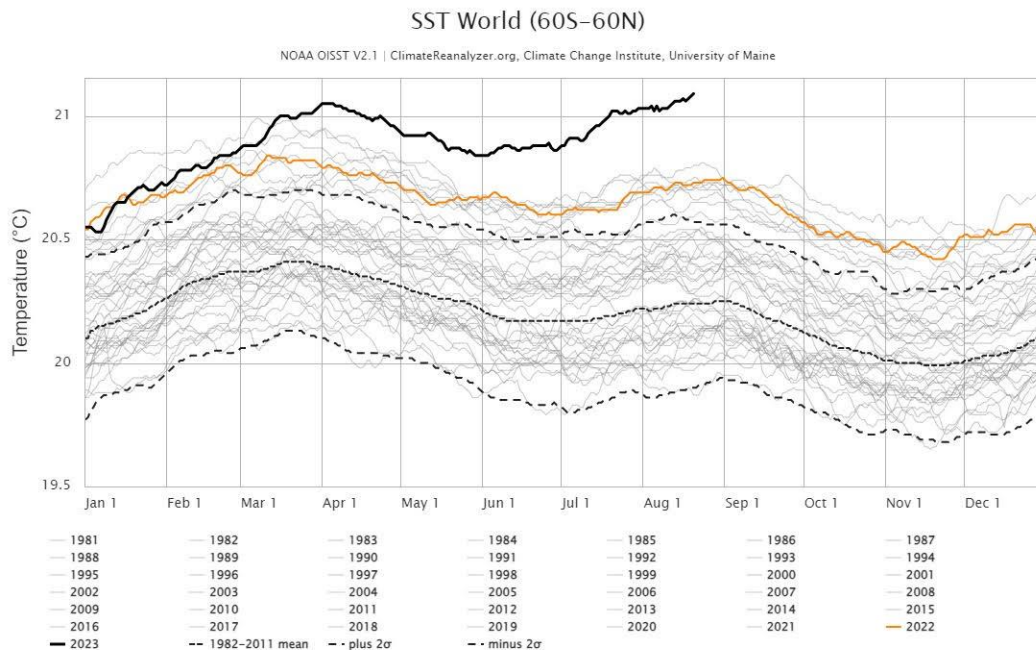


Figure X: Global Sea Surface Temperatures

Jacobson, E. [@EliotJacobson]. (2023, August 21). *We are living through crazy times. Global sea surface temperatures continue to reach new records almost daily...and this is happening at a time of year when sea surface temperatures are typically lower than their March/April peak.* [Tweet, graph of Global Sea Surface Temperatures]. Twitter.
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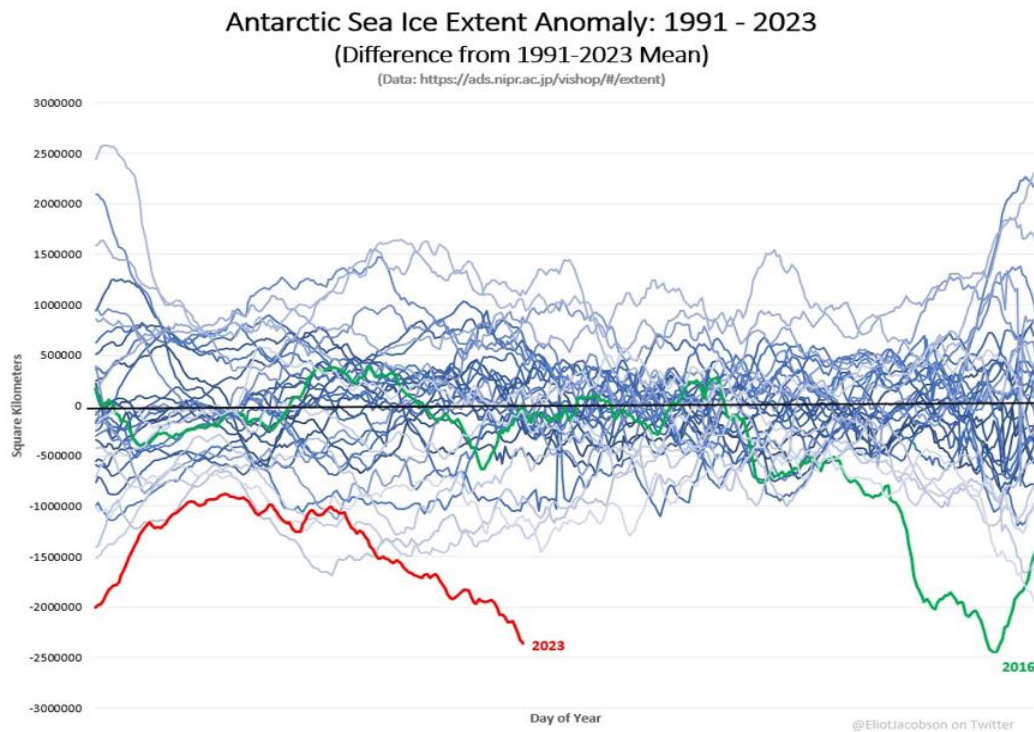


Figure Y: Antarctic Sea Ice Anomaly: 1991-2023
Jacobson, E. [@EliotJacobson]. (2023, June 18). *What's happening to Antarctic sea ice extent isn't getting enough global media attention. And by "enough" I mean none. Nothing.* [Tweet, graph of Antarctic Sea Ice Extent Anomaly].
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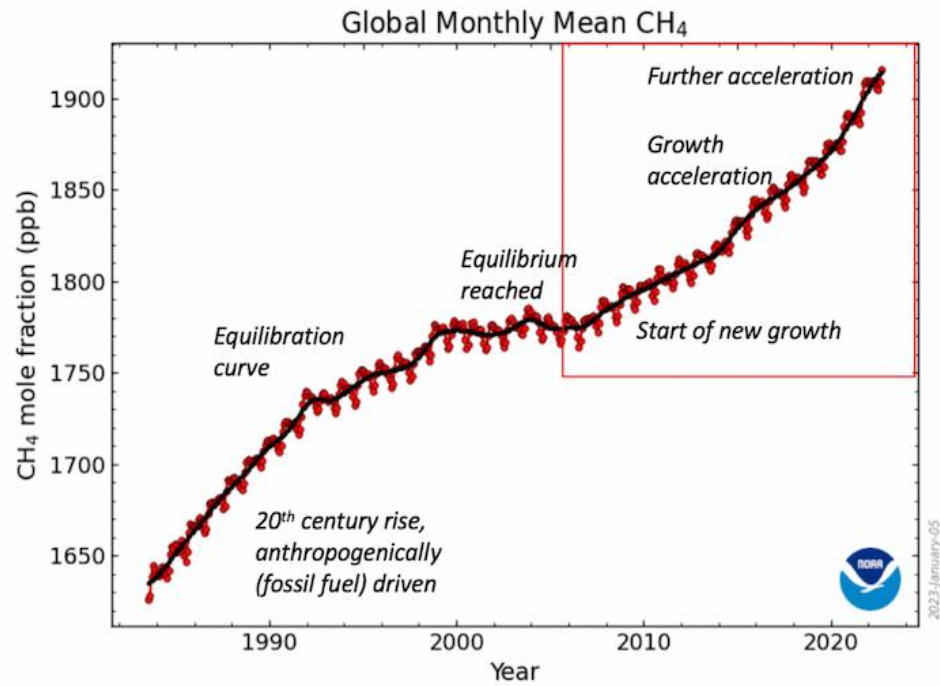


Figure Z: Evidence of a spike in monthly methane levels measured over time from 1992 to 2022 (Nisbet et al., 2023).