Assessment and Validation: An Updated Climate Change Plausibility Perception Measure

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Abstract

Plausibility perceptions about climate change influence learner engagement, motivation, and knowledge acquisition, thereby shaping the effectiveness of climate change education. The Plausibility Perception Measure (PPM) was originally developed following the Fourth Assessment Report of the Intergovernmental Panel on Climate Change in 2007. There was a need to update the scale to measure individuals' plausibility perceptions regarding the current climate crisis. This study updated the PPM scale to reflect the IPCC's 2022 report on impacts, adaptation, and vulnerability. The updated PPM scale is a ten-point Likert scale consisting of 15 items. Data were collected from 330 pre-service teachers at a public research university. The reliability of the scale represents an excellent consistency measure (α=.92). Confirmatory factor analysis results indicated that the three-factor model fit the data very well (TLI ≥ .90, CFI ≥ .90, RMSEA ≤ .08). The updated PPM scale shows promising reliability and validity for assessing individuals' plausibility perceptions of the current climate crisis.

Keywords: Global climate change, Plausibility perception, Instrument validation, SDG 13: Climate action

1. Introduction

Global climate change (GCC) is a complex and constantly evolving issue, with its impacts and expected outcomes changing and worsening over time. (Abbass et al., 2022; Lambert, et al., 2012). While GCC has a long history marked by gradually rising global temperatures, we are now clearly seeing its various effects in different places worldwide, strongly indicating that these changes are largely due to human actions, a concern scientists have been highlighting for some time. Since GCC is one of the world's most important crises today, it encompasses both scientific complexity and social relevance, earning it the status of a socioscientific issue (SSI) (Fawzy et al.,2020; Zeidler & Nichols, 2009). Therefore, a holistic and argumentative understanding is needed to comprehend GCC (Sharma, 2012).

Education plays an important role in tackling the climate crisis by raising knowledgeable and courageous generations on this issue that all humanity has been facing for a long time. On the other hand, educating individuals about SSIs like GCC poses significant challenges and requires their active engagement in discussion, communication, and debate (Zeidler & Nichols, 2009). Although the GCC is an essential issue that requires action, numerous studies show that many students have limited understanding and hold misconceptions about GCC (Boon, 2010; Ceyhan et al., 2021; Dal et al., 2015; Hansen, 2010; Huxster et al., 2015; Kilinc et al., 2008; Niebert & Gropengießer, 2014; Österlind, 2005; Papadimitriou, 2004; Ratinen, 2016; Sahin et al., 2021; Shepardson et al., 2011; Wachholz et al., 2014). When the focus is switched to pre-service teachers, the above notions appear similarly.

Many studies revealed teachers lack knowledge about the GCC and they have difficulty integrating the climate crisis into their teaching (Karami et al., 2017; Khalidi & Ramsey, 2021; Lambert et al., 2012; Lombardi & Sinatra, 2013; Michail et al., 2007; Plutzer et al., 2016; Seroussi et al., 2019; Stevenson et al., 2016; Summer et al., 2000; Sundblad et al., 2009). While these deficiencies make it difficult for students to learn and assimilate ways to cope with the climate crisis, they also negatively affect teachers' teaching practices (Arslan et al., 2012; Lambert et al., 2012; Michail et al., 2007). Teachers have a critical position in the field of GCC. They guide students through the process of conceptual transformation in the course of learning GCC. It is noteworthy that teachers may also struggle with misconceptions related to GCC (Erol, 2005; Karami et al., 2017).

Given that students and teachers have misconceptions, misinformation, or disinformation about GCC, it is critical for individuals to experience the conceptual change process to improve their understanding of GCC and eliminate misconceptions (Posner et al., 1982). Conceptual change involves structuring knowledge by integrating it with new and existing ideas (Posner et al., 1982). Conflicting judgments may be encountered in understanding SSIs that create debate and dilemmas, such as GCC. In this context, new concepts should be plausible for learners to reconstruct information throughout the learning process and overcome misunderstandings and misconceptions (Dole & Sinatra, 1998; Duit & Treagust, 2003; Lombardi et al., 2016). Plausibility has also been addressed as a crucial component in conceptual change models to produce a strong conceptual change (Dole & Sinatra, 1998; Lombardi et al., 2016; Posner et al., 1982). Sinatra and Lombardi (2020) argued that plausibility in the context of climate change is essential as it allows individuals to critically evaluate the credibility of information and knowledge claims critically, enhancing informed decision-making and understanding of complex environmental issues.

Lombardi and Sinatra (2012) stated that while learners can record some information about GCC by measuring or observing, they may find the reasons behind the data they collect implausible and may experience confusion. For this reason, individuals' plausibility perceptions about GCC are critical because they reveal the degree to which new information is seen as fruitful, plausible, and intelligent (Lombardi et al., 2016). Perceptions of plausibility play a significant role in helping individuals understand and take action related to climate change. Therefore, fostering understanding and awareness among students is essential, making GCC education vital. Plausibility strongly influences how seriously individuals take the issue and their willingness to engage in mitigation and adaptation efforts. Using validated scales or tools to measure plausibility perceptions is a powerful way for educators to evaluate students' perceptions of climate change.

The substantial impact of plausibility perceptions about GCC on education has been empirically demonstrated in several studies. For example, Sinatra and Lombardi (2020) found that plausibility judgments play a crucial role in how individuals evaluate evidence and information about climate change, influencing their understanding and decision-making. Lombardi et al. (2016) showed that students' plausibility perceptions predicted their engagement and conceptual change when learning about climate change. These findings underscore the importance of considering plausibility in educational efforts to improve understanding of climate change. Researchers can develop more effective strategies and materials that help improve understanding of how individuals perceive climate change information's plausibility. Therefore, this study aimed to update the Plausibility Perceptions Measure (PPM) Scale (Lombardi & Sinatra, 2012) according to the Intergovernmental Panel on Climate Change (IPCC) 2022 report.

It is important to follow the IPCC reports when developing a scale related to GCC because they represent the most comprehensive and rigorous assessment of climate science. The IPCC produces assessment reports that outline the current state of knowledge, impacts, potential hazards, and mitigation and adaptation strategies for GCC to improve people's understanding of GCC (IPCC, 2022). In addition, IPCC reports provide scientific consensus, policy guidance, insight into future climate scenarios, and a basis for global cooperation (IPCC, 2023). As knowledge, impacts, future risks, potential mitigation, and adaptation strategies change over time, IPCC reports include new aspects related to the GCC. For example, the 2022 IPCC report focuses on three primary aspects of GCC: observed and projected impacts and hazards, adaptation and enabling conditions, and climate-resilient development (IPCC, 2022).

Lombardi and Sinatra (2012) developed the PPM scale using the scientific statements in the IPCC report published in 2007. However, there is a need to update the current PPM scale by considering ever-changing climate data and research results. Following the development and validation procedures of the original PPM scale (Lombardi & Sinatra, 2012), we updated the PPM scale according to the scientific explanations and statements in the IPCC 2022 report. In this study, we focused on teacher candidates who will be the teachers of the future. Given the urgency and significance of the climate crisis as a major global challenge, it is crucial to recognize the pivotal role that pre-service teachers play in fostering awareness and understanding of the impacts of GCC among the next generations. Pre-service teachers will subsequently impact students in the near future; thus, concentrating on them is also notable. In an ever-changing and developing world, examining individuals' plausibility perceptions about GCC may help to find whether and to what degree they find the statements regarding this issue plausible. Since the focus is especially on pre-service teachers, participants' demographic information requested during the updating process may provide insight into the content of teacher training programs.

This study has important implications for GCC education. Educators can benefit by seeing how plausible today's students perceive GCC and its impacts since plausibility is key to understanding students' perceptions (Sinatra & Lombardi, 2020). To achieve this goal, using an updated PPM scale is important because today's IPCC reports emphasize different factors than those included in the original PPM scale. For example, instead of emphasizing melting glaciers, the IPCC report (2022) emphasizes extreme weather events and their impact on the relationship with the current GCC. In addition, one study found that teachers could use resources to assist them in guiding their students' environmental education (Baker et al., 2021). An updated PPM scale could help teachers examine students' perceptions of the current GCC. The literature suggests that perceptions of plausibility play a crucial role in shaping students' perceptions of climate change (Lombardi et al., 2016), and research has found a clear relationship between perceptions of plausibility and understanding of GCC (Dole & Sinatra, 1998; Lombardi et al., 2016). These findings highlight the importance of considering plausibility in education. It could help improve students' understanding of climate change issues. Therefore, it is important to have a valid plausibility perception scale about GCC, especially for pre-service teachers, as teachers hold a critical position in the field of GCC. Pre-service teachers participated in the current study, so this study also has implications for educating teachers about GCC who will communicate about GCC to future generations.

2. Theoretical Background

2.1. Conceptual Change and Plausibility

Conceptual change is a promising method for teaching SSI, in which learners' misconceptions are transformed into scientifically accepted concepts (Heddy et al., 2017). Conceptual change is a key theory that promotes meaningful and deep learning in the conceptual learning process by making concepts understandable, believable, and useful for learners (Beeth, 1998). Various theorists (Chen et al., 2020; Lombardi & Sinatra, 2012; Lombardi et al., 2016; Sinatra & Lombardi, 2020) claimed that plausibility judgments play a crucial role in conceptual change because they are fundamental for conceptual understanding to occur. The conceptual change theory claims that for conceptual change to occur, new knowledge must be intelligible, plausible, and fruitful (Casper & Balgopal, 2018; Posner et al., 1982). Intelligibility refers to the consistency and coherence of the new information, plausibility refers to the relative potential truthfulness of the information received, and fruitfulness refers to the potential of the new information to expand scientific knowledge and generate practical applications in new situations (Posner et al., 1982). According to Nadelson et al. (2018), if a student lacks this sense of plausibility, conceptual change may not fully occur. For learners to have strong cognitive processing, new ideas must be plausible (Dole & Sinatra, 1998). Research has shown that learners need to judge the information as potentially valid to avoid undergoing the conceptual restructuring required for conceptual change (Lombardi & Sinatra, 2012).

Researchers have also argued that a new concept must be plausible if students engage in greater cognitive processing and adopt that concept as their own (Dole & Sinatra, 1998; Posner et al., 1982). Plausibility is subjective and represents an individual's assessment of a statement's veracity (Lombardi & Sinatra, 2012). Also, plausibility is an essential component of conceptual change theory, which emphasizes the development of conceptual knowledge (Duit & Treagust, 2003; Nadelson et al., 2018; Posner et al., 1982). There are several theoretical orientations to conceptual change, but for our purposes, we focus on plausibility and view conceptual change as the reconstruction of individuals' conceptual knowledge about scientific phenomena (Dole & Sinatra, 1998; Lombardi et al., 2016; Malleus et al., 2023).

2.2. Plausibility Perception Measure (PPM) Scale

Lombardi and Sinatra (2012) developed the Plausibility Perception Measure (PPM) instrument in response to the IPCC Fourth Assessment Report (2007) to measure students' plausibility perceptions about GCC. Lombardi and Sinatra (2012) examined the participants' perceptions of GCC because plausibility is an important factor when studying a controversial scientific topic such as GCC, as it is an important element of conceptual change. The statements of the PPM were consistent with the main conclusions of the 2007 IPCC report (Lombardi & Sinatra, 2012). The PPM instrument is a ten-point Likert scale, with 1 = highly implausible or even impossible and 10 = highly plausible, and has eight statements (Lombardi & Sinatra, 2012). The PPM scale aims to assess participants' plausibility perceptions of anthropogenic GCC.

Lombardi et al. (2016) differentiate plausibility and understanding because plausibility refers to whether individuals view presented information as potentially true or credible rather than verifying its absolute truth (Lombardi & Sinatra, 2012). The PPM scale aims to identify individuals' plausibility perceptions, which may be influenced by, but is distinct from, one's factual knowledge about GCC. Since the 2007 IPCC report, possible consequences, vulnerabilities, and available strategies for dealing with GCC significantly changed. The 2022 IPCC report on impacts, adaptation, and vulnerability includes various factors about the climate crisis. Therefore, the impact of plausibility perceptions about GCC on education is substantial (Ceyhan & Mugaloglu, 2020), and the substantial impact of plausibility perceptions about GCC on education has been empirically demonstrated (Sinatra & Lombardi, 2020; Lombardi et al., 2016). Implications for future research in environmental education include further examining the factors that influence plausibility perceptions about GCC, such as prior knowledge (Lombardi et al., 2013), cognitive biases (Sinatra et al., 2014), and social influences (Broomell et al., 2015).

The PPM scale has been widely used in research across various fields to assess individuals' perceptions about the plausibility of GCC. In psychology, the PPM has been used to examine how plausibility judgments influence learners' engagement and motivation related to GCC (Lombardi et al., 2016; Nadelson et al., 2018). In science education, researchers have used the PPM to investigate the relationship between students' plausibility perceptions and conceptual understanding regarding GCC (Lombardi et al., 2013). In environmental education and GCC communication, the PPM scale has been utilized to assess how educational interventions impact participants' views on GCC's plausibility and willingness to act (Ceyhan & Mugaloglu, 2020). Comparative studies have administered the PPM to different cultural groups to examine cross-cultural variability in GCC plausibility perceptions (Lu & Schuldt, 2016). Given the substantial research conducted using the original PPM scale across disciplines and its demonstrated utility as a measure, there is a clear need to update the scale to reflect the latest scientific evidence and consensus around GCC, as presented in the IPCC 2022 report. The current study answers this need by revising and validating an updated version of the PPM scale, providing an improved instrument for continued research on the educational, psychological, and social dimensions of GCC perceptions.

Furthermore, studies could also investigate effective strategies for enhancing the plausibility of scientifically accurate information about climate change. For example, clear explanations, credible sources, and relatable examples may help make abstract climate science concepts more plausible to learners (Danielson et al., 2016). Longitudinal research could track how plausibility perceptions evolve over time (Lombardi et al., 2016) and relate to actual knowledge gains and behavior changes (Sinatra & Seyranian, 2016). Exploring the role of emotions in shaping plausibility judgments is another promising avenue, as emotions have been shown to interact with conceptual change (Heddy et al., 2017). Additionally, researchers could examine how plausibility perceptions differ across diverse populations and cultural contexts (Lombardi et al., 2014) to inform equitable and inclusive climate change education efforts. Overall, attending to plausibility in both research and practice is key for advancing effective climate change education. For these reasons, there is a need for an updated version of the PPM scale to measure individuals' plausibility perceptions regarding GCC effectively.

2.3. Current Study

Research in the literature evaluates GCC perception by conducting interviews with specific groups (Altschuler & Brownlee, 2016; Banerjee, 2015; Bloodhart et al., 2015; Hopkins & Maclean, 2014; Kelman et al., 2017). Studies include fishermen (Mulyasari et al., 2023), farmers (Fosu-Mensah et al., 2012; Mertz et al., 2009), people living in coastal areas in different parts of the world (Altschuler & Brownlee, 2016; Bloodhart et al., 2015; Kelman et al., 2017; Rahman et al., 2023), ski industry workers (Hopkins & Maclean, 2014, 2012), people living in arid regions (Banerjee, 2015). Studies have found similar results that participants have difficulty implementing adaptation strategies for GCC (Altschuler & Brownlee, 2016; Fosu-Mensah et al., 2012; Mertz et al., 2009; Mulyasari et al., 2023). Studies have also found high perceptions of GCC, stating that participants could not associate concepts such as high temperatures, extreme weather events, and climate change with GCC and that they had difficulty understanding the long-term effects of GCC (Altschuler & Brownlee, 2016; Banerjee, 2015; Bloodhart et al., 2015).

Additionally, some research measured the perception of GCC based on various GCC reports or databases (Baer et al., 2019; Van Valkengoed et al., 2021). Baer et al. (2019) surveyed the perceptions of high school students, their parents, and teachers towards the GCC based on the document published by the 2015 Lancet Commission on Health and Climate Change. The research revealed that the participants had low perceptions and knowledge of GCC (Baer et al., 2019). Additionally, the internal consistency value of the developed scale was low ($\alpha = .39$) (Baer et al., 2019). The study emphasizes the importance of educational strategies and teachers in shaping perceptions towards GCC (Baer et al., 2019). In another study that measured perceptions towards the GCC, a scale was developed based on a literature review and expert opinions (Van Valkengoed et al., 2021). The scale was tested with participants from the USA and the Netherlands, demonstrating good reliability (α > .80). Based on the study, most participants recognized that humans are responsible for GCC and acknowledged its negative impacts. This study contributes to the literature by updating the PPM scale developed by Lombardi and Sinatra (2012), which includes unmodified scientific statements taken directly from the IPCC report. Since the original instrument used all the items from the IPCC (2007), the current scale contains statements from the IPCC 2022, which are positively worded, similar to the original scale. Also, in some instrument development and validation articles, researchers used all positively worded items in their scales and found them reliable and valid (Horry et al., 2023; Verhelst et al., 2022).

The present PPM scale (2017) must be updated in light of the constantly evolving climatic data and scientific findings. Given the need to update the PPM scale, this study aims to update the PPM scale according to the 2022 IPCC report and to answer the following research question: Does the updated PPM scale measure the three identified factors in the 2022 IPCC report?

3. Materials and Methods

This study was designed as a survey-based quantitative study to update the PPM scale by the 2022 IPCC report on GCC's impacts, adaptation, and vulnerability. Data sources for the current study included the updated PPM scale.

3.1. Context and Participants

Participants in the current study were pre-service teachers from a large, research-intensive public university. The university primarily focuses on undergraduate and graduate engineering and applied and social sciences education. The university has an Institute of Environmental Sciences that offers elective courses for pre-service teachers in the School of Education. Additionally, the university's Center for Climate Change and Policy Studies conducts interdisciplinary research on the impacts of GCC and related policies and shares news about GCC worldwide. However, teacher education programs lack a strong focus on climate change education, leaving many educators underprepared to effectively teach this complex and dynamic topic (Ceyhan & Mugaloglu, 2020).

In this study, the participants were selected using convenience sampling with a group available to participate (Gay et al., 2012). 330 pre-service teachers participated in the study, studying chemistry education, physics education, science education, mathematics education, computer education, and primary education programs in the summer of 2022. 207 (63%) of the participants were in their first or second year, and 123 (37%) of them were senior or junior pre-service teachers (aged between 18-21 years old). 221 (67%) of the participants were female, 103 (31%) of them were male, 4 (1%) of them were non-binary, and 2 (≈1%) preferred not to answer. 247 (75%) participants indicated they had not taken an environmental course in their undergraduate education, while 83 (25%) indicated they had taken an environmental course. (See Table 1).

Table 1. Demographic information of the participants

Demographic information		Number of participants
Gender	Female	221
	Male	103
	Non-binary	4
	Preferred not to answer	2
Department	Chemistry education	12
	Computer education	24
	Primary mathematics education (Middle school)	68
	Secondary mathematics education (High school)	63
	Primary education	71
	Physics education	11
	Science education	47
	Foreign Language Education	34
Grade	First year	50
	Second year	157
	Third year	63
	Fourth year	60
Taking environmental course(s)	Yes	247
	No	83

Pre-service teachers in the science, physics, and chemistry education programs are required to take environmental elective courses as part of their curriculum. In contrast, those in mathematics education, computer education, primary education, and foreign language education programs do not have a mandatory environmental elective course. This difference in program requirements may lead to variations in pre-service teachers' exposure to and understanding climate science. Therefore, it is important to acknowledge that the diverse undergraduate programs represented in this study may differ in their coverage of climate change science, which could influence participants' plausibility perceptions. This variation in background knowledge is a limitation of the current study. Future research should consider more homogeneous samples or directly assess and control for differences in prior knowledge.

3.2. Updating Process

First, the 2022 IPCC report was reviewed, and three factors were identified: observed and projected impacts and risks, adaptation and enabling conditions, and climate-resilient development. The IPCC 2022 report has three main titles and statements under the titles. The items were revised according to the 2022 IPCC report, and new items were added to the scale. For example, in the original PPM scale, one item stated "Continued emissions of carbon dioxide at or above current rates will cause further warming and induce many changes in global climate during the 21st century that are likely to be larger than those observed during the 20th century" (Lombardi & Sinatra, 2012, p. 215), in the updated PPM scale it has been changed to "Even if global warming is reduced, some impacts will cause the release of additional greenhouse gases and will be irreversible" (IPCC, 2022). While the original PPM scale had eight items (see Appendix A) and the factors were not specified, in the updated scale, the factors and the items they belong to were specified. The current PPM scale has items suitable for the current GCC, such as extreme weather events. Then, based on the high-confidence statements under the headings of these factors, 16 items were identified.

During the scale update process, the researchers received feedback and approval from the corresponding author of the original PPM scale (Lombardi & Sinatra, 2012). The expert opinion was obtained, and minor changes have been made to some of the statements to clarify and improve the readability of the statements without changing their meaning (see Appendix A). The IPCC report (2022) defined observed and projected impacts and risks based on scientific explanations and observations, considering many different aspects such as general global warming, rising sea levels, melting glaciers, demographic changes, destruction of ecosystems, and unsustainable consumption of natural resources. The report defined adaptation and mitigation strategies to manage the impacts of GCC and adaptation processes to reduce climate risks and vulnerability (IPCC, 2022). Climate-resilient development was defined as implementing mitigation and adaptation together in support of sustainable development for all. The IPCC report (2022) also includes achieving climate-resilient development for natural and human systems. The table of specifications for the updated PPM scale is shown in Table 2 below. The PPM Scale has 16 ordinal items, where from item 1 to item 6 are related to factor 1 (observed and projected impacts and risks), from item 7 to item 11 are related to factor 2 (adaptation measures and enabling conditions), from item 12 to item 16 are related to factor 3 (climate resilient development).

Table 2. Table of specifications for the PPM scale

Category	Example Item in the Category	Item Numbers
Observed and Projected Impacts and Risks	Item 3: On average, Earth will warm 1.5°C by 2040, and this will cause unavoidable increases in climate hazards and risks to ecosystems and humans.	1,2,3,4,5,6
Adaptation Measures and Enabling Conditions	Item 10: Implementation of maladaptive actions can result in infrastructure and institutions that are inflexible and/or expensive to change.	7,8,9,10,11
Climate Resilient Development	Item 15: Biodiversity and ecosystems play a key role in adaptation and mitigation. In light of the threats climate change poses to them, safeguarding biodiversity and ecosystems is fundamental to climate-resilient development.	12,13,14,15,16

*Items are based on the high-confidence statements in the IPCC (2022) report

3.3. Data Collection

After the updating process, the scale consisted of 16 16-item ten-point Likert scale ranging from 10 = highly plausible to 1 = highly implausible. First, the Institutional Review Board for Research with Human Subjects approved the study, and its approval number is E-84391427-050.01.04-77278. Then, academics from the school of education at the university were contacted, and the data were collected from pre-service teachers studying at a research-oriented public university.

The data collection took about fifteen minutes during the allowed class time. Participation in the research was completely voluntary; before the survey, pre-service teachers were asked to agree to participate in the research. The letter of invitation was placed at the beginning of the survey. The cover letter included the purpose and importance of the study and how the results would be shared. Informed consent was obtained through this cover letter to address ethical issues. All the data collected were confidential, and no personal information, including the names of the survey respondents, was available to ensure complete anonymity.

3.4. Data Analysis

After data collection, descriptive statistics were performed using SPSS, and CFA analysis was performed using JASP. Reliability and validity analyses were conducted to update the priority according to the IPCC 2022 report. Confirmatory Factor Analysis (CFA) was used to determine construct validity to validate the updated PPM scale. CFA is a valuable tool for researchers who want to assess the validity and reliability of their measures and test theoretical models of latent constructs. By using CFA, researchers can ensure that their measures accurately reflect the underlying constructs they intend to measure and can use the results to inform further research and theory development (Brown & Moore, 2012; Suhr, 2006). The reason for using CFA is that this study is not developing a new scale but rather revising the drivers based on the old PPM scale. In addition, the revision of the scale followed the procedures of developing the original PPM scale and received expert approval from one of the developers of the original PPM scale. Therefore, CFA was conducted to determine whether or not the updated PPM scores fit the model. A three-factor model was used because there are three identified factors in the updated PPM scale.

4. Results

According to the descriptive statistics, Table 3 shows the statistics for the updated PPM scale items. Item 16 has the lowest mean (*M*=5.95, *SD*= 2.236), whereas Item 4 has the highest mean (*M*=8.46, *SD*=1.699).

Table 3. Item statistics

Item	M	SD	n
Item 1: Human-caused climate change has caused widespread losses and damages to nature and people, including more frequent and intense extreme events.	8.22	1.779	330
Item 2: Human activities intensify the vulnerability of ecosystems to climate change.	8.11	1.754	330
Item 3: On average, Earth will warm 1.5°C by 2040, and this will cause unavoidable increases in climate hazards and risks to ecosystems and humans.	8.14	1.958	330
Item 4: Depending on the level of global warming, climate change will lead to numerous risks to natural and human systems beyond 2040.	8.46	1.699	330
Item 5: Concurrent and repeated climate hazards are occurring in all world regions, increasing impacts and	8.28	1.790	330

risks to health, ecosystems, infrastructure, livelihoods, and food.			
Item 6: Even if global warming is reduced, some impacts will cause the release of additional greenhouse gases and be irreversible.	7.24	1.957	330
Item 7: Progress in adaptation planning and implementation has been observed across all sectors and regions generating many benefits. However, this progress is unevenly distributed with observed adaptation gaps.	7.07	1.812	330
Item 8: Adaptation to water-related risks and impacts make up the majority of all documented adaptation.	7.05	1.893	330
Item 9: Soft limits to some human adaptation have been reached, but can be overcome by addressing financial, governance, institutional, and policy constraints.	7.26	1.932	330
Item 10: Implementation of maladaptive (improper) actions can result in infrastructure and institutions that are inflexible and/or expensive to change.	7.22	1.927	330
Item 11: Political commitment across all levels of government accelerates the implementation of adaptation actions.	7.45	2.031	330
Item 12: Opportunities for climate resilient development are not fairly distributed around the world. This undermines efforts to achieve sustainable development, particularly for vulnerable and marginalized communities.	7.60	1.989	330
Item 13: Climate resilient development is enabled when governments, civil society, and the private sector make inclusive development choices that prioritize risk reduction, equity, and justice.	7.61	1.979	330
Item 14: Climate resilient development is enabled when decision-making processes, finance, and actions are integrated across governance levels, sectors, and timeframes.	7.65	1.839	330

Item 15: Biodiversity and ecosystems play a key role in adaptation and mitigation. In light of the threats climate change poses to them, safeguarding biodiversity and ecosystems is fundamental to climate resilient development.	7.99	1.795	330
Item 16: Past and current development trends (past emissions, development, and climate change) have not advanced global climate resilient development.	5.95	2.236	330

4.1. Reliability

Reliability is the consistency with which the same results can be replicated over time or by different observers (Gay et al., 2012). Internal consistency reliability is the degree to which the items on a single test are consistent within themselves and with the rest of the test (Gay et al., 2012). In this study, Cronbach’s Alpha and Split-Half were used to evaluate the internal consistency reliability of test scores. The scale's reliability is determined with Cronbach’s Alpha coefficient (α=.92) using SPSS 27.0 (Pallant, 2016). The value of Cronbach’s alpha represents an excellent consistency measure since it is .92 (> .90) for the corresponding scale (Crocker & Algina, 1986).

The item total statistics of the instruction evaluation instrument indicated that all items' corrected item-total correlation values show good discrimination. The value of the corrected item-total correlation is <.30, which means no problematic item exists. Additionally, it is revealed that the value for Cronbach's Alpha would increase (α=.93) when Item 16 is removed from the scale.

4.1.1. Split-Half

The split-half reliability is used to calculate the internal consistency, which measures the same constructs in the scale (DeVellis, 2012). Since the PPM scale measures the same construct plausibility, the split-half reliability was calculated by dividing the test into two halves: an odd number of items and an even number of items. Then, the correlation between these two groups was computed using SPSS 27.0 (Pallant, 2016). As seen in Table 4, the mean for odd was 62.01 (*SD* = 11.20), and the mean for even was 59.27 (*SD* = 10.33). The Pearson correlation results revealed a statistically significant positive relationship between odds and evens (r=.91, p<.01). In addition, the internal consistency was assessed using the Spearman-Brown coefficient. The values between .70 and .90 are acceptable for the Spearman-Brown coefficient (Pallant, 2016).

Table 4. Descriptive statistics and correlations for study variables

Variable	n	M	SD	1	2
Total 1 (Odd)	330	62.01	11.20	1	.91**
Total 2 (Even)	330	59.27	10.33		1

*** p<.01*

Longer tests have a stronger tendency to be reliable, and the split-half reliability coefficient represents the reliability of a test half the length of the true test (Pallant, 2016). Therefore, the Spearman-Brown formula determines the test's overall reliability.

Spearman Brown formula (Crocker & Algina, 1986):

$$r_{SB} = 2 \times r_{HH} / 1 + r_{HH}$$

$$= 2 \times .91 / 1 + .91$$

$$= .95$$

As seen in Figure 1, it can be stated that there is a positive relationship based on the interpretation that the data presents a pattern that is uphill between the items.

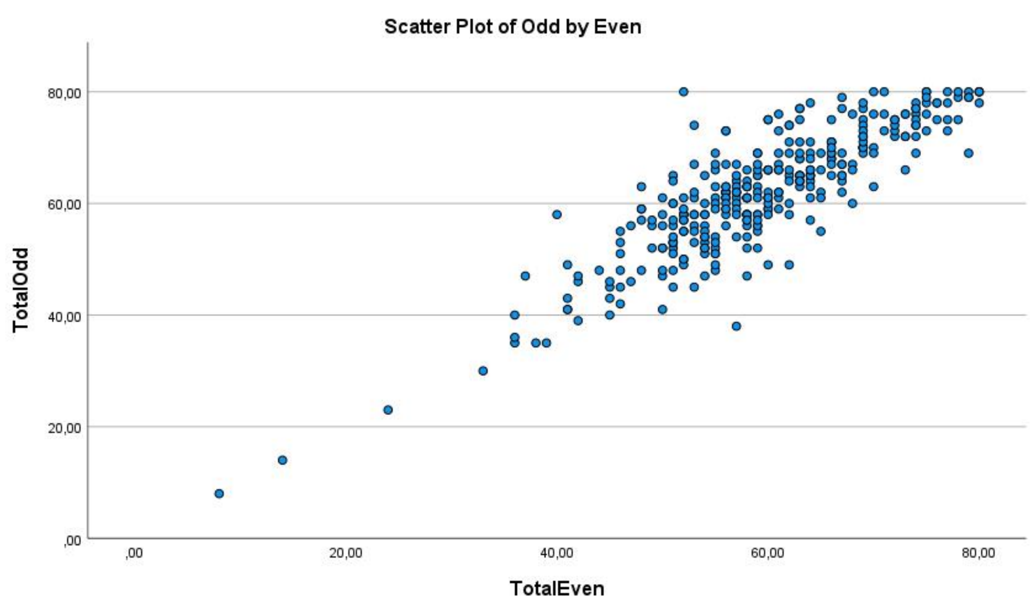

Figure 1. Scatterplot

During the reliability analysis process, 1 of the 16 items, Item 16, which is 'Past and current development trends (past emissions, development, and climate change have not advanced global climate resilient development', decreased the reliability value. Therefore, the validity analysis was continued with 15 items. In its final form, the scale included 15 items, and the participants rated each statement on a ten-point Likert scale ranging from 10 = highly plausible to 1 = highly implausible. In the final form of the updated PPM scale, items 1 through 6 relate to Factor 1, items 7 through 11 relate to Factor 2, and items 12 through 15 relate to Factor 3 (see Appendix B).

After Item 16 was removed from the scale, reliability analysis with Cronbach's Alpha was also conducted according to each of the three factors of the updated scale. While the value of Cronbach's Alpha represents a good consistency for Factor 1, which has six items, and Factor 3, which has four items (α=.88 and α=.85, respectively), the reliability value for Factor 2, which has five items, shows an acceptable consistency for the updated PPM scale (α=.79).

The split-half reliability was also calculated by dividing each factor of the scale into two halves an odd number of items and an even number of items. As seen in Table 5, the mean for odd items in Factor 1 was 24.63 (*SD* = 4.78), and the mean for even items in Factor 1 was 23.80 (*SD* = 4.35). The mean for odd items in Factor 2 was 21.78 (*SD* = 4.58), and the mean for even items in Factor 2 was 14.27 (*SD* = 3.17). The mean for odd items in factor 3 was 15.60 (*SD* = 3.36), and the mean for even items in factor 3 was 15.24 (*SD* = 3.42). The results of the Pearson correlation revealed that there is a statistically significant positive relationship between odd and even items in Factor 1 (r=.81, p<.01), Factor 2 (r=.67, p<.01), and Factor 3 (r=.76, p<.01).

Table 5. Descriptive statistics and correlations for the factors

Variable	n	M	SD	1	2
Factor 1 Total 1 (Odd)	330	24.63	4.78	1	.81**
Factor 1 Total 2 (Even)	330	23.80	4.35		1
Factor 2 Total 1 (Odd)	330	21.78	4.58	1	.67**
Factor 2 Total 2 (Even)	330	14.27	3.17		1
Factor 3 Total 1 (Odd)	330	15.60	3.36	1	.76**
Factor 3 Total 2 (Even)	330	15.24	3.42		1

*** p<.01*

4.2. Validity

Validity is the degree to which something measures what it purports to measure (Gay et al., 2012). In this study, two types of validity, content and construct validity, were investigated.

4.2.1. Content Validity

The extent to which a test measures an intended content area is called content validity (Gay et al., 2012). For content validity, the judgments of subject matter experts with expertise in the test content were reported. Two content experts scored each item on a scale of 1 to -1. A score of 1 indicates that the item measures the objective, 0 indicates that it is unclear to what extent it measures the item, and a score of -1 indicates that the objective does not measure the item.

According to the results of the content experts' ratings, two experts scored items 1-6 as 1 for Factor 1 (observed and projected impacts and risks), -1 for Factor 2 (adaptation measures and enabling conditions), and Factor 3 (climate resilient development). Items between 7-11 were scored as -1 for Factor 1, 1 for Factor 2, and -1 for Factor 3. Items between 12-16 were rated -1 for Factors 1 and 2 and 1 for Factor 3. These ratings show that the experts have approved the items and the factors to which they belong. As a result, the items measure the factors.

Table 6 represents the results of the index of Item–Objective Congruence. The item-objective congruence index developed by Rovinelli and Hambleton (1977) is used in test development to assess content validity at the item development stage. It is a method for measuring judgments of items by content experts to assess the congruence between the items and the specification table (Turner & Carlson, 2003). For all the items of the PPM scale, the item-objective congruence index was 1. Items with item-objective congruence greater than .70 are accepted as valid measures of their proposed objectives (Rovinelli & Hambleton, 1976). The item-objective congruence scores for all the items are valid because the index is greater than .70.

Table 6. The results of the index of item-objective congruence

		Factors		
Items	Item-Objective Congruence Index	Observed and Projected Impacts and Risks	Adaptation Measures and Enabling Conditions	Climate Resilient Development
Item 1	1	1*	0	0
Item 2	1	1*	0	0
Item 3	1	1*	0	0
Item 4	1	1*	0	0

Item 5	1	1*	0	0
Item 6	1	1*	0	0
Item 7	1	0	1*	0
Item 8	1	0	1*	0
Item 9	1	0	1*	0
Item 10	1	0	1*	0
Item 11	1	0	1*	0
Item 12	1	0	0	1*
Item 13	1	0	0	1*
Item 14	1	0	0	1*
Item 15	1	0	0	1*
Item 16	1	0	0	1*

** indicates the factor on which the item depends. For all items: ¾ (1-(-1:3)=1*

The intra-class correlation coefficient and its 95% confidence intervals were calculated based on the absolute-agreement, 2-way mixed-effects model, which represents a measure of the reliability of ratings when two or more expert raters are involved in the studies. The results indicated that the value of intra-class correlation is .91, which is an excellent value for the agreement; the items can be rated with an excellent reliability by different raters (Field, 2013).

4.2.2. Construct Validity

4.2.2.1. Confirmatory Factor Analysis (CFA)

A factor is defined as an unobservable variable, and it is possible to calculate the correlations between factors and tests. Confirmatory Factor Analysis (CFA) is used to test competitive models and confirm relationships among variables (Harrington, 2009). It is a statistical technique used to test hypotheses about the latent structure of a set of observed variables (Suhr, 2006). The primary importance of CFA lies in its ability to assess the construct validity of a measure or questionnaire by testing whether the observed data fit a hypothesized factor structure (DiStefano & Hess, 2005; Harrington, 2009). CFA also provides a way to estimate each factor's reliability and validity and compare different models to see which one best fits the data. CFA was conducted using JASP (JASP Team, 2022) to evaluate whether the hypothesized structure fits the observed data well or not and to test the construct validity of the instrument. It was used to evaluate the factor structure of the model, which is a three-factor model and has 16 items, where from item

1 to item 6 are related to Factor 1, from item 7 to item 11 are related to Factor 2, from item 12 to item 15 are related to Factor 3. For the analysis, fit indices of values such as root mean square error of approximation (RMSEA), goodness of fit index (GFI), and comparative fit index (CFI) were examined. RMSEA values below .08 and GFI and CFI values greater than .90 indicate a good and fit model (Ullman, 2001). The results of the confirmatory factor analysis reported in Table 7 revealed that the three-factor model had a very good fit for the data (TLI ≥ .90, CFI ≥ .90, RMSEA ≤ .08).

Table 7. The results of the confirmatory factor analysis

Model	χ^2	df	TLI	CFI	RMSEA	GFI
Factor Model	248.744	87	.92	.93	.07	.98

χ^2 = Chi-square; df = degrees of freedom; TLI = Tucker Lewis index; CFI = comparative fit index; RMSEA = root mean square error of approximation; CI = confidence interval.

According to Table 8, all p values are less than .001, meaning all factor loadings are significant (p <.001).

Table 8. Factor loadings

Factor	Indicator	Estimate	Std. Error	*p*
Factor 1	Item 1	1.399	.084	<.001
	Item 2	1.306	.085	<.001
	Item 3	1.520	.093	<.001
	Item 4	1.323	.081	<.001
	Item 5	1.488	.082	<.001
	Item 6	1.160	.102	<.001
Factor 2	Item 7	1.248	.092	<.001
	Item 8	1.163	.100	<.001
	Item 9	1.285	.100	<.001
	Item 10	1.269	.100	<.001
	Item 11	1.339	.105	<.001
Factor 3	Item 12	1.515	.096	<.001
	Item 13	1.514	.096	<.001
	Item 14	1.462	.088	<.001
	Item 15	1.400	.086	<.001

The standardized factor loadings of the items reported in Figure 2 ranged from .59 to .83

for Factor 1; .62 to .69 for Factor 2; and .76 to .80 for Factor 3. Since it is indicated that factor loadings should be greater than .5 for better results (Hair et al., 2009), all of the factor loadings of the items are significant. Additionally, all the correlations between items and factors were significant (p = < .001). As seen in the Figure 2, cross factor loadings indicate good discriminant validity (Ab Hamid et al., 2017).

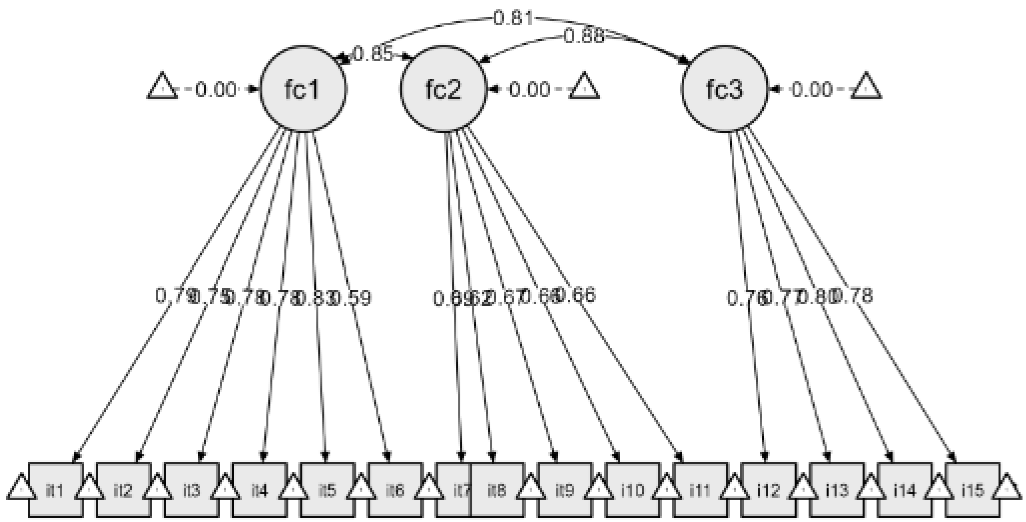

Figure 2. Model plot

4.2.2.2. Measurement Invariance

The participants were pre-service teachers who were studying in eight different departments from first grade to senior year. Six of these eight different departments [Chemistry education, Computer education, Primary mathematics education (Middle school), Secondary mathematics education (High school), Physics education, and science education] were required to take science, math, physics, and chemistry courses during their four-year undergraduate education. The other two departments (Primary education and Foreign Language education) were not required to take any science-related courses during their undergraduate education. Therefore, the measurement invariance of the PPM scale was measured across departments that took required science-related courses and those that did not, using the multigroup confirmatory factor analysis technique. Structural, metric, and scalar invariance were tested to see whether the factorial structure, item content, and factor loadings represent measurement equivalence (Vandenberg & Lance, 2000) (see Table 9).

Measurement invariance is critical in determining whether the measuring instrument and the construct being measured are operating in the same way across the populations of interest in terms of factorial structure, factor loadings, item content, and intersections (Byrne & Van de Vijver, 2010, p. 108). In this context, firstly, the configural invariance analysis was conducted. Configural invariance across departments that took required science-related courses and those that did not show that the factor structure of the scale was similar for both groups since the fit indices were very good, TLI = .911, CFI = .975, RMSEA (%90 CI) = 080 [.071; 095]. Secondly, metric invariance analysis was examined by constraining the factor loadings (Cheung & Rensvold, 2002). Metric invariance results indicated that the fit index values supported the invariance, TLI = .918, CFI = .928, RMSEA (%90 CI) = .080 [.068;.091]. The change in the fit statistics also supported the invariance; therefore, the factor loadings were equivalent across departments that took required science-related courses and those that did not (ΔCFI = .001, ΔRMSEA = .000). Lastly, scalar invariance was assessed by constraining item thresholds to be equal, beside factor loadings (Cheung & Rensvold, 2002). Scalar invariance results showed that the fit indexes values also supported the invariance, TLI = .924, CFI= .928, RMSEA (%90 CI = .077 [.066;.088]. The changes in the CFI and RMSEA also met the fit criteria (ΔCFI = .000, ΔRMSEA = -.003). These statistical findings revealed that the factor loadings and item thresholds were invariant; the configural, metric, and scalar invariance models were supported by the PPM scale.

Table 9. The results of the measurement invariance analysis

	χ^2	df	χ^2/df	TLI	CFI	RMSEA= (%90 CI)	ΔCFI	ΔRMSEA
Configural	371.880	174	2.14	.911	.927	.080 [.071; 095]	–	–
Metric	381.272	186	2.05	.918	.928	.080 [.068;.091]	.001	.000
Scalar	390.989	198	1.97	.924	.928	.077 [.066;.088]	.000	-.003

χ^2 = Chi-square; df = degrees of freedom; TLI = Tucker Lewis index; CFI = comparative fit index; RMSEA = root mean square error of approximation; CI = confidence interval; ΔCFI = change in values of CFI; ΔRMSEA = change in values of RMSEA.

An independent sample t-test was also conducted to examine whether there was a difference between the responses of the pre-service teachers in the departments that took compulsory science courses and those that did not. The results showed that there was no significant difference between the responses of the pre-service teachers in the departments that took compulsory science courses (M = 112.81, SD = 18.98) and the departments that did not (M = 120.70, SD = 21.15) ($t(328) = 3.39$, $p > .05$).

5. Discussion and Conclusion

In this study, the PPM scale developed by Lombardi and Sinatra (2012) was updated by reviewing the IPCC 2022 report. Data were collected from 330 pre-service teachers studying in various departments of the School of Education, including science, mathematics, chemistry, physics, computer, primary, and foreign language.

Collecting data from pre-service teachers was critical because teachers' perceptions, ideas, and attitudes can influence their and their students' lives. The way GCC was addressed in the classroom was influenced by the teachers' perceptions (Seow & Ho, 2016; Stevenson et al., 2016), and it may impact their teaching material and skills (Glackin, 2016; Ulug et al., 2011). Therefore, teachers' perceptions regarding environmental teaching are quite important (Lidstone & Stoltman, 2008). Prior research indicates that in-service and pre-service teachers often lack robust knowledge about climate science and solutions (Papadimitriou, 2004; Lambert et al., 2012) and have various plausibility perceptions about GCC (Ceyhan & Mugaloglu, 2020; Ceyhan et al., 2021). Since pre-service teachers will educate future generations, evaluating their plausibility perceptions of GCC is also crucial (Henriques, 2002). Given the impacts of teachers' plausibility perceptions, improving their understanding of and engagement with GCC should be a priority (Cordero et al., 2008; Lambert et al., 2012). The updated PPM provides a useful tool to identify areas where teachers' plausibility perceptions may need strengthening through educational interventions. Therefore, the current study aimed to update the PPM scale that measures students' plausibility perceptions on GCC according to the 2007 IPCC report (Lombardi & Sinatra, 2012). The updated scale is based on the 2022 IPCC report, which includes significant elements of GCC that have changed since the 2007 IPCC report.

The Cronbach's alpha for the instrument in final form was calculated to be .93, indicating excellent reliability (Crocker & Algina, 1986). As a result of the item sum statistics, it was observed that Item 16 decreased the reliability, Item 16 was removed, and the validity analysis was continued with 15 items. In this context, it can be inferred that item 16 decreases the scale's reliability value because it is a negative item. Crocker & Algina (1986) stated that using negatives such as not, none, or never should be avoided in Likert-type scales. Therefore, we updated the scale with minor changes to reduce its incompatibility with the high-confidence statements in the IPCC 2022 report. The only item that was formed as negative was Item 16, and item statistical analysis showed that Item 16 decreased the scale's reliability. In this regard, the low statistical values of item 16 are supported by the existing literature, which shows that negative statements confuse respondents (DeVellis, 2012).

Regarding the content validity results, each item was rated as appropriate for the factor to which it belongs. The confirmatory factor analysis provided strong evidence that the scale aligns with the hypothesized model comprising factors of observed GCC risks, adaptation measures, and climate-resilient development. According to the results, the updated PPM scale is reliable and valid, and this study contributes to the literature by presenting an updated scale to measure individuals' plausibility judgments about the GCC crisis, according to the 2022 IPCC report. The most significant influence on how people viewed the plausibility of GCC impacts was their perception of the risks already happening, such as increasing global temperatures, extreme weather events, and irreversible environmental changes (Lombardi et al., 2014). These impacts feel more immediate and real to many people (Lu & Schuldt, 2015). On the other hand, climate-resilient development did not seem to impact people's opinions as much. This might be because considering climate-resilient development requires looking ahead and considering the global picture (Schuldt et al., 2018). It may seem more remote or distant to individuals than the direct effects of GCC they are experiencing now.

The adaptation measures factor fell in the middle, with moderately high loadings. This may indicate that pre-service teachers found societal adaptation efforts reasonably plausible. However, some items, like maladaptive actions that limit flexibility, had lower means, which may indicate uncertainty (Metzger et al., 2021). The multi-dimensional scale structure allows nuanced insights into different views of GCC dimensions (Lu & Schuldt, 2016). Educators can use these factor-level findings to identify strengths and weaknesses in plausibility perceptions (Lombardi & Sinatra, 2013). For example, teacher preparation programs could focus more on generating plausibility around long-term resilient development. The validated PPM provides a psychometrically sound instrument for this diagnostic assessment.

As a limitation, this study used an updated PPM scale in light of its commitment to replicate previous methodologies. The updated PPM scale was developed to assess the plausibility perceptions about GCC rather than specific knowledge or understanding of climate science. As such, it may not be sensitive enough to capture differences in plausibility perceptions due to differences in educational background or disciplinary training. Also, discriminating power is only one aspect of a scale's psychometric properties, and the updated PPM scale demonstrated good reliability and validity in other aspects, such as internal consistency and factor structure. Another limitation is that there are no implausible items in our current measure. Given the misconceptions about climate change, the presence of implausible deterrent items could strengthen the measure. However, the current study focuses on replicating the earlier scale's focus and methods.

As the world continues to face the consequences of GCC, there is an urgent need to strengthen climate change education at all levels. The results of this study highlight the importance of providing pre-service teachers with more comprehensive training on climate science and pedagogy. Integrating climate change education into teacher preparation programs and offering professional development opportunities, such as those initiated by universities and non-governmental organizations, can help build teachers' knowledge, skills, and confidence in addressing this critical issue. By enhancing teachers' plausibility perceptions and readiness to teach about climate change, teachers can foster a new generation of informed and engaged citizens prepared to respond to the challenges posed by GCC.

5.1.Implications for Instruction and Future Research

In a changing and developing world, to measure individuals' perceptions of GCC, it is necessary to examine the factors highlighted in the new report to obtain more valid results. This study updates and validates an updated tool, and educators can benefit by seeing how plausible today's students perceive GCC and its effects. According to the literature, many educated people and pre-service teachers have inadequate perceptions of GCC, even if they have a scientific background (Feldman, 2010; Li & Liu, 2022).

As GCC poses many challenges today and in the future, the current study aims to update the PPM scale because the latest IPCC report in 2022 focuses on different factors and contents from the old PPM scale. Further studies can examine students' plausibility perceptions of GCC in a comparative manner across different majors/departments. The updated PPM scale can be used in different contexts and with different age groups, as it is updated according to the latest IPCC reports. The updated PPM provides researchers with a survey related to the current GCC. This instrument plays an important role in seeing the current plausibility perceptions of different groups about GCC, as the items are taken from the IPCC 2022 report.

Future research can use this new instrument to see people's perceptions, especially college students, pre-service teachers, and teachers considering GCC training. Based on this, the deficiencies in GCC education can be reviewed. The data in this study was collected from pre-service teachers; data can be collected from different groups to look at plausibility perceptions on GCC. The results of the current study may guide the curriculum of GCC education and teacher preparation programs. Furthermore, the results may guide future studies on determining the plausibility perceptions of pre-service teachers, who play a critical role in guiding students to become conscious citizens who may cope with the GCC crisis.

Since the participants in this study were pre-service teachers from different departments and backgrounds, PPM scores were examined to see if there was a significant difference in PPM scores. Results showed that PPM scores do not show statistically significant differences depending on the participants' departments. GCC training is insufficient in the literature (Li & Liu, 2022), and this insufficiency may be one of the reasons why the PPM scores of the participants did not differ in the current study. Regardless of the department at the university where the participants studied, environmental courses are offered to all students as an elective course option. For this reason, the adequacy of GCC training and the extent to which pre-service teachers' interest in GCC affects their undergraduate education may be the subject of future studies. Additionally, as a limitation, results based on the participants' demographic information (e.g., grade level and gender) have not been examined. Future studies may compare PPM scale results according to participants' grade levels, gender, and whether they have taken environmental courses.

It is important to acknowledge that the pre-service teachers in this study were drawn from diverse undergraduate programs, which may differ in their coverage of climate change science. For example, pre-service teachers in science and mathematics education programs likely had more exposure to climate change concepts through their coursework than in primary or foreign language education. This variation in background knowledge is a limitation of the current study, as it may influence participants' plausibility perceptions about climate change. Future research could consider more homogeneous samples or directly assess and control for differences in prior knowledge.

Declaration of interest statement

The authors reported no potential conflict of interest.

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Ethics statements

This study met the ethics requirements for human subject research. The Institutional Review Board for Research with Human Subjects reviewed the study, and its approval number is E-84391427-050.01.04-77278.

References

Abbass, K., Qasim, M. Z., Song, H., Murshed, M., Mahmood, H., & Younis, I. (2022). A review of the global climate change impacts, adaptation, and sustainable mitigation measures. *Environmental Science and Pollution Research, 29*(28), 42539-42559. https://doi.org/10.1007/s11356-022-19718-6

Ab Hamid, M. R., Sami, W., & Sidek, M. M. (2017, September). Discriminant validity assessment: Use of Fornell & Larcker criterion versus HTMT criterion. In *Journal of Physics: Conference series* (Vol. 890, No. 1, p. 012163). IOP Publishing.

Altschuler, B., & Brownlee, M. (2016). Perceptions of climate change on the Island of Providencia. *Local Environment, 21*(5), 615-635. https://doi.org/10.1080/13549839.2015.1004165

Arslan, H. O., Cigdemoglu, C., & Moseley, C. (2012). A three-tier diagnostic test to assess pre-service teachers' misconceptions about global warming, greenhouse effect, ozone layer depletion, and acid rain. *International Journal of Science Education, 34*(11), 1667-1686. https://doi.org/10.1080/09500693.2012.680618

Baer, A. D. P., Sestili, C., Cocchiara, R. A., Barbato, D., Del Cimmuto, A., & La Torre, G. (2019). Perception of climate change: Calidation of a questionnaire in Italy. *La Clinica Terapeutica, 170*(3), e184-e191. https://doi.org/10.7417/CT.2019.2131

Baker, C., Clayton, S., & Bragg, E. (2021). Educating for resilience: Parent and teacher perceptions of children's emotional needs in response to climate change. *Environmental Education Research, 27*(5), 687-705.

Banerjee, R. R. (2015). Farmers' perception of climate change, impact and adaptation strategies: A case study of four villages in the semi-arid regions of India. *Natural Hazards, 75*, 2829-2845. https://doi.org/10.1007/s11069-014-1466-z

Beeth, M. E. (1998). Teaching for conceptual change: Using status as a metacognitive tool. *Science Education*, *82*(3), 343-356.

Bloodhart, B., Maibach, E., Myers, T., & Zhao, X. (2015). Local climate experts: The influence of local TV weather information on climate change perceptions. *PloS One, 10*(11), e0141526. https://doi.org/10.1371/journal.pone.0141526

Boon, H. J. (2010). Climate change? Who knows? A comparison of secondary students and pre-service teachers. *Australian Journal of Teacher Education*, *35*(1), 104-120. https://doi.org/10.14221/ajte.2010v35n1.9

Brown, T. A., & Moore, M. T. (2012). Confirmatory factor analysis. *Handbook of Structural Equation Modeling*, *361*, 379.

Byrne, B. M., & Van de Vijver, F. J. (2010). Testing for measurement and structural equivalence in large-scale cross-cultural studies: Addressing the issue of nonequivalence. *International Journal of Testing*, *10*(2), 107-132. https://doi.org/10.1080/15305051003637306

Casper, A. M. A., & Balgopal, M. M. (2018). Conceptual change in natural resource management students' ecological literacy. *Environmental Education Research*, *24*(8), 1159-1176. https://doi.org/ 10.1080/13504622.2017.1350830

Ceyhan, G. D., Lombardi, D., & Saribas, D. (2021). Probing into pre-service science teachers' practices of scientific evaluation and decision-making on socio-scientific issues. *Journal of Science Teacher Education*, 32(8), 865-889.

Ceyhan, G. D., & Mugaloglu, E. Z. (2020). The role of cognitive, behavioral and personal variables of pre-service teachers' plausibility perceptions about global climate change. *Research in Science & Technological Education*, 38(2), 131-145.

Chen, C., Sonnert, G., Sadler, P. M., Sasselov, D., & Fredericks, C. (2020). The impact of student misconceptions on student persistence in a MOOC. *Journal of Research in Science Teaching*, *57*(6), 879-910. https://doi.org/10.1002/tea.21616

Cheung, G. W., & Rensvold, R. B. (2002). Evaluating goodness-of-fit indexes for testing measurement invariance. *Structural Equation Modeling*, *9*(2), 233-255. https://doi.org/10.1207/S15328007SEM0902_5

Cordero, E. C., Todd, A. M., & Abellera, D. (2008). Climate change education and the ecological footprint. *Bulletin of the American Meteorological Society*, *89*(6), 865-872. https://doi.org/10.1175/2007BAMS2432.1

Crocker, L.,& Algina, J. (1986). *Introduction to classical and modern test theory*. New York: Holt, Rinehart and Winston, 6277 SeaHarbor Drive, Orlando, FL 32887.

Dal, B., Alper, U., Özdem-Yilmaz, Y., Öztürk, N., & Sönmez, D. (2015). A model for preservice teachers' climate change awareness and willingness to act for pro-climate change friendly behavior: Adaptation of awareness to climate change questionnaire. *International Research in Geographical and Environmental Education*, *24*(3), 184–200. https://doi.org/10.1080/10382046.2015.1034456

DeVellis, R. F. (2012). *Scale development. Theory and Applications* (3rd ed.). Thousand Oaks, CA: Sage.

DiStefano, C., & Hess, B. (2005). Using confirmatory factor analysis for construct validation: An empirical review. *Journal of Psychoeducational Assessment*, *23*(3), 225-241. https://doi.org/10.1177/073428290502300303

Dole, J. A., & Sinatra, G. M. (1998). Reconceptalizing change in the cognitive construction of knowledge. *Educational Psychologist*, *33*(2-3), 109-128. https://doi.org/10.1080/00461520.1998.9653294

Duit, R., & Treagust, D. F. (2003). Conceptual change: A powerful framework for improving science teaching and learning. *International Journal of Science Education*, *25*(6), 671-688. https://doi.org/10.1080/09500690305016

Erol, G. H. (2005). *Sınıf öğretmenliği ikinci sınıf öğrencilerinin çevre ve çevre sorunlarına yönelik tutumları.* Unpublished Master's Thesis, Pamukkale University.

Fawzy, S., Osman, A. I., Doran, J., & Rooney, D. W. (2020). Strategies for mitigation of climate change: a review. *Environmental Chemistry Letters*, *18*, 2069-2094. https://doi.org/10.1007/s10311-020-01059-w

Feldman, L. (2010). The Climate Change Generation? Survey Analysis of the Perceptions and Beliefs of Young Americans: 20.

Field, A. (2013). *Discovering statistics using IBM SPSS statistics* (4th ed.). London: SAGE Publications.

Fosu-Mensah, B. Y., Vlek, P. L., & MacCarthy, D. S. (2012). Farmers' perception and adaptation to climate change: a case study of Sekyedumase district in Ghana. Environment, *Development and Sustainability*, *14*, 495-505. https://doi.org/10.1007/s10668-012-9339-7

Gay, L. R., Mills, G. E., & Airasian, P. W. (2012).*Educational research: Competencies for analysis and applications* (10th ed). Boston: Pearson.

Glackin, M. (2016). 'Risky fun'or 'Authentic science'? How teachers' beliefs influence their practice during a professional development programme on outdoor learning. *International Journal of Science Education*, *38*(3), 409-433. https://doi.org/10.1080/09500693.2016.1145368

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2009). *Multivariate data analysis* (7th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.

Hansen, P. J. K. (2010). Knowledge about the greenhouse effect and the effects of the ozone layer among Norwegian pupils finishing compulsory education in 1989, 1993, and 2005—What now?. *International Journal of Science Education*, *32*(3), 397-419. https://doi.org/10.1080/09500690802600787

Heddy, B. C., Danielson, R. W., Sinatra, G. M., & Graham, J. (2017). Modifying knowledge, emotions, and attitudes regarding genetically modified foods. *The Journal of Experimental Education*, *85*(3), 513-533.

Harrington, D. (2009). Confirmatory Factor Analysis. New York: Oxford University Press.

Henriques, L. (2002). Children's ideas about weather: A review of the literature. *School Science and Mathematics*, *102*(5), 202-215.

Hopkins, D., & Maclean, K. (2014). Climate change perceptions and responses in Scotland's ski industry. *Tourism Geographies, 16*(3), 400-414. https://doi.org/10.1080/14616688.2013.823457

Horry, R., Rudd, J. A., Ross, H., & Skains, R. L. (2023). Development and Validation of the Climate Capability Scale. *Sustainability*, *15*(15), 11933. https://doi.org/10.3390/su151511933

Hu, L. T., & Bentler, P. M. (1998). Fit indices in covariance structure modeling: Sensitivity to underparameterized model misspecification. *Psychological Methods*, *3*(4), 424. https://doi.org/10.1037/1082-989X.3.4.424

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indices in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling*, *6*, 1–55. https://doi.org/10.1080/10705519909540118

Huxster, J. K., Uribe-Zarain, X., & Kempton, W. (2015). Undergraduate understanding of climate change: The influences of college major and environmental group membership on survey knowledge scores. *The Journal of Environmental Education*, *46*(3), 149-165. https://doi.org/10.1080/00958964.2015.1021661

IPCC, (2022). Summary for policymakers. In: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)). United Kingdom and New York, NY, USA: Cambridge University Press. https://doi.org/10.1017/9781009325844

JASP Team (2022).JASP (Version 0.16.2) [Computer software]. https://jasp-stats.org/

Kahyaoğlu, M., & Özgen, N. (2012). Öğretmen adaylarının çevre sorunlarına yönelik tutumlarının çeşitli değişkenler açısından incelenmesi. *Journal of Theoretical Educational Science*, 173.

Karami, S., Shobeiri, S.M., & Jafari, H.R. (2017). Assessment of knowledge, attitudes, and practices (KAP) towards climate change education (CCE) among lower secondary teachers in Tehran, Iran. *International Journal of Climate Change Strategies and Management, 9*, 402-415. https://doi.org/10.1108/IJCCSM-04-2016-0043

Kelman, I., Upadhyay, H., Simonelli, A. C., Arnall, A., Mohan, D., Lingaraj, G. J., ... & Webersik, C. (2017). Here and now: perceptions of Indian Ocean islanders on the climate change and migration nexus. *Geografiska Annaler: Series B, Human Geography, 99*(3), 284-303. https://doi.org/10.1080/04353684.2017.1353888

Kilinc, A., Stanisstreet, M., & Boyes, E. (2008). Turkish students' ideas about global warming. *International Journal of Environmental and Science Education, 3*(2), 89-98.

Khalidi, R., & Ramsey, J. (2021). A comparison of California and Texas secondary science teachers' perceptions of climate change. *Environmental Education Research, 27*(5), 669-686. https://doi.org/10.1080/13504622.2020.1838447

Lambert, J. L., Lindgren, J., & Bleicher, R. (2012). Assessing elementary science methods students' understanding about global climate change. *International Journal of Science Education*, *34*(8), 1167-1187. https://doi.org/10.1080/09500693.2011.633938

Lee, H., Calvin, K., Dasgupta, D., Krinner, G., Mukherji, A., Thorne, P., ... & Ruane, A. C. (2024). CLIMATE CHANGE 2023 Synthesis Report Summary for Policymakers. *CLIMATE CHANGE 2023 Synthesis Report: Summary for Policymakers*.

Lidstone, J., & Stoltman, J. P. (2008). Global environmental change: What is the role of geography and environmental education?. *International Research in Geographical and Environmental Education*, *17*(2), 89-92. https://doi.org/10.1080/10382040802148539

Li, Y. Y., & Liu, S. C. (2022). Examining Taiwanese students’ views on climate change and the teaching of climate change in the context of higher education. *Research in Science & Technological Education*, *40*(4), 515-528.

Lombardi, D., & Sinatra, G.M. (2012). College students’ perceptions about the plausibility of human-induced climate change. *Research in Science Education*, *42*(2), 201-217. https://doi.org/10.1007/s11165-010-9196-z

Lombardi, D., & Sinatra, G. M. (2013). Emotions about teaching about human-induced climate change. *International Journal of Science Education*, *35*(1), 167-191. https://doi.org/10.1080/09500693.2012.738372

Lu, H., & Schuldt, J. P. (2016). Compassion for climate change victims and support for mitigation policy. *Journal of Environmental Psychology*, *45*, 192-200.

Malleus, E., Arro, G., Jesmin, T., Kaal, E., Kangur, M., Olesk, A., ... & Väljataga, T. (2023). Asking meaningful questions in digital outdoor learning tool-a way to support conceptual change. *Environmental Education Research*, 1-19. https://doi.org/10.1080/13504622.2023.2213415

Mertz, O., Mbow, C., Reenberg, A., & Diouf, A. (2009). Farmers’ perceptions of climate change and agricultural adaptation strategies in rural Sahel. *Environmental Management*, *43*, 804-816.

Metzger, J., Carlsson Kanyama, A., Wikman-Svahn, P., Mossberg Sonnek, K., Carstens, C., Wester, M., & Wedebrand, C. (2021). The flexibility gamble: challenges for mainstreaming flexible approaches to climate change adaptation. *Journal of Environmental Policy & Planning*, *23*(4), 543-558. https://doi.org/10.1080/1523908X.2021.1893160

Michail, S., Stamou, A. G., & Stamou, G. P. (2007). Greek primary school teachers' understanding of current environmental issues: An exploration of their environmental knowledge and images of nature. *Science Education*, *91*(2), 244-259. https://doi.org/10.1002/sce.20185

Mulyasari, G., Trisusilo, A., Windirah, N., Djarot, I. N., & Putra, A. S. (2023). Assessing Perceptions and Adaptation Responses to Climate Change among Small-Scale Fishery on the Northern Coastal of Bengkulu, Indonesia. *The Scientific World Journal, 2023. https://doi.org/10.1155/2023/8770267*

Nadelson, L. S., Heddy, B. C., Jones, S., Taasoobshirazi, G., & Johnson, M. (2018). Conceptual change in science teaching and learning: Introducing the dynamic model of conceptual change. *International Journal of Educational Psychology, 7*(2), 151-195. https://doi.org/10.17583/ijep.2018.3349

Niebert, K., & Gropengießer, H. (2014). Understanding the greenhouse effect by embodiment–Analysing and using students' and scientists' conceptual resources. *International Journal of Science Education*, *36*(2), 277-303. https://doi.org/10.1080/09500693.2013.763298

Österlind, K. (2005). Concept formation in environmental education: 14-year olds' work on the intensified greenhouse effect and the depletion of the ozone layer. *International Journal of Science Education*, *27*, 891–908. https://doi.org/10.1080/09500690500038264

Pallant, J. (2016). SPSS survival manual: A step by step guide to data analysis using IBM SPSS (6th ed.). McGraw Hill Education.

Papadimitriou, V. (2004). Prospective primary teachers' understanding of climate change, greenhouse effect, and ozone layer depletion. *Journal of Science Education and Technology*, *13*(2), 299-307. https://doi.org/10.1023/B:JOST.0000031268.72848.6d

Plutzer, E., McCaffrey, M., Hannah, A. L., Rosenau, J., Berbeco, M., & Reid, A. H. (2016). Climate confusion among US teachers. *Science, 351*(6274), 664-665. https://doi.org/10.1126/science.aab3907

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66*(2), 211–227. https://doi.org/10.1002/sce.3730660207

Rahman, M. S., Zulfiqar, F., Ullah, H., Himanshu, S. K., & Datta, A. (2023). Farmers' perceptions, determinants of adoption, and impact on food security: case of climate change adaptation measures in coastal Bangladesh. *Climate Policy*, 1-14. https://doi.org/10.1080/14693062.2023.2212638

Ratinen, I. (2016). Primary student teachers' climate change conceptualization and implementation on inquiry-based and communicative science teaching: A design research. *Jyväskylä Studies in Education, Psychology and Social Research*, (555).

Rovinelli, R. J., & Hambleton, R. K. (1977). On the use of content specialists in the assessment of criterion-referenced test item validity. *Tijdschrift Voor Onderwijs Research, 2*, 49-60.

Sahin, E., Alper, U., & Oztekin, C. (2021). Modelling pre-service science teachers' proenvironmental behaviours in relation to psychological and cognitive variables. *Environmental Education Research, 27*(1), 1-21. https://doi.org/10.1080/13504622.2020.1812538

Seroussi, D. E., Rothschild, N., Kurzbaum, E., Yaffe, Y., & Hemo, T. (2019). Teachers' knowledge, beliefs, and attitudes about climate change. *International Education Studies, 12*(8), 33-45. https://doi.org/10.5539/ies.v12n8p33

Seow, T., & Ho, L. C. (2016). Singapore teachers' beliefs about the purpose of climate change education and student readiness to handle controversy. *International Research in Geographical and Environmental Education, 25,* 358–371. https://doi.org/10.1080/10382046.2016.1207993

Sharma, A. (2012). Global climate change: What has science education got to do with it?. *Science & Education*, *21*, 33-53.

Shepardson, D. P., Niyogi, D., Choi, S., & Charusombat, U. (2011). Students' conceptions about the greenhouse effect, global warming, and climate change. *Climatic Change*, *104*(3-4), 481-507. https://doi.org/10.1007/s10584-009-9786-9

Sinatra, G. M., & Lombardi, D. (2020). Evaluating sources of scientific evidence and claims in the post-truth era may require reappraising plausibility judgments. *Educational Psychologist*, *55*(3), 120-131. https://doi.org/10.1080/00461520.2020.1730181

Solomon, S. (2007, December). IPCC (2007): Climate change the physical science basis. In *Agu fall meeting abstracts* (Vol. 2007, pp. U43D-01).

Stevenson, K. T., Peterson, M. N., & Bradshaw, A. (2016). How climate change beliefs among US teachers do and do not translate to students. *PloS one, 11*(9), e0161462. https://doi.org/10.1371/journal.pone.0161462

Suhr, D. D. (2006). Exploratory or confirmatory factor analysis?.

Sundblad, E. L., Biel, A., & Gärling, T. (2009). Knowledge and confidence in knowledge about climate change among experts, journalists, politicians, and laypersons. *Environment and Behavior, 41*(2), 281-302. https://doi.org/10.1177/0013916508314998

Summers, M., Kruger, C., Childs, A. & Mant, J. (2000). Primary school teachers' understanding of environmental issues: An interview study. *Environmental Education Research, 6*(4): 293– 312. https://doi.org/10.1080/713664700

Turner, R. C., & Carlson, L. (2003). Indexes of item-objective congruence for multidimensional items. *International Journal of Testing*, *3*(2), 163-171. https://doi.org/10.1207/S15327574IJT0302_5

Turner, R. C., Mulvenon, S. W., Thomas, S. P., & Balkin, R. S. (2002, April). Computing indices of item congruence for test development validity assessments. In *SAS Conference Proceedings: SAS Users Group International* (Vol. 27, pp. 14-17).

Ullman, J. B. (2001). Structural equation modeling. In B. Tabachnick & L. S. Fidell (Eds.), *Using multivariate statistics* (4th ed.) (pp. 653-771). Boston, MA: Allyn & Bacon.

Ulug, M., Ozden, M. S., & Eryilmaz, A. (2011). The effects of teachers' attitudes on students' personality and performance. *Procedia-Social and Behavioral Sciences*, *30*, 738-742. https://doi.org/10.1016/j.sbspro.2011.10.144

Van Valkengoed, A. M., Steg, L., & Perlaviciute, G. (2021). Development and validation of a climate change perceptions scale. *Journal of Environmental Psychology*, *76*, 101652. https://doi.org/10.1016/j.jenvp.2021.101652

Vandenberg, R. J., & Lance, C. E. (2000). A review and synthesis of the measurement invariance literature: Suggestions, practices, and recommendations for organizational research. *Organizational Research Methods*, *3*(1), 4-70. https://doi.org/10.1177/109442810031002

Verhelst, D., Vanhoof, J., & Van Petegem, P. (2022). Development and validation of the education for sustainable development school organisation questionnaire. *Environmental Education Research*, *28*(2), 241-259. https://doi.org/10.1080/13504622.2021.2007219

Wachholz, S., Artz, N., & Chene, D. (2014). Warming to the idea: university students' knowledge and attitudes about climate change. *International Journal of Sustainability in Higher Education*, *15*(2), 128-141. https://doi.org/10.1108/IJSHE-03-2012-0025

Zeidler, D. L., & Nichols, B. H. (2009). Socioscientific issues: Theory and practice. *Journal of Elementary Science Education*, *21*(2), 49-58. https://doi.org/10.1007/BF03173684

Zelezny, L. C. (1999). Educational interventions that improve environmental behaviors: A metaanalysis. *The Journal of Environmental Education*, *31*(1), 5-14. https://doi.org/10.1080/00958969909598627

APPENDIX A

2022 IPCC report statements, items on the updated PPM scale, and items on the previous PPM scale

IPCC 2022 Statements	Updated PPM Items	Lombardi & Sinatra PPM Scale (2017)
Human-induced climate change, including more frequent and intense extreme events, has caused widespread adverse impacts and related losses and damages to nature and people, beyond natural climate variability (p.9).	1-Human-caused climate change has caused widespread losses and damages to nature and people, including more frequent and intense extreme events.	1- Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.
Since AR5 there is increasing evidence that degradation and destruction of ecosystems by humans increases the vulnerability of people (p.12).	2-Human activities intensify the vulnerability of ecosystems to climate change.	2-Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases.

Global warming, reaching 1.5°C in the near-term, would cause unavoidable increases in multiple climate hazards and present multiple risks to ecosystems and humans (p.13).	3-On average, Earth will warm 1.5°C by 2040, and this will cause unavoidable increases in climate hazards and risks to ecosystems and humans.	3-Worldwide concentrations of atmospheric greenhouse gases, such as carbon dioxide, have increased markedly as a result of human activities since 1750 and now far exceed preindustrial values determined from ice cores spanning many thousands of years.
Beyond 2040 and depending on the level of global warming, climate change will lead to numerous risks to natural and human systems (p.14).	4-Depending on the level of global warming, climate change will lead to numerous risks to natural and human systems beyond 2040.	4- Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the increase in human-caused emissions of greenhouse gases, such as carbon dioxide.
Concurrent and repeated climate hazards occur in all regions, increasing impacts and risks to health, ecosystems, infrastructure, livelihoods and food (p.18).	5-Concurrent and repeated climate hazards are occuring in all world regions, increasing impacts and risks to health, ecosystems, infrastructure, livelihoods, and food.	5- Human influences on climate extend beyond average global temperature to other aspects, such as rising sea levels and widespread melting of snow and ice.
Depending on the magnitude and duration of overshoot, some impacts will cause release of additional greenhouse gases (medium confidence), and some will be irreversible, even if global warming is reduced (p.19).	6-Even if global warming is reduced, some impacts will cause the release of additional greenhouse gases and be irreversible.	6- Continued emissions of carbon dioxide at or above current rates will cause further warming and induce many changes in the global climate during the 21st century that would probably be larger than those observed during the 20th century.

Progress in adaptation planning and implementation has been observed across all sectors and regions, generating multiple benefits (very high confidence). However, adaptation progress is unevenly distributed with observed adaptation gaps (p.20).	7-Progress in adaptation planning and implementation has been observed across all sectors and regions generating many benefits. However, this progress is unevenly distributed with observed adaptation gaps.	7-Human caused global warming and sea level rise will continue for centuries due to the time scales associated with climate processes and feedbacks, even if greenhouse gas concentrations are stabilized at current levels.
Adaptation to water-related risks and impacts make up the majority of all documented adaptation (p.21).	8-Adaptation to water-related risks and impacts make up the majority of all documented adaptation.	8-Human caused global warming will lead to some impacts that are abrupt or irreversible, such as massive polar ice melt.
Soft limits to some human adaptation have been reached, but can be overcome by addressing a range of constraints, primarily financial, governance, institutional and policy constraints (p.26).	9-Soft limits to some human adaptation have been reached, but can be overcome by addressing financial, governance, institutional, and policy constraints.	
The implementation of these maladaptive actions can result in infrastructure and institutions that are inflexible and/or expensive to change (p.27).	10-Implementation of maladaptive (improper) actions can result in infrastructure and institutions that are inflexible and/or expensive to change.	
Political commitment and follow-through across all levels of government accelerate the implementation of adaptation actions (p.27).	11-Political commitment across all levels of government accelerates the implementation of adaptation actions.	

Opportunities for climate resilient development are not equitably distributed around the world (very high confidence). Climate impacts and risks exacerbate vulnerability and social and economic inequities and consequently increase persistent and acute development challenges, especially in developing regions and sub-regions, and in particularly exposed sites, including coasts, small islands, deserts, mountains and polar regions. This in turn undermines efforts to achieve sustainable development, particularly for vulnerable and marginalized communities (p.29).	12-Opportunities for climate resilient development are not fairly distributed around the world. This undermines efforts to achieve sustainable development, particularly for vulnerable and marginalized communities.	
Climate resilient development is enabled when governments, civil society and the private sector make inclusive development choices that prioritise risk reduction, equity and justice, and when decision-making processes, finance and actions are integrated across governance levels, sectors and timeframes (p.29).	13-Climate resilient development is enabled when governments, civil society, and the private sector make inclusive development choices that prioritize risk reduction, equity, and justice.	

Climate resilient development is enabled when governments, civil society and the private sector make inclusive development choices that prioritise risk reduction, equity and justice, and when decision-making processes, finance and actions are integrated across governance levels, sectors and timeframes (p.29).	14-Climate resilient development is enabled when decision-making processes, finance, and actions are integrated across governance levels, sectors, and timeframes.	
Safeguarding biodiversity and ecosystems is fundamental to climate resilient development, in light of the threats climate change poses to them and their roles in adaptation and mitigation (p.32).	15-Biodiversity and ecosystems play a key role in adaptation and mitigation. In light of the threats climate change poses to them, safeguarding biodiversity and ecosystems is fundamental to climate resilient development.	
It is unequivocal that climate change has already disrupted human and natural systems. Past and current development trends (past emissions, development and climate change) have not advanced global climate resilient development (p.33).	16-Past and current development trends (past emissions, development, and climate change) have not advanced global climate resilient development.	

APPENDIX B

Updated PPM Scale

Read the following statements. Rate the plausibility on a scale from 1 to 10: 1 being greatly implausible (or even impossible) and 10 being highly plausible. Try to use the full range of numbers in your responses.

1. Human-caused climate change has caused widespread losses and damages to nature and people, including more frequent and intense extreme events.

2. Human activities intensify the vulnerability of ecosystems to climate change.
3. On average, Earth will warm 1.5°C by 2040, and this will cause unavoidable increases in climate hazards and risks to ecosystems and humans.
4. Depending on the level of global warming, climate change will lead to numerous risks to natural and human systems beyond 2040.
5. Concurrent and repeated climate hazards are occurring in all world regions, increasing impacts and risks to health, ecosystems, infrastructure, livelihoods, and food.
6. Even if global warming is reduced, some impacts will cause the release of additional greenhouse gases and be irreversible.
7. Progress in adaptation planning and implementation has been observed across all sectors and regions generating many benefits. However, this progress is unevenly distributed with observed adaptation gaps.
8. Adaptation to water-related risks and impacts make up the majority of all documented adaptation.
9. Soft limits to some human adaptation have been reached, but can be overcome by addressing financial, governance, institutional, and policy constraints.
10. Implementation of maladaptive (improper) actions can result in infrastructure and institutions that are inflexible and/or expensive to change.
11. Political commitment across all levels of government accelerates the implementation of adaptation actions.
12. Opportunities for climate resilient development are not fairly distributed around the world. This undermines efforts to achieve sustainable development, particularly for vulnerable and marginalized communities.

Climate Resilient Development: The process of implementing mitigation and adaptation together in support of sustainable development for all.

13. Climate resilient development is enabled when governments, civil society, and the private sector make inclusive development choices that prioritize risk reduction, equity, and justice.
14. Climate resilient development is enabled when decision-making processes, finance, and actions are integrated across governance levels, sectors, and timeframes.

15. Biodiversity and ecosystems play a key role in adaptation and mitigation. In light of the threats climate change poses to them, safeguarding biodiversity and ecosystems is fundamental to climate resilient development.