COLLEGE STUDENTS' PLAUSIBILITY PERCEPTIONS ABOUT GLOBAL CLIMATE CHANGE

by

Gizem Özyazıcı

B.S., Science Education, Boğaziçi University, 2021

Submitted to the Institute for Graduate Studies in
Science and Engineering in partial fulfillment of
the requirements for the degree of
Master of Science

Graduate Program in Mathematics and Science Education
Boğaziçi University
2023

ACKNOWLEDGEMENTS

I would like to express my gratitude to the people who have supported and encouraged me during the completion of this thesis. First of all, I would like to express my gratitude to my advisor, Gaye Defne Ceyhan. Her guidance and encouragement have been an important part of shaping my academic life. She always believes in me and motivates me even when I am struggling. She supported me not to give up and helped me to see the desire for academia in me. I will never forget the knowledge I learnt from her. I will always remember her patience during a discussion with her about a change in my career. She allowed me to participate in projects and papers because she believed in me from the beginning. I would like to thank my jury members Ebru Mugaloglu and Deniz Saribas for their valuable feedback and contributions.

I would like to express my deep gratitude to John Tillotson for his assistance throughout my journey. Additionally, I extend my appreciation to Doug Lombardi, whose significant influence has played a pivotal role in shaping my research interests. I would like to thank all the members of the Department of Mathematics and Science Education for their support and contribution to my academic life and the peaceful environment in the department strengthened my desire to be an academic. I would like to thank all my friends who supported me and helped me to write my thesis and shared valuable information with me. Also, I would like to thank all my colleagues.

Last but not least, I would like to thank all my family members for believing in me and supporting me. I would like to thank my brother for always believing in me, for making me a better person as a sister and for always supporting me and making me proud of his achievements. I am grateful to my dear mum and dad for supporting me in every way, for always believing in me and for giving me freedom and support in making my choices. They play an important role in my life and I am thankful for having them.

ABSTRACT

COLLEGE STUDENTS' PLAUSIBILITY PERCEPTIONS ABOUT GLOBAL CLIMATE CHANGE

Human-induced climate change is causing an increase in extreme weather events due to its profound effect on the Earth's atmospheric balance. The main purpose of the current study was to investigate whether college students' plausibility perceptions on global climate change (GCC) increased after participating in a scaffolding activity. The study sample consisted of 62 students from a private research university in the United States. Three instruments were used to investigate the research questions. First, the demographic information form for the participants' and Plausibility Perception Measure (PPM) scale were used. PPM scale was implemented before and after the Extreme Weather (EW) Model Evidence Link (MEL) activity. The results showed that students' plausibility perceptions changed significantly after the MEL activity. Secondly, in the EW MEL activity, students were asked to evaluate two different models and the results showed that more students found Model A (scientific explanation) more plausible than Model B (alternative explanation). However, Model B was also found plausible by many students. Students' alternative explanations were mostly found to be in the erroneous evaluation category for the EW MEL diagram. The results showed that students were aware that human activities have a major impact on current GCC, but they still have misconceptions about GCC and its link to EW events. This study contributes to the literature by using an updated PPM scale and a current EW MEL diagram, as EW events have increased significantly in recent years. This study also shows that college students have a lack of understanding of GCC and EW events. Critical evaluation is a scientific practice that could be explicitly taught in higher education programs to improve students' engagement and understanding of evidence-based decision-making practices.

ÖZET

ÜNİVERSİTE ÖĞRENCİLERİNİN İKLİM DEĞİŞİKLİĞİNE YÖNELİK AKLA YATKINLIK ALGILARI

Bu çalışmanın temel amacı, üniversite öğrencilerinin küresel iklim değişikliğine (GCC) ilişkin akla yatkınlık algılarını araştırmaktır. Çalışmanın örneklemi, Amerika Birleşik Devletleri'ndeki özel bir üniversiteden 62 öğrenciden oluşmaktadır. Araştırma soruları için üç araç kullanılmıştır. İlk olarak, katılımcılar için demografik bilgi formu ve inandırıcılık algısı ölçeği (PPM) kullanılmıştır. PPM ölçeği, Aşırı Hava Durumu (EW) Model Kanıt İlişki (MEL) diyagramından önce ve sonra kullanılmıştır. Sonuçlar, öğrencilerin akla yatkınlık algılarının MEL diyagramından sonra istatistiksel olarak anlamlı bir şekilde değiştiğini göstermiştir. İkinci olarak, EW MEL aktivitesinde model değerlendirmeleri istenmiş ve sonuçlar daha fazla öğrencinin Model A'yı (bilimsel açıklama) Model B'den (alternatif açıklama) daha makul bulduğunu göstermiştir. Model B de birçok öğrenci tarafından akla yaktın bulunmuştur. Öğrencilerin alternatif açıklamaları EW MEL diyagramı için çoğunlukla hatalı bulunmuştur. Sonuçlar, öğrencilerin insan faaliyetlerinin mevcut GCC üzerinde önemli bir etkisi olduğunun farkında olduklarını, ancak yine de GCC ve bunların arkasındaki bilimsel nedenler hakkında kavram yanılgılarına sahip olduklarını göstermiştir. Bu çalışma, son yıllarda aşırı hava olaylarının artması nedeniyle güncellenmiş bir ölçeği (PPM) ve güncel bir aşırı hava olayları MEL diyagramı kullanarak literatüre katkıda bulunmaktadır. Bu çalışma aynı zamanda üniversite öğrencilerinin GCC ve EW olaylarını anlama konusunda eksiklikleri olduğunu göstermektedir.Eleştirel değerlendirme, öğrencilerin kanıta dayalı karar verme uygulamalarına katılımını ve anlayışını geliştirmek için yükseköğretim programlarında açıkça öğretilebilecek bilimsel bir uygulamadır.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS/ABBREVIATIONS

CC	Conceptual Change
EW	Extreme Weather
GCC	Global Climate Change
GHG	Greenhouse Gases
HICC	Human Induced Climate Change
IPCC	Intergovernmental Panel on Climate Change
PPM	Plausibility Perception Measure

1. INTRODUCTION

Global climate change (GCC) is a major global crisis that is a socially relevant, controversial and scientific topic, known as a socioscientific issue (SSI) (Dawson and Carson, 2020; Zeidler and Nichols, 2009). As such, it is of interest not only to students studying science, but also to students in non-science fields, as it affects every citizen of the world. GCC has been a major concern since the industrial revolution at the turn of the 20th century; the Earth's annual mean temperature has been steadily increasing (Mikhaylov *et al.*, 2020). However, there is evidence that GCC education in the United States (U.S.) is still a work in progress and that K-12 education has not been sufficient to effectively articulate the scientific agreement at the national level (Kuppa, 2018; Plutzer *et al.*, 2016; Siegner and Stapert, 2020). According to Siegner and Stapert (2020), evidence of the expanded practice of holistic global climate education is still lacking. Collins and Hess (2018) stated that across all schools, 0.17 percent of students are expected to take at least one core curriculum course on the GCC. Even though some have taken courses on the GCC, climate change education has been found to be inadequate across grade levels (Hartley and Wilke, 2017).

According to Mark (2020), there was a statistically significant difference between middle school students' attitudes toward GCC after watching a video about climate change developed by National Geographic. Also, Huxster *et al.* (2015) reported that college students' knowledge of the GCC is significantly higher among science majors than non-science majors. In addition, there was a statistically significant difference between the knowledge scores of college students who were involved in an environmental organization and those who were not (Huxster *et al.*, 2015). Therefore, it may be crucial to explicitly teach non-science majors 74 about the GCC. Researchers have also examined how concerned students are about GCC (Kuppa, 2018). According to one survey-based study, results revealed that the majority of American teenagers do not understand the basic concepts of GCC and are not very concerned about GCC even though some schools have begun to teach GCC (Leiserowitz *et al.*, 2011). The responses suggested that both youth and adults have a lack of knowledge and have crucial misconceptions. These misconceptions may lead young people to doubt GCC and most young people don't understand climate science (Leiserowitz *et al.*, 2011, Monroe et al, 2019).

According to a study conducted by Chawla (2020), it was revealed that numerous young individuals are grappling with a sense of loss due to the gradual deterioration of the natural world. One study also found that millennials are less likely to discuss GCC with their friends and family than older generations (Kuppa, 2018). Similar results were found by Leiserowitz *et al.* (2013), who reported that only 49% of Americans believe that human activity is the primary cause of GCC and only 42% are aware that the majority of scientists agree that human-induced GCC is occurring. A recent report, An International Public Opinion on Climate Change, 2022 (Leiserowitz *et al.*, 2022), highlights that people in only a few regions believe that GCC will cause them great personal harm. Another study supporting these findings, the Yale Climate Opinion Map (2021), shows that 54% of people believe they have not personally experienced the effects of global warming. Similarly, in one study it was found that concern and willingness to take actions about GCC are lower in the U.S., Australia and the United Kingdom compared to other countries (Lee *et al.*, 2020).

In addition, studies on GCC have been conducted in different countries. For example, in a study in Turkey, Saribas *et al.* (2014) found a remarkable relationship between participants' self- efficacy beliefs and their level of environmental awareness. Research has shown that even highly educated people have misconceptions about GCC (Chen, 2011; Feldman *et al.*, 2010; Li and Liu, 2021). This finding supports the idea that GCC education in schools may not be sufficient. Still, there haven't been many studies in recent years specifically examining how much college students know and care about GCC (Wachholz *et al.*, 2014). To ensure that college graduates are aware of the scientific consensus on GCC and its impacts and are actively involved in suggesting or finding solutions in their roles as a citizen, higher education needs to increase its educational efforts on GCC (Wachholz *et al.*, 2014). Despite the fact that GCC is regarded as a global crisis, the literature reveals that many people believe Americans are unaware of their country's significant impact on GCC and that GCC understanding is relatively low among the general public, including college students (Leiserowitz, 2010; Li and Liu, 2021; Marquart-Pyatt *et al.*, 2011; Howe *et al.*, 2018). Howe *et al.* (2018) examined the knowledge and beliefs of college students in the U.S. about GCC and reported that many college students had misconceptions and gaps in understanding climate change. In one study about U.S. public opinion on GCC, it was revealed that only less than a majority of Americans recognize that scientists overwhelmingly agree that climate change is happening (Egan and Mullin, 2017). Furthermore, society has non-scientific notions about GCC and its effects (Urry, 2015). Therefore, it is essential to implement instructional scaffolds that explicitly target the GCC concepts of college students.

Conceptual change theory has been widely used in GCC education (Ceyhan and Mugaloglu, 2020; Lombardi and Sinatra, 2012; Lombardi *et al.*, 2013), which refers to the theoretical and empirical standpoint of reconstructing concepts (Dole and Sinatra, 1998). Also, plausibility is one key element in conceptual change (Sinatra and Lombardi, 2020) that emphasizes developing conceptual understanding and it is considered an individual's subjective view of the truthfulness of a message (Ceyhan and Mugaloglu, 2020; Lombardi and Sinatra, 2012; Nadelson *et al.*, 2018; Posner *et al.*, 1982). According to Lombardi and Danielson (2018), there are some challenges to teaching and learning conceptual change. The challenges of conceptual change instruction may only be extensively applicable to concepts resistant to change. However, there are ways to deal with the problems and one of them can be using argumentation and model-based reasoning (Lombardi and Danielson, 2018).

The Plausibility Perception Measure (PPM) scale was developed by Lombardi and Sinatra (2012) to examine individuals' plausibility perceptions about GCC. Lombardi and Sinatra (2012) developed the PPM in response to the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report, published in 2007, to measure the plausibility of perceptions of individuals about the GCC. However, the last IPCC report on impacts, vulnerability and adaptation was published in 2022. Since this report includes different factors on the climate crisis since 2007 and analyzes new factors and different perspectives, there was a need to update the PPM scale according to the latest IPCC report. For that reason, researchers of this study, working together with the corresponding author of the original scale, updated the PPM scale (Hanedar *et al.*, Under Review). In plausibility studies, Model Evidence Link (MEL) diagrams were found to be useful (Ceyhan *et al.*, 2021) because it emphasizes the coordination of evidence, models and ideas. Also, critical thinking and critical evaluation were emphasized as a core practice in a Framework for K-12 Science Education (NRC, 2012). The MEL diagram can be used to promote critical evaluation because it is an instructional tool that helps students evaluate how the evidence fits different models and encourages them to think critically (Lombardi and Bailey, 2016). However, not all students are predisposed to critical thinking and critical evaluation. Instructional scaffolding may be needed to help students make critical evaluations.

The MEL diagram was initially developed by Rutgers University researchers for middle school students as part of the NSF-funded PRACCIS (Promoting Reasoning and Conceptual Change in Science) project. After that, to use the MEL diagram in different grade levels, the project team developed MEL diagrams on various topics such as GCC, wetlands and land use, fracking and earthquakes (Lombardi, 2016).

Also, Lombardi and his colleagues (2018) investigated the change in plausibility judgments and knowledge of high school students about earth science due to the four MEL activities (climate change, fracking, wetlands as well as moon) and found that the activity helped students develop critical evaluations based on evidence. In a study of college students (specifically pre- service teachers), researchers found that some groups did not demonstrate extensive critical thinking and cognitive elaboration processes and practices when evaluating the credibility of the scientific and alternative answers (Ceyhan *et al.*, 2021).

In addition, although each response shows that the groups considered describing the connection between the facts and the model, the incorrect evaluation shows that they lacked the initial understanding to make a meaningful evaluation. In the MEL explanation tasks for GCC, their explanations were primarily categorized as incorrect evaluation (Ceyhan *et al.*, 2021).

In the current study, extreme weather (EW) MEL was used because the distinction between weather and climate is often found to be unclear to students (Bozkurt, 2019). Also, Howe (2021) established links between different indicators of exposure to extreme weather events and individuals' attitudes. The main significance of this study is that the MEL activity to be used in this study is not GCC MEL but EW MEL chart and it is a contextual study.

The reason for using EW MEL is that it was developed in 2020 to understand the increasing EW events and their relationship with GCC (Lombardi *et al.*, 2020). Stott (2016) reported that EW events have increased and human-induced climate change has led to EW events such as floods, droughts and heat waves. Furthermore, according to the Science Education Resource Center (SERC) at Carleton College, the MEL on extreme weather encourages students to evaluate the correlation between extreme weather and climate change, a critical ecological issue affecting the planet and its inhabitants. For this reason, the EW MEL diagram was used in this study. Another significance of the current study is that the study also focused on non-science majors and the updated version of the PPM scale was used to examine college students' plausibility perceptions about current GCC. This study examined the change in college students' plausibility perceptions before and after the implementation of the MEL diagram since MEL diagrams help students make connections, evaluate evidence and models and show how well they can critically evaluate scientific arguments and deepen their understanding (Chinn and Brewer, 1993; Lombardi *et al.*, 2013; 2018). Since the updated PPM scale has items related to EW events such as item 1, item 2, item 5 and item 8 (see Appendix 2), it was appropriate to use the EW MEL diagram. In the current study, data were collected from a private research university in the U.S.

1.1. The Purpose of the Study

This study explores whether college students' plausibility perceptions about the climate crisis changed after an intervention in the evaluation of alternative explanations. The second purpose of this study is to explore how college students evaluate competing explanations of current climate change.

1.2. Research Questions

Considering the aim of the study, the current study was designed to answer three research questions.

Research Question 1: How, if any, do college students' plausibility perceptions about GCC change after the implementation of the EW MEL diagram?

Research Question 2: How do college students evaluate scientific and alternative explanations about global climate change and extreme weather events?

Research Question 3: How plausible do college students find the models in the EW MEL activity about extreme weather events and global climate change?

1.3. Significance of the Study

Participants in this study are non-major science students and current study focuses link between extreme weather events and climate change. For this reason, the Extreme Weather (EW) Model Evidence Link (MEL) diagram was used as instructional scaffold in this study.

2. LITERATURE REVIEW

2.1. Global Climate Change (GCC)

GCC is one of the most significant crises in our world. In the current literature, it is defined as long-lasting changes in weather (Abbass *et al.*, 2021) and scientists strongly agree that recent GCC is caused by humans (Cook *et al.*, 2016). Also, GCC is a global complex issue with its influence on different components (Feliciano *et al.*, 2022). The concentration of greenhouse gasses (GHGs), such as carbon dioxide (CO2), has increased with the industrial revolution (Zhao *et al.*, 2022). It is reported that the last 30 years have been the hottest period (Allen *et al.*, 2019). In addition, CO2 is one of the major GHGs and it can last for nearly 100 years or more. Depending on this, even if we stop emitting it, the Earth will continue to warm as a result of these gasses (Seager *et al.*, 2019).

Furthermore, energy consumption is another main reason for the increase in GHGs. Current studies show that most of the energy production in developing countries comes from fossil fuels and energy consumption has increased GHG levels (Balsalobre-Lorente *et al.*, 2022). Research indicates that the release of GHGs is also strongly influenced by human activities (Lahsen and Ribot, 2022). For instance, the Intergovernmental Panel on Climate Change (IPCC) predicts that if the current trends in fossil fuel use and deforestation are not reversed, the average global temperature will increase by 6°C over the next century (Denisova *et al.*, 2019) even though the target is to keep the global mean temperature increase to well below 2°C (Zhao *et al.*, 2022). In a study examining changes in cumulative human impact (CHI), researchers examined the cumulative impact of stressors related to human activities (fishing, land-based pressures and other commercial activities) on marine ecosystems. Results revealed that the cumulative impact on the world's oceans increased significantly by 59 % between 2003 and 2013 (Halper *et al.*, 2019).

Similarly, another study found that agricultural manure and fertilizers, as well as human and animal waste, are the main sources of water pollution (Islam *et al.*, 2019). Depending on this, the impact of human activities in the GCC causes significant damage to nature and humanity and the impact of the GCC on human health cannot be underestimated. For example, it was found that extreme weather-related mortality and morbidity are responsible for many deaths (Lemery *et al.*, 2021; United Nations Environment Program (UNEP), 2017). To better understand the causes, impacts and potential adaptation and mitigation strategies about GCC, IPCC produces assessment reports to describe the state of knowledge, impacts and potential hazards of climate change. The IPCC reports are generated as the most informative sources on GCC because many scientists evaluate the data and reports are presented carefully with subheadings such as causes, impacts as well as potential solutions.

The IPCC reports are important because, firstly they provide an objective and comprehensive assessment of the latest scientific research on GCC. IPCC reports also provide a thorough resource for future research that may contribute to a better understanding of the GCC. According to the IPCC (2007) report, climate change is defined as long-term changes that affect the climate and emphasized the anthropogenic drivers of the current climate change. It is important to follow the IPCC reports because the reports do not emphasize the same factors each year as the GCC and its effects change throughout years. For example, the most recent IPCC report emphasizes three main areas of climate change: Observed and projected impacts and risks, adaptation and enabling conditions and climate-resilient development (IPCC, 2022). Moreover, a review study of the 928 articles published between 1993 and 2003 found that 75% of the articles supported the consensus view of GCC and no article strongly disagreed with it (Malla *et al.*, 2022). In short, the GCC remains a major problem that affects the entire world.

2.2. Climate Change Education

Nowadays, it is important to get updated scientific information about GCC and one of the most important factors to achieve this is education. To raise an awareness about the

GCC issue, the role of education is crucial in recognizing the GCC and its risks to the planet. Research has highlighted the importance of GCC education (Henderson and Drewes, 2020) and teaching environmental issues and the GCC in classes (Higde *et al.*, 2017). Research conducted with teachers shows that teachers prioritize GCC education and teachers also have strong opinions about the scientific causes and effects of climate change. Research also found that teachers express high levels of concern about the future (Nation and Feldman, 2021). In contrast, some studies have found that GCC knowledge is not sufficient, teaching about GCC is difficult and many young people have misconceptions about GCC and climate science (Leiserowitz *et al.*, 2011; Lester *et al.*, 2006; Monroe *et al.*, 2019; Shepardson *et al.*, 2009; Taber and Taylor, 2009), even as educators work to dispel myths about the causes of GCC through school programs, extension programs and non-formal settings (Chen, 2011; Choi *et al.*, 2010; Sterman, 2011). Research on GCC is important not only in terms of people's understanding of GCC, but also in terms of identifying misconceptions about GCC. For example, in one study, it was found that people believe that climate and weather are the same and few respondents were aware of the properties of greenhouse gases (Bostrom *et al.*, 1994).

In a recent study conducted with 688 undergraduate students at five colleges in the United States, it was highlighted that GCC misconceptions were related to students' cognitive reflection skills, such as the misconception that sudden changes in weather are evidence of climate change (da Rosa, 2022). Also, results revealed that students have misconceptions related to confusing weather with climate, these misconceptions have been well documented among adults in other studies too (da Rosa, 2022; Leiserowitz *et al.*, 2010). Similarly, another study found that a large proportion of Americans believe that scientists cannot predict the future climate (Leiserowitz *et* *al.*, 2010). To overcome misconceptions, some studies suggest using conceptual change theory because conceptual change is a process by which concepts such as SSIs and the relationships between them change over time (Duit and Widodo, 2013; Gooding and Metz, 2011). According to the 2022 IPCC report, meeting the goal of limiting global warming to 1.5°C would require strong efforts, including major investments in low-carbon infrastructure and changes in human behavior and consumption patterns. The report also emphasizes that time for effective action is rapidly running out and that delaying action would only make it more difficult and costly to achieve the goal of limiting warming to 1.5°C (IPCC, 2022).

To achieve this goal, people need to be aware of the threat of GCC. In this context, Rickinson (2001) mentioned in a study that specific programs could be helpful to bring about some changes in students' knowledge and attitudes about environmental problems. However, the recommended activities were found to be mainly short-term, measurable programs. As a result, their long-term sustainability is rarely evaluated (Hanson, 1993).

GCC is considered as a socio-scientific issue, which means it is socially relevant and controversial and it has a scientific background (Dawson and Carson, 2020; Zangori *et al.*, 2017). Since education is the key factor for understanding socio-scientific issues, GCC integration in education throughout formal education systems has the potential to be one of the most successful strategies to increase GCC understanding (Stevenson *et al.*, 2017). According to the Pew Research Center (2019), people from all cultural backgrounds tend to trust scientists and are willing to use what they learn to improve their lives. However, another study found that there was no relationship between higher levels of scientific literacy and acceptance of the GCC (Kahan, 2015). Moreover, in one research, Chang and Pascua (2016) found that students created incomplete mental models of GCC. Since students are the future of our world, it is important to examine their perspectives on GCC and teachers play an important role in increasing awareness and knowledge of GCC. It is also important to study pre-service science teachers' learning about misconceptions and teaching strategies for conceptual change

(Henriques, 2002). Researchers strongly agree that attitudes toward environmental problems are very important because these attitudes are a step toward changing the world and informed teachers should be trained against environmental problems (Ceyhan and Mugaloglu, 2020; Zelezny, 1999). Similarly, Falaye and Okwilagwe (2016) conducted a study with 1,103 senior secondary school students to find out what they knew about GCC and how they felt about it. The results showed no change in students' views and actions as a result of what they learned about GCC. In many schools, environmental issues are not emphasized or addressed by teachers, so these findings are not surprising. As a result, students struggle to apply what they have learned to comparable situations (Falaye and Okwilagwe, 2016).

In addition, Kahyaoglu and Ozgen (2012) found that the environmental attitudes of science teacher candidates were inadequate compared to other departments, despite their science backgrounds. However, not only the knowledge and beliefs of people in the sciences that are important, but also people who are not educated or not in scientific fields and their knowledge is important because GCC is a socio-scientific issue. Since GCC is of vital importance, it concerns not only science teacher candidates in colleges but every college student.

According to the American Teens' Climate Change Report (2011) provided by Yale University, knowledge levels vary about the GCC, but a few teens have a deep understanding of the GCC (Leiserowitz *et al.*, 2011). For this reason, it is very important to increase the quality of GCC education so that both science and non-science groups have the necessary understanding of GCC. If students do not have sufficient knowledge about GCC, a change in their attitudes cannot be expected. Even if they have knowledge about GCC, they might still not change their attitudes towards GCC, so increasing their understanding of GCC is sufficient but not enough. For instance, people usually experience environmental problems such as GCC and know the negative effects, but they ignore these effects and their attitudes do not generally change (Kızıl, 2012). To reduce the negative effects on the environment, people should change their attitudes toward the environment (Zelezny, 1999). To understand the impact of university education on GCC, researchers have conducted studies. For example, in one study it was found that many American teenagers do not understand the concept of GCC (Leiserowitz *et al.*, 2011). Another study conducted by the Pew Research Center found that young adults between the ages of 18 and 29 were more likely than older adults to view GCC as a major threat to the world (Dimock and Johnson, 2019). Other research has also found that young adults tend to have more favorable attitudes toward policies and actions that address global climate change. For example, a study by Lorenzoni *et al.* (2007) found that young adults were more supportive of GCC mitigation policies, such as carbon pricing, than older adults. However, a 2018 study found that young people's attitudes toward the GCC were more strongly influenced by their political ideology than their age (Hmielowski *et al.*, 2018). As a result, university education can be argued to be significant in shifting views toward GCC (Özmen *et al.*, 2005).

In contrast, according to Akyol (2014), teacher candidates' opinions regarding environmental challenges do not differ considerably by grade level. Moreover, unfortunately, despite United Nations Educational, Scientific and Cultural Organization's (UNESCO) clear efforts, including the 2013 book, there is still much to encourage GCC education in terms of its applicability and practice in the school setting (Karami *et al.*, 2017). According to the literature, persuasion is more likely to occur when individuals are allowed to engage in reasoned conversation or debate, similar to normal scientific discourse and discourse environments can promote engagement in science classrooms (Alexander *et al.*, 1997; Dole and Sinatra, 1998; Karlsson *et al.*, 2020; Sinatra *et al.*, 2012). Similarly, Ferguson (1999) found that students were more enthusiastic about environmental learning in interactive classrooms. According to Bickel and Lombardi (2016), to understand social science issues and make connections between evidence and explanations, both students' knowledge of scientific issues and their ability to scientifically evaluate their knowledge are important. This is why instructors should encourage students to develop their ability to evaluate critically, as this is an important part of GCC education. The literature review highlights the need for more research to support the design and implementation of effective GCC education programs (Rebecca *et al.*, 2018).

2.3. Plausibility and Global Climate Change

Plausibility is considered an individual's subjective view of the truthfulness of a message (Lombardi and Sinatra, 2012) and plausibility is also one of the key elements of conceptual change theory (Nadelson *et al.*, 2018). According to the literature, conceptual change is an individual's plausible re-conceptualization of current knowledge with new knowledge (Hewson and Hennessey, 1992; Nelson *et al.*, 2018; Thorley and Stofflett, 1996). In other words, conceptual change is a type of learning that goes beyond simply updating one's thoughts and involves restructuring fundamental concepts. Conceptual change, which involves creating new concepts by rearranging existing ones, is a crucial aspect of knowledge acquisition in science education (Nadelson *et al.*, 2018). However, for conceptual change to occur, a student must find the new concept plausible (Lombardi *et al.*, 2016).

According to Nadelson *et al.* (2018), if a student lacks this sense of plausibility, then conceptual change may not happen fully. This is especially true when it comes to environmental issues, which are often complex, controversial, or conflicting, making conceptual change a challenging process in science education (Nadelson *et al.*, 2018).

Individuals must have a conceptual understanding of controversial topics such as GCC as they learn about them (Bofferding and Kloser, 2014; Papadimitriou, 2004; Sinatra and Lombardi, 2020). Moreover, it is important to examine conceptual change in the classroom, some classroom-based studies report that a conceptual approach is more effective than traditional (Treagust and Duit, 2008). Many researchers have also pointed out that a new idea must be plausible for students to engage in additional cognitive processing and accept it as their own (Dole and Sinatra, 1998; Pintrich *et al.*, 1993; Posner *et al.*, 1982). Conceptual change theorists often say that scientifically correct ideas must be perceived as plausible before they can be more plausible than existing ideas. For conceptual change to occur, new ideas must be accepted (Dole and Sinatra, 1998; Posner *et al.*, 1982). Furthermore, according to Connell and Keane (2004, 2006), plausibility perceptions are related to basic knowledge links, the complexity of relationships and the need for evaluation. A study shows that students and scientists use specific strategies when evaluating the persuasiveness of arguments. The results show that students, compared to scientists, find it more difficult to form judgments and rely on intuition and opinion rather than the internal coherence of arguments (Von der Mühlen *et al.*, 2016).

Research has shown that there is a strong relationship between plausibility and understanding of GCC (Ceyhan and Mugaloğlu, 2020; Lombardi and Sinatra, 2012). In a recent study, Sinatra and Lombardi (2020) reported that explicitly reevaluating plausibility perceptions may be an important part of figuring out how information sources relate to knowledge claims. Sinatra and Lombardi (2020) found that people can change the way they evaluate the plausibility of explanations and solutions that help everyone in society. To sum up, it is important to examine the plausibility perceptions of individuals about GCC to evaluate their cognitive processing. Instructional scaffolds that help individuals evaluate alternative explanations about GCC could be a powerful tool to improve their plausibility perceptions.

2.4. Model Evidence Link Diagram

Chinn and Brewer (1993) described the model evidence link (MEL) diagram as an instructional scaffold that supports students in developing arguments based on the relative weighting of evidence about an explanatory and an alternative model. Students construct various types of linking arrows between evidentiary facts and alternative models in MEL diagrams. Students draw arrows of various shapes to represent the relative weight of the evidence by critically thinking. Straight arrows denote evidence that supports the hypothesis; squiggly arrows denote evidence that strongly supports the model (Lombardi *et al.*, 2013). The Model Evidence Link (MEL) diagram allowed students to weigh the strength of the link between two alternative models of GCC and the MEL activities to improve their critical evaluation (Lombardi, 2016). Recent research suggests that the MEL activity can improve the critical evaluation of alternatives, stimulate the reassessment of scientific alternatives for plausibility and improve knowledge of basic scientific concepts (Ceyhan *et al.*, 2021; Governor *et al.*, 2021; Lombardi *et al.*, 2013; 2018).

Furthermore, MEL diagrams give students a tool to assess the value of scientific explanations by contrasting them with alternative ones (Ceyhan *et al.*, 2021; Dobaria *et al.*, 2022; Lombardi *et al.*, 2016) and using MEL diagrams in science classrooms helps the development of higher-order and analytical thinking skills (Can, 2017; Ceyhan *et al.*, 2019). Lombardi (2016) says that collaborative argumentation was the most important scientific part of the current study and that it helps students do scientific work. Also, Lombardi *et al.* (2013) found that the climate change MEL activity made students more likely to believe and understand the scientifically accepted explanation for GCC. Bickel and Lombardi (2016) emphasize the importance of engaging both teachers and students in the active observation and assessment of their cognitive abilities. This participatory process not only facilitates the development of essential scientific skills, but also plays a pivotal role in exposing students to the intricate practices of critical evaluation and reasoning in the geosciences. By immersing themselves in these evaluative exercises, students are afforded a unique opportunity to delve into the complexities of scientific inquiry and cultivate a deep understanding of various geoscience phenomena.

One of the most important goals of science education is to develop scientifically literate citizens. Scientifically literate citizens are expected to explain and evaluate scientific issues (Saribas and Akdemir, 2018). That is why it is considered appropriate to use the MEL diagram to promote the critical evaluation of GCC. Critical evaluation is a scientific practice that should be explicitly taught in teacher education programs (Ceyhan *et al.*, 2021). While studying the GCC, it is important to make critical evaluations to understand the evidence for GCC since many people have doubted its urgency (Leiserowitz *et al.*, 2011) despite growing evidence for GCC (Liu *et al.*, 2015) and studies found that the MEL diagram helped students judge and argue the relationships between the data and different models (Lombardi *et al.*, 2013).

2.5. Extreme Weather Model Evidence Link Diagram

According to a recent study, human-induced GCC has increased the frequency and severity of daily temperature extremes (Lombardi *et al.*, 2020). The primary extreme weather (EW) events can be classified as floods, droughts, tropical cyclones (hurricanes, typhoons, etc.), heat waves, cold waves, coastal storms and storm surges (Mirza, 2003) and there has also been an exacerbation of certain extreme weather and climate events such as more intense hurricanes, floods, droughts and heat waves (Stott, 2016). Moreover, GCC can alter the frequency, timing, intensity and duration of these events. There has been an increase in heavy precipitation over the past century. Future climate scenarios show a likely increase in the frequency of extreme precipitation events, including precipitation during hurricanes, increasing the risk of flooding (Greenough *et al.*, 2001).

In one study, it was found that students can believe that long-term climate patterns can be inferred from short-term weather trends (Lombardi and Sinatra, 2012) and students often confuse weather and climate and are unaware of the types and sources of radiation involved in the greenhouse effect (Henriques, 2002; Ozdem *et al.*, 2014). Another study supports the idea that students' knowledge of GCC is based on incomplete elements (Chang and Pascua, 2016). As climate-related extreme events have persisted longer than weather events and EW events have increased in recent years, the relationship between EW events and climate change has come to the forefront. For these reasons, Lombardi and colleagues (2020) created the EW MEL which focuses on weather-related events, such as the number of annual precipitation events in the U.S. during the 20th century (Bailey *et al.*, 2022). In the EW MEL diagram, four lines of scientific evidence and two different models Model A and Model B) are provided (Lombardi *et al.*, 2020) and students are expected to draw lines about connections between evidence and models (Lombardi *et al.*, 2020).

In the EW MEL activity, there are 4 types of arrows that students can use to make a connection: strongly supports, supports, contradicts and has nothing to do with. Students are expected to draw two arrows for each piece of evidence in each model. The EW MEL includes exploratory models and each explanatory model offers a different and compelling rationale for the increase in extreme weather events over the past 50 years. Since the updated PPM scale includes items related to extreme weather events, the use of the extreme weather events MEL was useful in this study.

3. THE METHODOLOGY

This section described the research methodology, data collection and data analysis for assessing college students' plausibility perceptions toward GCC and the difference between their plausibility perceptions before and after the MEL intervention.

3.1. Research Design

In the present study, the pre-post one group quasi-experimental design was used to examine college students' plausibility perspectives since this design is a type of quasi- experimental design that allows researchers to design and apply the treatment and allows researchers to evaluate participants' perceptions about a specific topic. In the study, the treatment was the EW MEL diagram and the participants' plausibility perceptions about GCC were assessed before and after the treatment.

3.2. Participants

The study was conducted with 62 college students at a private research university in the U.S. who were enrolled in a science course for non-science major students and who volunteered to participate in the study. The researcher is currently working as a teaching assistant at the university and teaching one of the three sections of the course. The characteristic of the science course was that the course was designed for non-major students, in other words, for those students who have yet to have substantive coursework in the physical sciences. Also, the goal of the course was for students to be able to develop their own, more scientific models and explanations of how the world works. The course was taught in 3 separate sections and the research portion of all three sections was led by the researcher. In total, 62 students participated in the pretest, Extreme Weather MEL diagram activity and post-test.

Table 3.1 provides descriptive information about the participants by gender, grade level and whether they had taken an environmental course. In the study, 35 of the participants identified themselves as female, 25 of the participants identified as male, 1 of the participants identified as non-binary and 1 of the participants identified as transgender. Table 3.1 also shows descriptive information for taking an environmental course and the results show that 51 of the participants had not taken an environmental course before, whereas 11 of them had.

Table 3.1. Descriptive information about the participants.

Descriptive criteria	**Categories**	**Frequency**
Gender	Female	35
	Male	25
	Non-binary	1
	Transgender	1
Grade level	First year	47
	Second year	6
	Third year	3
	Fourth year	6
Taking environment course	Yes	11
	No	51

3.3. Definitions of Key Terms, Concepts and Variables

This section is divided into two parts. The first section covers conceptual definitions, while the second section covers operational definitions.

3.3.1. Conceptual Definitions

Climate Change: Climate change is defined as long-term changes that affect the climate. In other words, climate change can be caused by both natural and human activities (IPCC, 2007).

Human-caused climate change: Climate changes occur due to human activities (IPCC, 2022).

Extreme Weather Events: Extreme weather events can be considered as thunderstorms, droughts and heat waves, resulting in health impacts including injury or death (McPhillips *et al.*, 2018).

Plausibility: It is a critical element of conceptual theory, which means knowing what the conception means or finding something believable (Duit and Treagust, 2013).

3.3.2. Operational Definitions

Plausibility Perceptions Measure: Updated Plausibility Perception of the GCC instrument is a ten-point Likert scale (1 = greatly implausible or even impossible and 10 = highly plausible) with fifteen statements (Hanedar *et al.*, Under Review).

Extreme Weather (EW) Mel Diagram: Weather-related events. Some examples of evidence include the annual precipitation events in the U.S. (Bailey *et al.*, 2022).

3.4. Data Collection Instruments

3.4.1. Demographic Form

The online demographic questionnaire was created to gather data about the participants (See Appendix 1). Participants were asked about their gender, grade, the primary subject of study and whether they had taken courses on environmental issues.

3.4.2. Updated Plausibility Perception Measure (PPM)

The PPM instrument was developed following the Fourth Assessment Report of the IPCC (2007) by Lombardi and Sinatra (2012). The goal of PPM is to assess participants' plausibility perceptions of human-induced climate change (Lombardi and Sinatra, 2012). The updated PPM Scale was developed by researchers, one of whom is the author of this manuscript, with the guidance of the corresponding author of the original PPM scale according to the IPCC reports in 2022 (Hanedar *et al.*, Under Review). This is because the IPCC 2022 report includes 3 different factors; Observed and Projected Impacts and Risks, Adaptation Measures and Enabling Conditions and Climate Resilient Development (Appendix 2).

3.4.3. Updating the PPM Scale

During the development of the survey, the PPM scale was revised according to the IPCC 2022 reports and with the guidance of the corresponding author of the original PPM scale. The researchers read the development and the validity processes of the original PPM scale. For the original PPM scale, statements in the IPCC 2007 observed changes report were taken and adopted to increase the readability. To update the PPM scale, the researchers read the IPCC 2022 report and determined the differences between the original PPM and the IPCC report. Consistent with the IPCC 2022 report, the updated PPM scale consists of three factors: observed impacts and risks, adaptation measures and enabling conditions for climate-resilient development- with a total of 15 items across these factors (see Table 3.2). The factors and items were determined in accordance with the IPCC 2022 report (Hanedar *et al.*, Under Review).

Table 3.2. Factors of each item in the updated PPM instrument.

Factors	**Items**
Observed and Projected Risks	1,2,3,4,5,6 (6 items)
Adaptation Measures and Enabling Conditions	7,8,9,10,11 (5 items)
Climate Resilient Development	12,13,14,15 (4 items)

Participants in the pilot study were from a public research university in Turkey and were studying at the Faculty of Education. 109 pre-service teachers completed the updated PPM scale. Reliability is the consistency with which the same results can be replicated over time or by different observers (Gay *et al.*, 2012). During the data analysis process, one of the 16 items was removed because it lowered the reliability values. Cronbach's alpha value is found as 0.93 when item 16 was deleted. Expert judgments were obtained to confirm the content validity of the instrument. Therefore, the analysis was continued with 15 items. In its final form, the scale contained 15 items (Appendix 2) and participants rated each statement on a ten-point Likert scale ranging from "1 = highly implausible" to "10 = highly plausible". Confirmatory factor analysis was used to evaluate the factor structure of the model, which is a three-factor model with fit indices such as root mean square error of approximation (RMSEA), goodness of fit index (GFI) and comparative fit index (CFI) were examined for the analysis. RMSEA values less than 0.08 indicate an acceptable model fit and GFI and CFI values greater than 0.90 indicate a good and appropriate model (Hu and Bentler, 1999). The results of the confirmatory factor analysis reported in Table 3.3 indicate that the three-factor model is a good fit for the data (TLI $\geqslant 0.90$, CFI $\geqslant 0.90$, RMSEA $\leqslant 0.08$). In addition, all p-values are less than 0.001, indicating that all factor loadings are significant ($p < 0.001$).

Table 3.3. Confirmatory factor analysis results.

Model	X^2	df	TLI	CFI	RMSEA	GFI
Factor Model	142.136	87	0.92	0.94	0.076	0.85

3.4.4. Extreme Weather Model Evidence Link (EW MEL) Diagram

Extreme weather is a critical environmental issue facing the earth and the people who live on it. The EW MEL diagram (Lombardi *et al.*, 2020) was used as a treatment in this research. Students were asked to evaluate the connections between the data and competing hypotheses regarding the relationship between extreme weather and climate change in the EW MEL diagram. Details of the EW MEL activity was provided in the following section.

3.5. Procedure

Students enrolled in an undergraduate science course at a private research university in the United States participated in the current study. The primary goal of this science course is to provide a basic level of scientific knowledge and understanding to students who may not have a specific academic focus on science as their major area of study. To facilitate this educational endeavor, the course has been thoughtfully structured into three distinct sections, each tailored to meet the diverse needs and backgrounds of our students. The course met for one hour and thirty minutes each week. Figure 3.1. illustrates the general flow of the study and provides a clear overview of the study.

Firstly, students voluntarily completed the consent form and demographics form by using the Google Forms link provided by the researcher. After that, students completed PPM scale individually on Google Forms link provided by the researcher. The consent form was provided (Appendix 1) on the first page of the PPM scale.

On the same form, students were also asked for some demographic information, i.e., the programs they were enrolled in, their grade level, whether they had previously taken courses related to the environment, their gender and the last 4 digits of their university ID number (Appendix 1). This procedure took approximately 1.5 hours to complete.

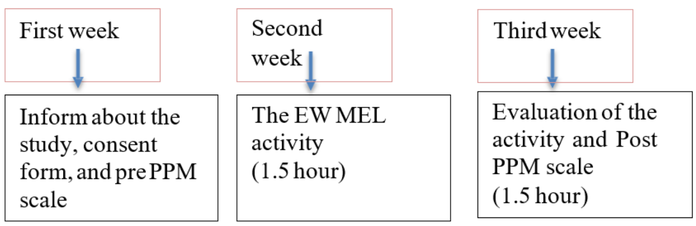


Figure 3.1. Procedure of the study.

In the next lesson, students worked on the EW MEL activity in class which is thoughtfully designed to foster a deep understanding of these essential principles by providing students with a comprehensive and enriching exploration of scientific models and the critical concept of plausibility checking. In the current study, a virtual version of EW MEL (Appendix 3) is used because students use their computers or tablets in every classroom activity. Therefore, it was easy for them to navigate the virtual

EW MEL chart. At the beginning of EW MEL activity, the researcher explained the EW MEL activity and shared a link for the activity using Blackboard system because students always use Blackboard system for their class. The EW MEL activity has 3 main parts. The first part is about models and plausibility checks. In the first part of the EW MEL activity, students were asked to individually complete the Model Plausibility Rating Google Form document provided by the researcher (see Figure 3.2). This form contains two models, Model A and Model B and students were asked to rate their plausibility. This activity fosters an environment of active learning and engagement, not only deepening their understanding of the material, but also improving their analytical and critical thinking skills. This portion took approximately 20 minutes to complete.

Plausibility of Models Explaining Increases in Extreme Weather Events

Name____________________**Date**________**Teacher**______________**Period**_______

Please work on this individually and read the following information carefully.

Humans create *models* to help explain things.

Below are two models. These provide different explanations for increases in extreme weather events over the last 50 years. These events include intense hurricanes, heavier rainfall and flooding, dangerous wildfires, and heat waves.

Model A: Increases in extreme weather events are linked to climate change. Current climate change is mainly caused by human activities, such as fossil fuel use.

A person who supports this model makes the following argument:

Human activities are increasing the amount of carbon in the atmosphere and changing Earth's climate. Increases in extreme weather events must then be linked to current climate change and human activities that cause this change.

Model B: Over time, increases and decreases in extreme weather events are mainly caused by changes in Earth's orbit around the Sun.

A person who supports this model makes the following argument:

The number and strength of extreme weather events varies over time. The amount of sunlight received by Earth also varies over time. Because energy from sunlight is a major contributor to Earth's climate and weather, changes in extreme weather are a result of orbital variations.

Plausibility is a judgment we make about the potential truthfulness of one explanatory model compared to another. The judgment may be tentative (not certain). You do not have to be committed to that decision.

Circle the plausibility of each model. [Make three circles, one for each model.]

	Greatly implausible (or even impossible)									Highly plausible
Model A	1	2	3	4	5	6	7	8	9	10
Model B	1	2	3	4	5	6	7	8	9	10

Figure 3.2. Plausibility rating form that was implemented before the EW MEL activity.

For the second part, students were then divided into groups (groups of 2 or 3) and accessed the EW MEL diagram and evidence text links provided by the researcher in the Blackboard system. In this diagram, there are four evidence texts and two models, where students were asked to select two arrows for each piece of evidence and match them to the models (see Figure 3.3). After students read the evidence text document link, they completed the EW MEL diagram by adding arrows of different shapes to represent their assessment of the degree of agreement between evidence and a model. A straight arrow with an "X" through the middle indicates the evidence contradicts the model, while a dashed arrow indicates that the evidence does not agree with the model. A squiggly arrow indicates that the evidence strongly supports the model and a straight arrow indicates that the evidence supports the model. The researcher assisted the students throughout the process. This part took about one hour to complete. Upon completion, the participants saved the final version as a slide and uploaded it to Blackboard.

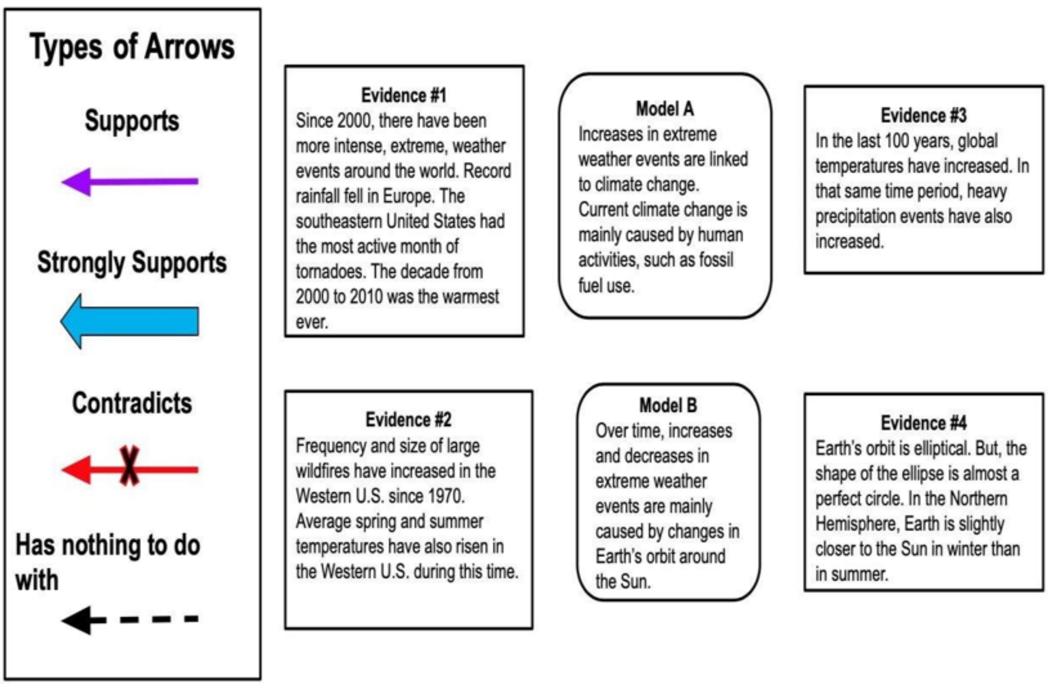


Figure 3.3. EW MEL diagram.

For the final part, students then individually completed an explanation task individually (see FFigure 3.4) using the Google Form link provided by the researcher to the Blackboard system to critically evaluate their connections and construct understanding. This task involved both selecting and writing about the evidence-model connections they made on their MEL diagram, as well as reassessing the plausibility of each model. The models were the same models presented in the first task (Model Plausibility Rating as shown in Figure 3.1) and they should also explain their reasoning and why they think the model they chose is more plausible. Students were expected to select two arrows they drew in Figure 3.2 to justify the plausibility of the model they selected. This part took 30 minutes.

Name_______________________________Date________Teacher________________________Period________Topic_______________

Please work on this part individually after you complete your diagram.

1. Now that you have completed the diagram, reconsider the plausibility of Models A and B (and C, if there is one). Circle the plausibility of each model. [Make one circle for each model.]

	Greatly implausible (or even impossible)									Highly plausible
Model A	1	2	3	4	5	6	7	8	9	10
Model B	1	2	3	4	5	6	7	8	9	10
Model C (if there is one)	1	2	3	4	5	6	7	8	9	10

2. For the model you selected as most plausible, explain why you think so.

3. Which arrows changed your plausibility judgments about the models? If your plausibility judgment did not change, which arrows supported your original plausibility judgments? Consider 2 lines of evidence. For each line, does it support, strongly support, or contradict one of the models? Why? When writing your explanation, consider the following:

- Use the specific information from the evidence text and figures to support your response. Ex: when looking at graphs or figures, be sure to describe the patterns in the data.
- Describe any cause and effect relationships found in the text.

Evidence #_____strongly supports | supports | contradicts | has nothing to do with Model______*because*:

Evidence #_____strongly supports | supports | contradicts | has nothing to do with Model______*because*:

Figure 3.4. EW MEL activity explanation task.

The EW MEL activity took one hour and thirty minutes in total. In the next class, as a final step, students completed the PPM scale again to see if there is significant difference between their PPM scale results before and after treatment. Overall data collection took 3 class hours in this study.

3.6. Data Analysis

This section explains how to analyze the data according to each research question.

3.6.1. Data Analysis for the First Research Question

To answer how do college students' plausibility perceptions about GCC change after the implementation of the EW MEL diagram, first, a descriptive analysis for the pre and post PPM scale was conducted to examine students' plausibility perceptions. The mean scores of the pre-and post-PPM scale were compared using the SPSS program. The maximum score students could get was 150. The minimum score was 15. Secondly, paired sample t-test was used to see if there is a significant difference between the pre-and post-test scores for the group (Dugard and Todman, 1995).

3.6.2. Data Analysis for the Second Research Question

To answer how do college students evaluate scientific and alternative explanations about global climate change and extreme weather events, the original explanation task rubric that was developed by Lombardi *et al.* 2016 was used to evaluate the students' explanations in the EW MEL diagram explanation tasks. According to Lombardi *et al.* (2016), there are four different explanation groups: a natural ordering (erroneous, score = 1), a low-moderate level of evaluation (descriptive, score = 2), a moderate level of evaluation (relational, score = 3) and a high level of evaluation (critical, score = 4). In current study, revised version of the rubric was used. Table 3.4 shows the rubric for the four types of evaluation and scores for explanations. The researcher read the explanations and scored according to the rubric. A second researcher independently scored the 20% of the explanations and the analysis continued the same way as there was a consensus.

Table 3.4. Types of evaluation rubric for explanatory tasks (Revised from Lombardi *et al.*, 2016).

Category of Evaluation	**Explanation**	**Score**
Erroneous	Explanation includes incorrect connections between the model and the evidence.	1
Descriptive	Explanation is accurate but does not require more explanation.	2
Relational	Explanation addresses textual similarities. It includes specific evidence about the association between models.	3
Critical	Explanation describes causality and meaning of a particular relationship between evidence and model.	4

3.6.3. Data Analysis for the Third Research Question

To answer how plausible do college students find the models in the EW MEL activity about extreme weather events and global climate change question, the researcher collected plausibility ratings for models included in the EW MEL diagrams in which students were asked to rate the plausibility of two different models. The researcher examined which model each group found more plausible (Model A or Model B) before and after EW MEL diagram evidence-model link part and then determined the mean scores for Model A and Model B to find which model students think more plausible before and after the EW model evidence matches.

4. RESULTS

This section explained the results for each research question. Firstly, descriptive statistics and paired sample t-test results were presented. Secondly, the results of the model plausibility ratings were presented. Lastly, EW MEL diagram analysis was introduced.

4.1. Descriptive Statistics

Descriptive statistics and paired sample tests were used to compare one group's pre and post-test scores in current study. Figure 4.1 shows the descriptive results for the PPM scale, a Likert scale from 0 to 10, before and after the implementation of the EW MEL diagram.

Descriptive statistics results showed that for the pre-test the mean score was found to be M= 118.48 SD= 22.83 and for the post-test the mean score was M=124.74 SD= 18.29. Also, for both the pre-test and the post-test, the maximum value was found to be 150, whereas the minimum value for the pre-test was found to be 64 and the minimum value for the post- test was found to be 90 while the maximum PPM score was 150.

Table 4.1. Descriptive statistics for PPM scale.

Number of the Participants		**Mean**	**SD**	**Min**	**Max**
Pre-test	62	118.48	22.83	64	150
Post-test	62	124.74	18.29	90	150

4.2. Paired Sample Test

Mean score in the post-test was higher than the mean score in the pre-test. Paired samples t-test was conducted to determine if there was a statistically significant difference between pre and post-test scores. Results showed that there was a statistically significant difference between pre-test (M= 118.48, SD= 22.83) and post-test (M= 124.74, SD= 18.29), t (df (61))= -3.37, p= 0.001) (see Table 4.1).

Table 4.2. Paired samples results.

Results	**t**	**df**	**Sig (2-tailed)**
Pretest-Posttest	-3.37	61	0.001

4.3. Extreme Weather Model Evidence Link Diagram Results

For the EW MEL diagram, students worked in groups and in total 30 groups matched 4 different types of evidence and two models, using different arrow shapes to indicate the relationship between each model and evidence (strongly supports/ supports/ nothing to do with/contradict, see Figure 4.1).

As shown in Table 4.3, analyses of the MEL diagrams revealed that majority of the groups made a correct model-evidence association for evidence lines and Model A in the EW MEL diagram. However, majority of the groups made an incorrect model-evidence association for evidence lines and Model B. Most of the model-evidence associations for MB-E2, MB-E3 and MB-E4 were incorrect. In total, 156 correct and 84 incorrect model- evidence matches were found in the EW MEL activity and incorrect associations were mostly related to Model B. Therefore, even though the number of correct associations almost doubled the incorrect ones, the number of incorrect associations was very high for especially evidence lines and Model B.

Table 4.3. The number of correct and false associations between evidence lines and models.

Association	MA-E1	MA-E2	MA-E3	MA-E4	MB-E1	MB-E2	MB-E3	MB-E4
Correct	28	27	29	24	15	14	12	7
False	2	3	1	6	15	16	18	23

For the explanation task, students were asked to provide explanations for the models and evidence links that they have chosen to be important or interesting. Evaluation rubric for explanatory tasks, revised by the researcher and originally developed by Lombardi *et al.* 2016, that included four increasing levels from erroneous to critical evaluation were used for the analysis (Lombardi *et al.*, 2016; Lombardi, Bailey, *et al.*, 2018). Table 4.4 shows sample-student statements for each category.

Table 4.4. Sample student statements for each category.

Category	Students' Answer	Score
Erroneous evaluation	Evidence 1 contradicts with Model A.	1
Descriptive evaluation	Evidence 2 supports Model A it talks about how the frequency and size of wildfires in the western US.	2
Relational evaluation	Evidence 1 shows that EW patterns have occurred since the industrial revolution and shows a correlation with climate change.	3
Critical evaluation	Explanation describes causality and meaning of a particular relationship between evidence and model.	4

Although students had more correct model-evidence links in the EW MEL, as shown in Figure 4.1 their explanations were mostly grouped as in erroneous evaluation, indicating a lack of initial understanding to make a meaningful assessment (Lombardi *et al.*, 2016). For example, as an erroneous explanation, one student's response was that 'Evidence 4 supports Model B because they both discuss the Earth's orbit around the Sun'. Descriptive evaluation, indicating that the assessment contains a correct relationship without elaborating on the relationship or correctly interpreting the evidence without stating a relationship, was the second most frequent group (Lombardi *et al.*, 2016). As a descriptive explanation, one students' answer results revealed as 'Model A says that the increase in extreme weather events is linked to climate change, so the two support each other'.

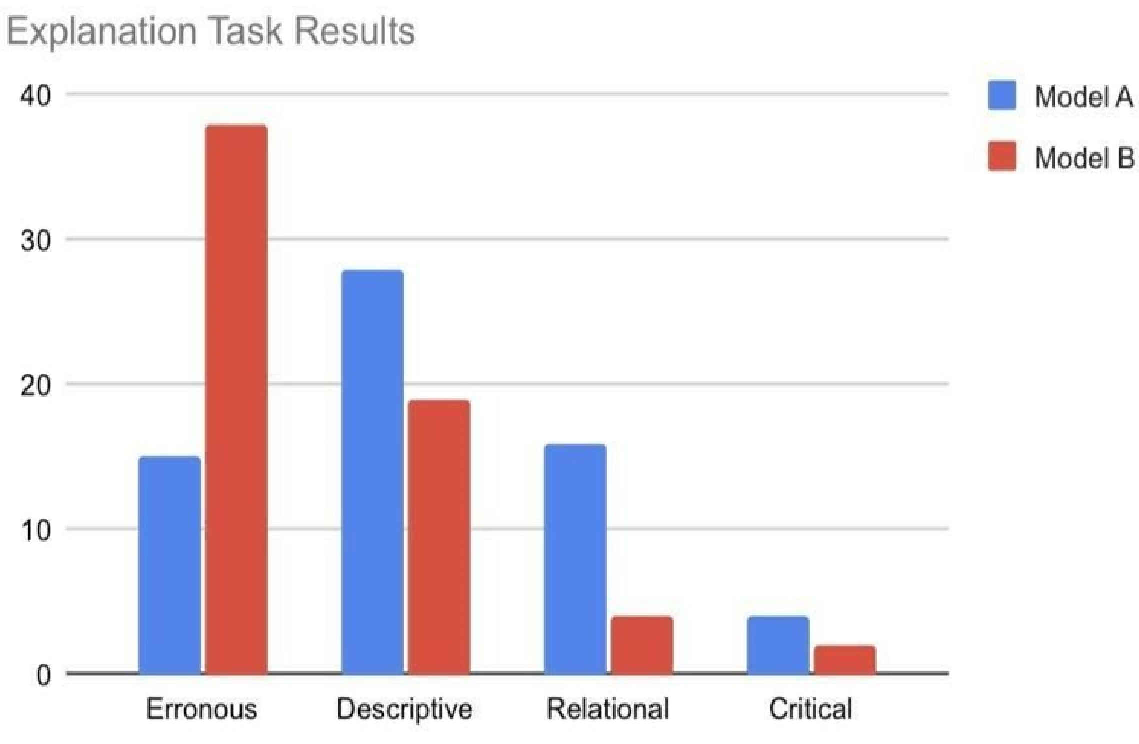


Figure 4.1. Explanation task results.

In addition, in the explanation task, some students wrote that their plausibility judgements had changed after the implementation of the EW MEL diagram. For example, one student's response was 'Evidence two and three have greatly changed the plausibility of Model A'.

Overall, many students found Model A more plausible than Model B. However, their explanations for Model B were mostly found to be erroneous, which shows lack of understanding about the Model B, while their explanations for Model A were mostly found to be descriptive.

It can be concluded that students mostly linked the increase in EW events to GCC correctly. However, they have misunderstandings about relationship between GCC and EW events as well as main causes about EW events.

4.4. Plausibility Ratings

In the plausibility ratings, the mean plausibility rating of Model A was 8.3, while the mean plausibility rating of Model B was 5.4 before the EW MEL intervention.

Figure 4.2 shows the overall distribution of plausibility ratings among the students. Results showed that 87% of the participants found Model A (scientific explanation) more plausible than Model B (alternative explanation).

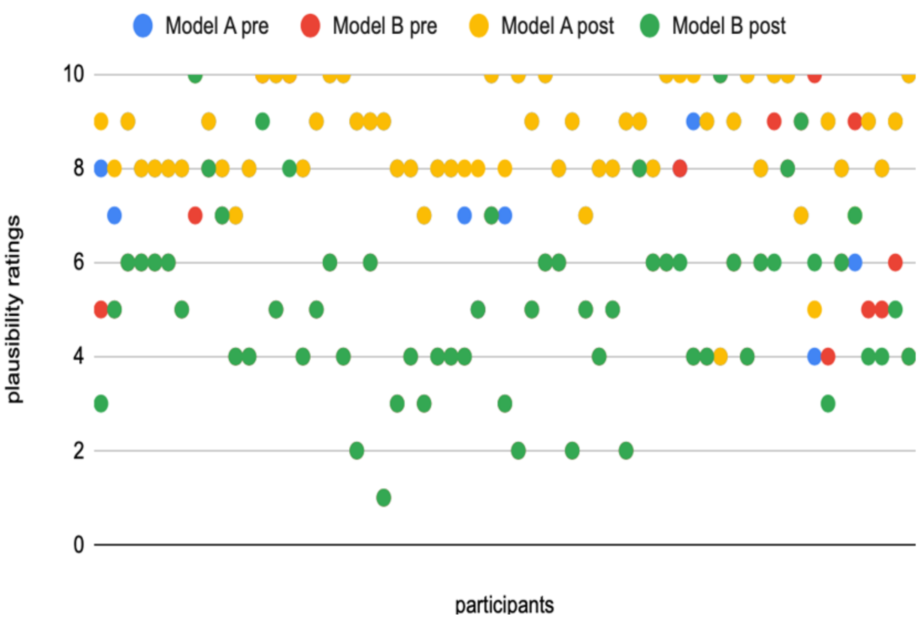


Figure 4.2. Overall plausibility ratings.

Figure 4.3 shows plausibility ratings for Model A and Model B before the intervention and Figure 4.4 shows plausibility ratings for Model A and Model B after the intervention.

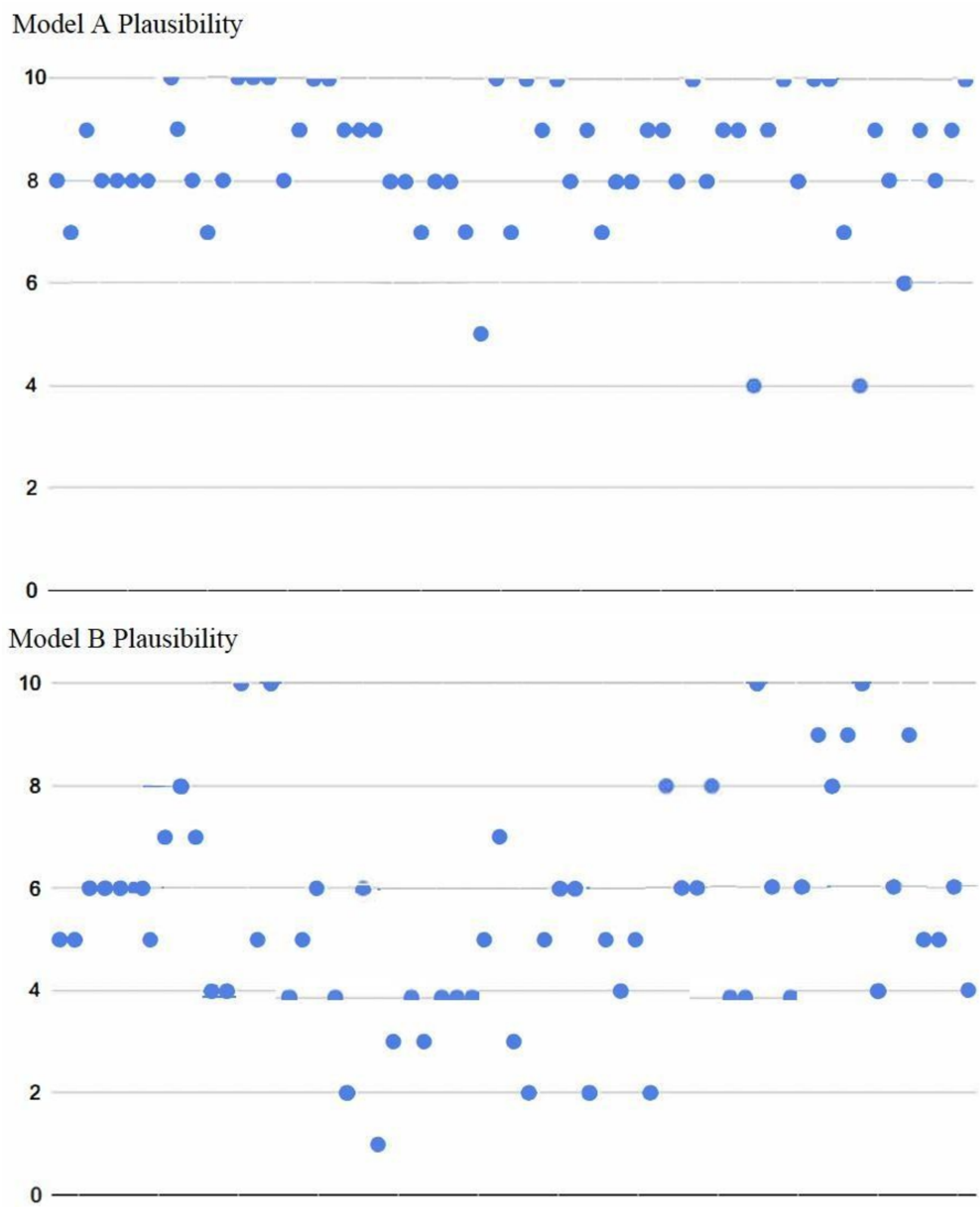


Figure 4.3. Plausibility ratings for Model A, Model B before the intervention.

Furthermore, after the EW MEL diagram, students were asked to rate the plausibility of two models again. Results showed that the mean plausibility rating of Model

A was 8.5, while the mean plausibility rating of Model B was 5.1 (Figure 4.4). Results showed that the average plausibility rating for Model A has increased while Model B has decreased after EW MEL activity. Also, 93.54% of the participants found Model A more plausible after the EW MEL activity. Even though the majority of the participants found Model A more plausible Model B, Model B was also rated as plausible for many students. This result is supported by the existing literature that may indicate students' misconceptions about GCC (Ceyhan *et al.*, 2021; Chang and Pascua, 2016; Chen, 2011; Klavon, 2023; Leiserowitz *et al.*, 2010; Shepardson *et al.*, 2012).

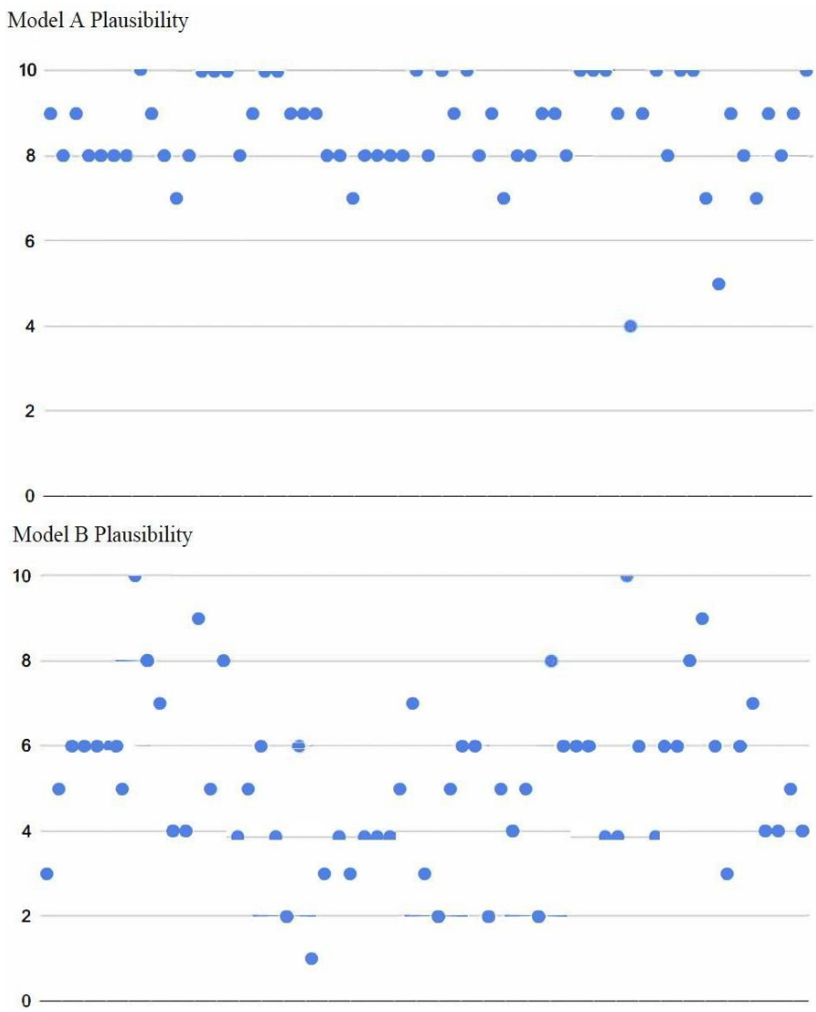


Figure 4.4. Plausibility ratings for Model A, Model B after the intervention.

5. DISCUSSION

This section started with a summary of the results. This provided an overview of the study. Then, the results of each research question were discussed. Finally, the limitations and implications of the study were discussed in the last section of the chapter.

5.1. Summary of the Results

This study was conducted using a one group pre-post quasi-experimental research design supported by qualitative data with 62 participants from various departments at a private research university in the United States. The purpose of the study was to investigate students' plausibility perceptions of GCC and to examine students' critical evaluations of extreme weather events using the EW MEL Diagram activity, as activities such as the MEL activity can help students develop more scientific evaluation skills (Klavon *et al.*, 2023). Three instruments were used for data collection: Demographic Form, Plausibility Perceptions Measure scale and Virtual Extreme Weather Model Evidence Link Diagram.

An updated PPM scale was used to measure students' plausibility perceptions about GCC before and after the EW MEL Diagram, while the difference between pre- and post- test scores was examined. The EW MEL analysis was also examined to understand students' critical evaluations and plausibility judgments on two different models. The results of the study showed that there was a statistical difference between the pre- and post-PPM scores. It was found that students' plausibility perceptions had increased significantly ($p < 0.05$).

In the EW MEL diagram activity, where students were asked to rate the plausibility of the models (Model A and Model B), students found the scientific explanation (Model A) more plausible than the alternative explanation (Model B). Another important finding was that students' alternative and critical explanations of EW MEL showed that although students' model and evidence links were mostly correct. However, their explanations were mostly in the erroneous evaluation category.

5.2. Discussion of the Results

This section presented the relationship of the findings with the literature. Each research question and their results were discussed. First, the change in plausibility perceptions before and after the EW MEL diagram was discussed. Second, the results of the EW MEL activity and students' critical evaluations were discussed. Finally, plausibility ratings for the EW MEL activity were discussed. Based on existing research studies and theoretical perspectives on increasing autonomy in classroom learning situations, findings suggested that MEL scaffolds can significantly contribute to plausibility shifts toward scientific thinking and knowledge gains from pre- to post-instruction (Lombardi *et al.*, 2018). MEL scaffolds create an environment that leads critical thinking (Ceyhan *et al.*, 2021; Klavon, *et al.*, 2023; Lombardi *et al.*, 2013). According to the pre-post PPM results, students' plausibility perceptions about GCC increased significantly after the EW MEL activity, which was supported by the literature because MEL activities were found useful in developing students' critical evaluations (Ceyhan *et al.*, 2021; Lombardi *et al.*, 2013; Lombardi *et al.*, 2018). Similarly, in one study, it was found that the arguments of the group using the MEL tool were significantly different from the group using the traditional method (Can, 2017).

In contrast, in a recent study of middle school students, researchers used the MEL chart and the results showed that the paired-samples t-test revealed no significant shifts in plausibility from pre- to post-teaching (Klavon, *et al.*, 2023), whereas in the current study, there was a significant difference between the pre- and post-test scores on the PPM scale, but the students who had higher assessment levels showed a significant increase in both science plausibility judgments and depth of knowledge in the post-test period (Klavon, *et al.*, 2023). The results of the current study provided evidence that the ability to critically evaluate information plays a crucial role in students' plausibility perspectives (Lombardi *et al.*, 2013). The significant difference found between the pre- and post-test PPM scores in the paired samples t-test indicated that the instructional interventions, such as EW MEL diagram, had a positive impact on the students' plausibility perceptions. In the literature, MEL diagrams have been used by researchers as a valuable tool to assess students' critical evaluations (Ceyhan *et al.*, 2021; Saribas and Can, 2019; Lombardi *et al.*, 2022). Recent research also supports these findings as it used MEL diagrams to analyze students' evaluations (Ceyhan *et al.*, 2021; Saribas and Can, 2019; Lombardi and Sinatra, 2012). In the explanation task, students were asked to articulate their reasoning and represent arrows connecting lines of evidence to explanatory models. They were asked to provide two explanations for the connections they found most compelling or about which they had the strongest conviction. The goal was to encourage students to explore their thought processes and express the rationale for their chosen connections. The results of students' critical evaluation showed that although students mostly made correct model-evidence matches, their explanations for the evidence-model links were mostly found to be erroneous, which is consistent with the existing literature on this topic (Ceyhan *et al.*, 2021) which shows that even when students make accurate associations, their explanations and critical evaluation skills are still lacking. Similarly, Ceyhan *et al.* (2021) reported that students' explanations for MEL diagram connections were mostly erroneous. In the current study, the results showed that students demonstrated considerable success in constructing accurate connections in MEL diagrams. However, their evaluations of model-evidence relationships were mainly limited to the erroneous and descriptive levels.

Moreover, Can and Saribas (2019) used a MEL diagram on an SSI and pre-service elementary teachers participated in their study. They found that the participants were able to construct accurate links; however, they were unable to critically evaluate the model-evidence links similar to current study. In current study, it was found that students challenged to critically evaluate EW MEL explanation tasks. Additionally, similar findings were observed in another study conducted by Saka and Saribas (2019) where pre-service teachers were challenged to critically evaluate and assess the relationship between evidence presented in a given text and an argument or counter argument about genetically modified organisms (Can and Saribas, 2019; Saka and Saribas, 2019). However, in the current study, the EW MEL diagram was used because EW events have increased with GCC and participants were not science majors and students were challenged in the assessment task and in performing critical assessments.

Findings in current study are consistent with discussions by Osborne, Erduran and Simon (2004), who emphasized that simply presenting science and social science issues to students is not enough to improve their argumentation skills, even with opportunities for discussion. In addition, Christensen (2009) emphasized the importance of understanding risk in decision-making about SSIs. Given the importance of GCC as an SSI and the increasing frequency of EW events, there remains a need to improve students' in-depth understanding and critical evaluation of GCC and EW events. The process of making decisions regarding socio-scientific issues (SSIs) necessitates not only the acquisition of relevant information, but also the use of critical evaluation to assess the evidence and explanations available.

There were two models in the EW MEL activity. Model A was a scientific consensus, while Model B was a non-scientific consensus. For the plausibility rating part, students rated the plausibility of Model A and Model B at the beginning and at the end of the EW MEL activity. The results showed that although the plausibility rating of Model A was higher than that of Model B, Model B was also found plausible by many students. One of the reasons for this could be the lack of GCC training (Leiserowitz *et al.*, 2011, Monroe *et al.*, 2019). In addition, 51 of the students have reported that they had never taken an environmental course before. This may also lead to misunderstandings about GCC and EW events. It has been found in the literature that students have misconceptions about extreme weather events and the results are in line with the literature (Henriques, 2002; Lombardi and Sinatra, 2012; Ozdem et al, 2014). After model-evidence links, students rated the plausibility for Model A and Model B again. The results showed that the average plausibility rating for Model A increased while Model B decreased after the EW MEL activity. The results are consistent with the results of the MEL conducted with 40 science teacher candidates in 2021. Ceyhan *et al.* (2021) reported that a model rated as low in plausibility, but still plausible, also reveals the erroneous evaluations of the groups similarly in the current study.

5.3. Implications of the Study

The findings of the current study have significant implications for curriculum developers and climate change educators. Conceptual change models have been recognized as crucial in education (Berrang-Ford, 2019; Dole and Sinatra, 1998; Posner *et al.*, 1982; Russell and 2023) and this study emphasized the importance of plausibility as a key component of conceptual change (Dole and Sinatra, 1998; Lombardi *et al.*, 2016; Sinatra and Lombardi, 2020). It is evident that SSIs like GCC demand critical evaluation, as misconceptions about climate change persist despite the increasing occurrence of extreme weather events.

The implications of the study's findings are significant in terms of facilitating the development of critical evaluation skills among college students. To achieve this goal, social science topics can be taught through the use of instructional scaffolds such as MEL diagrams. Understanding students' plausibility perceptions and scientific evaluations of GCC is vital, as these perceptions not only impact their conceptual understanding but also influence their behavior. Sinatra and colleagues (2012) underlined the increasing importance of students' plausibility perceptions, as they can affect both their understanding and behavior. By utilizing tools like the MEL diagram, educators can guide students in scientifically evaluating their judgments, thus enhancing awareness and fostering a more scientific approach to addressing climate change. Implementing student-centered approaches, such as MEL scaffolds, is a promising avenue for educators to improve the learning experience and facilitate meaningful knowledge acquisition among students (Klavon *et al.*, 2023). Prior studies have demonstrated the effectiveness of MEL diagrams in enhancing students' evaluation and argumentation skills, particularly in connecting evidence with alternative models (Ceyhan *et al.*, 2021; Chinn and Brewer, 1993; Lombardi *et al.*, 2013; Saka and Saribas, 2019).

In conclusion, this study highlights the importance of integrating MEL diagrams into GCC lessons to eliminate misconceptions and promote a scientific understanding of climate change among students, as there is still a need for effective GCC education that promotes critical thinking.

Results in current study shows college students are not able to make critical evaluations about different models about GCC and EW events. With such approaches, educators can play a critical role in raising awareness and promoting climate-friendly behaviors to positively impact environmental issues in the GCC region.

5.4. Limitations and Suggestions

In this section the limitations of the study and possible suggestions were presented. The first limitation was related to generalizability. A purposive sampling method was used to select the participants in the current study. Therefore, the results may not be generalizable to all college students in the U.S. In particular, the current study was limited to one private research university in the U.S. This study can be conducted with participants from a larger sample in other public and private universities.

The second limitation was the language of the instrument. Since the students in this study were in different faculties, some students have a scientific background while others do not. The items in the PPM measure and the evidence texts in the EW MEL activity may not be understood by some students because they have scientific language. It should also be taken into account that there are international students participating in this study. The language of the instrument and the EW MEL activity may be a limitation for a student whose first language is not English or who does not have a scientific background. Further research could investigate the plausibility perceptions of different SSIs or different groups' plausibility perceptions of GCC.

As a suggestion, MEL diagrams such as the EW MEL diagram can be incorporated into climate change training. The EW MEL diagram is a new MEL diagram and it will help emphasize the importance of EW events and GCC. Since EW events are something that observers can observe in their daily lives, it is important for GCC training to be able to critically evaluate them.

REFERENCES

Abbass, K., M.Z. Qasim, H. Song, M. Murshed., H. Mahmood and I. Younis, 2022, "A Review of the Global Climate Change Impacts, Adaptation and Sustainable Mitigation measures", *Environmental Science and Pollution Research*, Vol. 29, No. 28, pp. 42539-42559.

Akyol, G., 2014, "Teachers' Views of Environmental Education", *Journal of Education and Practice*, Vol. 5, No. 8, pp. 124-130.

Alexander, P.A., J.M. Kulikowich and T.L. Jetton, 1997, "The Role of Subject-Matter Knowledge and Interest in the Processing of Linear and Nonlinear Texts", *Review of Educational Research*, Vol. 61, No. 2, pp. 145-179.

Allen, C.D., A.K. Macalady, H. Chenchouni, D. Bachelet, N. McDowell, M. Vennetier and N. Cobb, 2010, "A Global Overview of Drought and Heat-Induced Tree Mortality Reveals Emerging Climate Change Risks for Forests", *Forest Ecology and Management*, Vol. 259, No. 4, pp. 660-684.

Bailey, J.M.C. Girtain and D. Lombardi, 2016, "Understanding the Formation of the Earth's Moon", *The Earth Scientist*, Vol. 32, No. 2, pp. 11-16.

Bickel, E.S. and D. Lombardi, 2016, "The Effectiveness of Model-Based Instruction for Promoting Complex Systems Understanding in Middle School Students", *Journal of Educational Psychology*, Vol. 108, No. 3, pp. 319-334.

Bostrom, A., M.G. Morgan, B. Fischhoff and D. Read, 1994, "What Do People Know About Global Climate Change? 1. Mental Models", *Risk Analysis*, Vol. 14, No. 6, pp. 959-970.

Bozkurt, F., 2019, "Evaluation of Geography Textbooks in Terms of Misconceptions About Climate Topic", *Review of International Geographical Education Online*, Vol. 9, No. 1, pp. 149-170.

Can, S.N, 2017, *Using a Model Evidence Link Diagram to Explore Nuclear Energy: The Effects on Seventh Graders' Risk Perception and Understanding of the Issues*, M.S. Thesis, Boğaziçi University.

Can, S.N. and D. Saribas, 2019, "An Argumentative Tool for Facilitating Critical Evaluation: Exploring Pre-service Teachers' Evaluation Levels of a Socio-scientific Topic Through MEL Diagrams", *Science and Education*, Vol. 28, No. 6-7, pp. 669-687.

Ceyhan, G. and E.Z. Muğaloğlu, 2020, "A Study on Sustainable Development and Education for Sustainable Development: Teachers' Views", *Journal of Education and Practice*, Vol. 11, No. 1, pp. 113-123.

Ceyhan, G.D., D. Lombardi and D. Saribas, 2021, "Probing into Pre-Service Science Teachers' Practices of Scientific Evaluation and Decision-Making on Socio- Scientific Issues", *Journal of Science Teacher Education*, Vol. 32, No. 8, pp. 865-889.

Chang, C.H. and L. Pascua, 2016, "Singapore Students' Misconceptions of Climate Change", *International Research in Geographical and Environmental Education*, Vol. 25, No. 1, pp. 84-96.

Chawla, L., 2020, "Childhood Nature Connection and Constructive Hope: A Review of Research on Connecting with Nature and Coping with Environmental Loss", *People and Nature*, Vol. 2, No. 3, pp. 619-642.

Chen, I.C., J.K. Hill, R. Ohlemüller, D.B. Roy and C.D Thomas, 2011, "Rapid Range Shifts of Species Associated with High Levels of Climate Warming", *Science*, Vol.

333, No. 6045, pp. 1024-1026.

Chinn, C.A. and W.F Brewer, 1993, “The Role of Anomalous Data in Knowledge Acquisition: A Theoretical Framework and Implications for Science Instruction”, *Review of Educational Research*, Vol. 61, No. 1, pp.1-49.

Clarke, B., F. Otto, R. Stuart-Smith and L. Harrington, 2022, “Extreme Weather Impacts of Climate Change: An Attribution Perspective”, *Environmental Research: Climate*, Vol. 1, No. 1, pp. 012001-012031.

Cook, J., N. Oreskes, P.T. Doran, W.R. Anderegg, B. Verheggen, E.W. Maibach and K. Rice, 2016, “Consensus on Consensus: A Synthesis of Consensus Estimates on Human-Caused Global Warming”, *Environmental Research Letters*, Vol. 11, No. 4, pp. 048002-048152.

Da Rosa, J.A., 2022, “Comparing Climate Science Misconceptions with Worldview and Cognitive Reflection Suggests Poor Understanding and Motivated Reasoning Among Undergraduates”, *Journal of Geoscience Education*, Vol. 70, No. 4, pp. 501-516.

Dawson, V. and K. Carson, 2020, “Introducing Argumentation about Climate Change Socio-scientific Issues in a Disadvantaged School”, *Research in Science Education*, Vol. 50, pp. 863-883.

Denisova, Y.V., G.N. Yakubova and O.V. Borodina, 2019, “On the Possibility of Using Geophysical Data for Detecting a Potential Landfill”, *Journal of Applied Geophysics*, Vol. 162, pp. 117-124.

Dimock, M. and C. Johnson, 2019, “In the US and UK, Climate Concern Is Rising, But So Is Divide on Severity of Problem. Pew Research Center”, https://www. pewresearch. org/ science/ 2019/ 04/ 18/ in- the- u- s- and -uk -climate- concern-is-rising- but- so- is- divide- on- severity- of- problem/, accessed on May 13, 2023.

Dole, J.A. and G.M. Sinatra, 1998, "Reconceptualizing Change in the Cognitive Construction of Knowledge", *Educational Psychologist*, Vol. 33, No. 2-3, pp. 109-128.

Dugard, P. and J. Todman, 1995, "Analysis of Pre-Test-Post-Test Control Group Designs in Educational Research", *Educational Psychology*, Vol. 15, No. 2, pp. 181-198.

Egan, P.J. and M. Mullin, 2017, "Climate change: US public Opinion", *Annual Review of Political Science*, No. 20, pp. 209-227.

Falaye, A.O. and O.A. Okwilagwe, 2016, "Assessment of Teachers' Knowledge, Attitude and Practices Towards Environmental Education in Primary Schools in Ogun State, Nigeria", *Journal of Education and Practice*, Vol. 7, No. 30, pp. 80-85.

Feldman, L., Nisbet, M.C., A. Leiserowitz and E. Maibach, 2010, *The Climate Change Generation? Survey Analysis of the Perceptions and Beliefs of Young Americans*, Center for Climate Change Communication, United States of America, Washington.

Feliciano, D., J. Recha, G. Ambaw, K. MacSween, D. Solomon and E. Wollenberg, 2022, "Assessment of Agricultural Emissions, Climate Change Mitigation and Adaptation Practices in Ethiopia", *Climate Policy*, Vol. 22, No. 4, pp. 427-444.

Ferguson, R.F., 1999, "Can Schools Narrow the Black-White Test Score Gap?", In C. Jencks and M. Phillips (Editors.), *The Black–White Test Score Gap, Brookings Institution Press*, Washington, DC, pp. 318–374.

Governor, D., Lombardi, D. and G.M. Sinatra, 2021, "Teachers' Views of Dialogic Argumentation in the Science Classroom: A Cross-National Study", *Research in Science Education*, pp. 1-26.

Gowda, C.L., P.N. Fox and R.D. Magelky, 1997, "The Role of International Agricultural Research in Reducing Poverty and Improving Food Security in the Developing World", *Outlook on Agriculture*, Vol. 26, No. 4, pp. 271-280.

Halper, E., L. Bressan and M. Leitner, 2019, "Mapping Global Gender Norms", *World Development*, Vol. 122, pp. 675-692.

Hanedar, M., G. Ozyazici and G.D. Ceyhan (Under Review) "Assessment and Validation: An Updated Climate Change Plausibility Perception Measure", *Environmental Education Research*.

Hanson, S., 1993, "Environmental Attitudes and Behaviors at Michigan State University", *Environment and Behavior*, Vol. 25, No. 3, pp. 316-342.

Henderson, J. and A. Drewes, 2020, *Teaching Climate Change in the United States*, Routledge, New York.

Hess, D.J. and B.M. Collins, 2018, "Climate Change and Higher Education: Assessing Factors that Affect Curriculum Requirements", *Journal of Cleaner Production*, Vol. 170, pp. 1451-1458.

Higde, P.R., S.S. Mote and S.D. Pawar ,2017, "Estimation of Soil Moisture Content using Neural Networks: A Review", *International Journal of Scientific Engineering and Research*, Vol 5, No. 1, pp. 397-400.

Howe, P.D., 2021, "Extreme Weather Experience and Climate Change Opinion", *Current Opinion in Behavioral Sciences*, Vol. 42, pp. 127-131.

Hu, L.T. and P.M. Bentler, 1999, "Cutoff Criteria for Fit Indexes in Covariance Structure Analysis: Conventional Criteria Versus New Alternatives", *Structural Equation Modeling: A Multidisciplinary Journal*, Vol. 6, No. 1, pp. 1-55.

Huxster, J.K., X. Uribe-Zarain and W. Kempton, 2015, "Undergraduate Understanding of Climate Change: The Influences of College Major and Environmental Group Membership on Survey Knowledge Scores", *The Journal of Environmental Education*, Vol. 46, No. 3, pp. 149-165.

Intergovernmental Panel on Climate Change, 2007, Climate Change 2007: "Synthesis Report, Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Climate Change 2007", Working Groups, I, II and III to the Fourth Assessment, Geneva, Switzerland.

Intergovernmental Panel on Climate Change (IPCC), 2021, "Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the IPCC", Cambridge University Press, New York, https://www.ipcc.ch/report/ ar6/ wg1/, accessed on April 15, 2023.

Intergovernmental Panel on Climate Change, 2022, Climate Change 2022: *Impacts, Adaptation and Vulnerability*, Cambridge, New York.

Islam, M.R., Hasanuzzaman, M., M.A. Malek and A. Ahad, 2019, "Impact of Climate Change on the Production and Yield of Summer Tomato in Bangladesh", *Journal of Agricultural Extension and Rural Development*, Vol. 11, No. 9, pp. 181-191.

Kahan, D.M., 2015, "Climate-Science Communication and the Measurement Problem", *Advances in Political Psychology*, Vol. 36, pp. 1-43.

Kahyaolu, H. and N. Ozgen, 2012, "Investigation of the Effect of Environmental Education on Environmental Attitudes, Awareness and Behavior", *Procedia-Social and Behavioral Sciences*, Vol. 46, pp. 4996-5001.

Karami, E., G. Van Der Werf and B. Csapó, 2017, "Exploring Secondary School Students' Understanding of Climate Change", *International Journal of Science Educa-*

tion, Vol. 39, No.1, pp. 1-19.

Karlsson, R., K. Bergqvist and L.A. Tibell, 2020, "Teaching climate change in Swedish Upper Secondary Schools: Teachers' Views and Experiences", *Research in Science Education*, Vol. 50, No. 3, pp. 831-853.

Klavon, T.G., S. Mohan, J.B. Jaffe, T. Stogianos, D. Governor and D. Lombardi, 2023, "Scientific Evaluations and Plausibility Judgements in Middle School Students' Learning about Geoscience Topics", *Journal of Geoscience Education*, pp. 1-15.

Kuppa, S., 2018, *Do Millennials See Climate Change as More Than Just a Meme?*, M.S. Thesis, Johns Hopkins University.

Lahsen, M., J. and C. Ribot, 2022, "Climate Research Filter: An Assessment of the Method Based on in-situ Observations and Model Simulations", *Hydrology and Earth System Sciences*, Vol. 14, No. 1, pp. 245-255.

Lee, K., N. Gjersoe, S. O'Neill and J. Barnett, 2020, "Youth Perceptions of Climate Change: A Narrative Synthesis", *Wiley Interdisciplinary Reviews: Climate Change*, Vol.11, No. 3, pp. 56-76.

Leiserowitz, A., E. Maibach, C. Roser-Renouf and N. Smith, 2011, *Global Warming's Six Americas, May 2011*, Yale University and George Mason University, CT: Yale Project on Climate Change Communication, New Heaven.

Leiserowitz, A., N. Smith and J.R. Marlon, 2010, *Americans' Knowledge of Climate Change, Yale University*, CT: Yale Project on Climate Change Communication, New Haven.

Lemery, J., S. Anenberg, C. Beyrer, J. Friberg, D. Griggs, A. Jha and J. Patel, 2021, "Protecting Health from Climate Change", *The Lancet Commission*, Vol. 398, No. 10307, pp. 1622-1674.

Li, Y.Y. and S.C. Liu, 2022, "Examining Taiwanese students' Views on Climate Change and the Teaching of Climate Change in the Context of Higher Education", *Research in Science and Technological Education*, Vol. 40, No. 4, pp. 515-528.

Lombardi, D., 2016, "Beyond the Controversy: Instructional Scaffolds to Promote", *The Earth Scientist*, Vol. 32, No. 2, pp. 5-10.

Lombardi, D., E.S. Bickel, J.M. Bailey and S. Burrell, 2018, "High School Students' Evaluations, Plausibility (Re) Appraisals and Knowledge About Topics in Earth Science", *Science Education*, Vol. 102, No. 1, pp. 153-177.

Lombardi, D., C.B. Brandt, E.S. Bickel and C. Burg, 2016, "Students' Evaluations About Climate Change", *International Journal of Science Education*, Vol. 38, No. 8, pp. 1392-1414.

Lombardi, D. and R.W. Danielson, 2018, On Learning and Teaching for Conceptual Change, in Angela O'Donnell, Nicole C. Barnes and Johnmarshall Reeve (Editors), "In The Oxford Handbook of Educational Psychology (Online Edition, Oxford Academic, 5 Apr. 2018)", https://doi. org/ 10. 1093/ oxfordhb/ 9780199841332. 013. 20, accessed on May 20, 2023.

Lombardi, D., R.W. Danielson and N. Young, 2016, "A Plausible Connection: Models Examining the Relations Between Evaluation, Plausibility and the Refutation Text Effect", *Learning and Instruction*, Vol. 44, pp. 74-86.

Lombardi, D. and G.M. Sinatra, 2012, "College Students' Perceptions About the Plausibility of Human-Induced Climate Change", *Research in Science Education*, Vol. 42, pp. 201-217.

Lombardi, D. and G.M. Sinatra, 2012, "Enhancing Science Literacy and Metacognition through Collaborative Argumentation", *Journal of Research in Science Teaching*, Vol. 49, No. 1, pp. 74-101.

Lombardi, D. and G.M. Sinatra, 2013, "Emotions about Teaching About Human-Induced Climate Change", *International Journal of Science Education*, Vol. 35, No. 1, pp. 167-191.

Lombardi, D., G.M. Sinatra and L. Mason, 2016, "Improving the Quality of Students' Argumentative Writing in Science: The Role of Explicit Instruction in Scaffolding Students' Understanding of the Scientific Argumentation Structure", *Journal of Research in Science Teaching*, Vol. 53, No. 9, pp. 1363-1384.

Lombardi, D., G.M. Sinatra and E.M. Nussbaum, 2013, "Mathematics and Science Teachers' Perceptions and Practices of Argumentation", *Journal of Research in Science Teaching*, Vol. 50, No. 2, pp. 194-214.

Lombardi, D., G.M. Sinatra and L. Mason, 2018, "Effects of Different Forms of Argumentative Scaffolding on Argumentation Quality and Learning Outcomes", *Instructional Science*, Vol. 45, No. 5, pp. 663-689.

Lombardi, D., B. Uslu and J.M. Bailey, 2020, "Extreme Weather Events and the Climate Crisis: What Is the Connection", *The Earth Scientist*, Vol 36, No. 3, pp. 22-26.

Lorenzoni, I., S. Nicholson-Cole and L. Whitmarsh, 2007, "Barriers Perceived to Engaging with Climate Change among the UK Public and Their Policy Implications", *Global Environmental Change*, Vol. 17, No. 3-4, pp. 445-459.

Malla, G., K. Koirala and T.P. Bhandari, 2022, "Livelihood Vulnerability Assessment of Transhumant Herders to Climate Change in Mustang District of Nepal", *Envi-*

ronmental Science and Pollution Research, Vol. 29, No. 9, pp. 12717-12728.

Mark, B., 2020, *Middle School Students and Climate Change: Assessing Attitudes and Emotions*, M.S. Thesis, Penn State University.

McPhillips, T., F. Chen, L. Zhang, W. Zarin and T. Killeen, 2018, "The Impact of Climate Change on the Range of Species: A Systematic Review", *Global Ecology and Biogeography*, Vol. 27, No. 11, pp. 1258-1268.

Mikhaylov, A., N. Moiseev, K. Aleshin and T. Burkhardt, 2020, "Global Climate Change and Greenhouse Effect", *Entrepreneurship and Sustainability Issues*, Vol. 7, No. 4, p. 2897.

Mirza, M., 2003, "Climate Change and Extreme Weather Events: Can Developing Countries Adapt?", *Climate Policy*, Vol. 3, No. 3, pp. 233-248.

Nadelson, L.S., B.C. Heddy, S. Jones, G. Taasoobshirazi and M. Johnson, 2018, "Conceptual Change in Science Teaching and Learning: Introducing the Dynamic Model of Conceptual Change", *International Journal of Educational Psychology*, Vol. 7, No. 2, pp. 151-195.

Nation, M.T. and A. Feldman, 2021, "Environmental Education in the Secondary Science Classroom: How Teachers' Beliefs Influence their Instruction of Climate Change", *Journal of Science Teacher Education*, Vol. 32, No. 5, pp. 481-499.

National Research Council, S.R. Singer, N.R. Nielsen and H. A. Schweingruber, 2012, *Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering*, National Academies Press, Washington, DC.

Özdem, Y., B. Dal, N. Öztürk, D. Sönmez and U. Alper, 2014, "What is that Thing

Called Climate Change? An Investigation into the Understanding of Climate Change by Seventh-Grade Students", *International Research in Geographical and Environmental Education*, Vol. 23, No. 4, pp. 294-313.

Özmen, H., L. Çetinkaya and S. Nehir, 2005, "Students' Conceptions of the Ozone Layer and Ozone Depletion", *Journal of Science Education and Technology*, Vol. 14, No. 1, pp. 47-60.

Papadimitriou, V., 2004, "Prospective Primary Teachers' Understanding of Climate Change, Greenhouse Effect and Ozone Layer Depletion", *Journal of Science Education and Technology*, Vol. 13, pp. 299-307.

Plutzer, E., M. McCaffrey, A.L. Hannah, J. Rosenau, M. Berbeco and A.H. Reid, 2016, "Climate Confusion Among US Teachers", *Science*, Vol. 351, No. 6274, pp. 664-665.

Posner, G.J., K.A. Strike, P.W. Hewson and W.A. Gertzog, 1982, "Toward a Theory of Conceptual Change", *Science Education*, Vol. 66, No. 2, pp. 211-227.

Russell, T. and A.K. Martin, 2023, "Learning to Teach Science", *In Handbook of Research on Science Education*, Routledge, New York, Vol. 3, pp. 1162-1196.

Sadler, T.D., F.W. Chambers and D. L. Zeidler, 2004, "Student Conceptualizations of the Nature of Science in Response to a Socio-scientific Issue", *International Journal of Science Education*, Vol. 26, No. 4, pp. 387-409.

Saribas, D. and O. Akdemir, 2018, "The Effects of Different Scaffolding Methods on Students' Argumentation Skills in Inquiry-Based Learning Environment", *Education and Science*, Vol. 43, No. 194, pp. 235-251.

Sarıbas, D. and M. Saka, 2018, "Öğretmen Adaylarının İklim Değişikliği ile İlgili Model-

Kanıt Ilişkisine Yönelik Kavrama ve Değerlendirme Düzeylerinin İncelenmesi", *Trakya Üniversitesi Eğitim Fakültesi Dergisi*, Vol. 8, No. 4, pp. 655-670.

Saribas, D. and Z, Gonca Akdemir, 2019, "Using an Innovative Tool in Science Education: Examining Pre-service Elementary Teachers' Evaluation Levels on the Topic of Wetlands", *International Journal of Science Education*, Vol. 41, No. 1, pp. 123-138.

Siegner, A. and N. Stapert, 2020, "Climate Change Education in the Humanities Classroom: a Case Study of the Lowell School Curriculum Pilot", *Environmental Education Research*, Vol. 26, No. 4, pp. 511-531.

Sinatra, G.M., C.A. Kardash and G. Taasoobshirazi, 2011, "Understanding and Promoting Conceptual Change: A Review of Instructional Strategies and Learning Contexts", *Handbook of Research on Learning and Instruction*, Vol. 2, pp. 137-179.

Sinatra, G.M. and D. Lombardi, 2020, "Evaluating Sources of Scientific Evidence and Claims in the Post-Truth Era May Require Reappraising Plausibility Judgments", *Educational Psychologist*, Vol. 55, No. 3, pp. 120-131.

Stevenson, K.T., M.N. Peterson, H.D. Bondell, A.G. Mertig and S.E. Moore, 2017, "Environmental Literacy in Teacher Preparation: Attitudes and Outcomes in an Undergraduate Course", *Journal of Environmental Education*, Vol. 48, No. 3, pp. 170-181.

Stott, P., 2016, "How Climate Change Affects Extreme Weather Events", *Science*, Vol. 352, No. 6293, pp. 1517-1518.

Treagust, D.F. and R. Duit, 2008, "Conceptual Change: A Discussion of Theoretical, Methodological and Practical Challenges for Science Education", *Cultural Studies of Science Education*, Vol. 3, pp. 297-328.

United Nations Environment Programme (UNEP), 2017, *Towards a Pollution-Free Planet, Nairobi, Kenya Urry, J., 2015, Climate Change and Society*, Palgrave Macmillan UK, pp. 45-59.

Vosniadou S., 2008, "International Handbook of Research on Conceptual Change", *Routledge*, Vol. 259, 487-503.

Wachholz, S., N. Artz and D. Chene, 2014, "Warming to the Idea: University Students' Knowledge and Attitudes about Climate Change", *International Journal of Sustainability in Higher Education*, Vol. 15, No. 2, pp. 128-141.

Zeidler, D.L. and B.H. Nichols, 2009, "Socioscientific Issues: Theory and Practice", *Journal of Elementary Science Education*, Vol. 21, No. 2, pp. 49-58.

Zelezny, L.C., 1999, "Educational Interventions that Improve Environmental Behaviors: A Meta-Analysis", *The Journal of Environmental Education*, Vol. 31, No. 1, pp. 5-14.

Zhao, X., X. Ma, B. Chen, Y. Shang and M. Song, 2022, "Challenges Toward Carbon Neutrality in China: Strategies and Countermeasures", *Resources, Conservation and Recycling*, Vol. 176, p. 105959.

APPENDIX A: DEMOGRAPHICS

Figure A.1 shows the demographics form.

Dear Participant,

This study is carried out to investigate college students' perceptions about global climate change. If you accept to be a participant in the research, you are expected to answer a total of 15 items and take approximately 10 minutes. Your responses will be automatically saved when you complete and submit the survey. Please be sincere when completing the survey. Participation in the research is voluntary. You can review the Information and consent form below.

Thank you in advance for your participation. If you would like additional information about the study or have any questions, you can contact us.

E-mail: gayeceyhan@gmail.com / gozyazic@syr.edu

Consent: We invite you to our research on college students' perceptions of climate change. Your participation in the study is completely optional. You can opt out of participating in thestudy at any time. This research is not expected to pose any risk to you.

I agree to participate in the

study.Yes /No

1. Gender
2. Program
3. Grade Level
4. Last 4 Digits of your SU ID
5. Have you ever taken a course about climate

    change?yes

    no

    if yes, please explain

Figure A.1. Demographics.

APPENDIX B: UPDATED PLAUSIBILITY PERCEPTION MEASURE SCALE

Figure B.1 shows the updated plausibility 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.

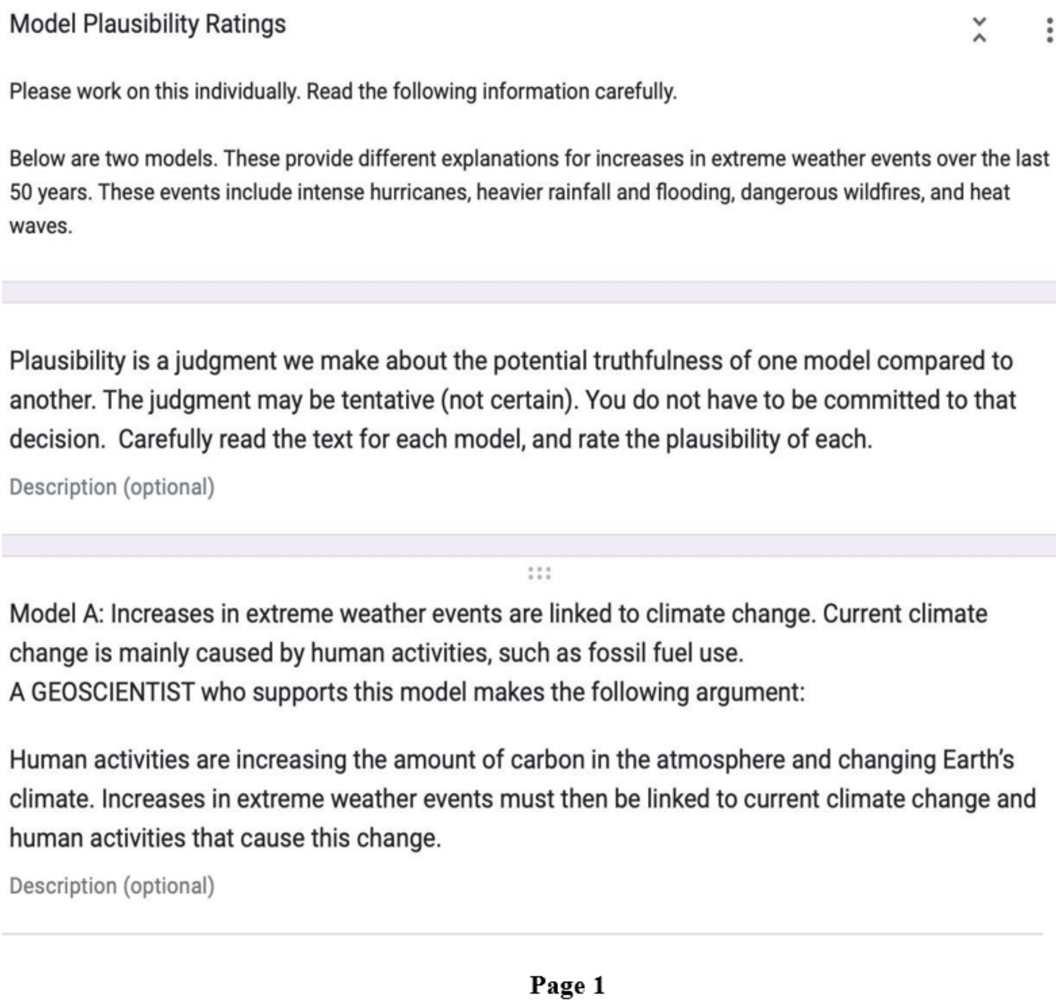
14. Climate resilient development is enabled when decision-making processes, finance, and actions are integrated across governance levels, sectors, and timeframes.

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.

Figure B.1. Updated plausibility perception measure scale.

APPENDIX C: MODEL EVIDENCE LINK (MEL) DIAGRAM

The figures below show the virtual MEL diagram pages.



Model Plausibility Ratings

Please work on this individually. Read the following information carefully.

Below are two models. These provide different explanations for increases in extreme weather events over the last 50 years. These events include intense hurricanes, heavier rainfall and flooding, dangerous wildfires, and heat waves.

Plausibility is a judgment we make about the potential truthfulness of one model compared to another. The judgment may be tentative (not certain). You do not have to be committed to that decision. Carefully read the text for each model, and rate the plausibility of each.

Description (optional)

Model A: Increases in extreme weather events are linked to climate change. Current climate change is mainly caused by human activities, such as fossil fuel use.
A GEOSCIENTIST who supports this model makes the following argument:

Human activities are increasing the amount of carbon in the atmosphere and changing Earth's climate. Increases in extreme weather events must then be linked to current climate change and human activities that cause this change.

Description (optional)

Page 1

Figure C.1. Model evidence link (MEL) diagram 1.

Rate the plausibility of Model A* *

	1	2	3	4	5	6	7	8	9	10	
Greatly Implausible (or even impossible)	○	○	○	○	○	○	○	○	○	○	Highly Plausible

Model B: Over time, increases and decreases in extreme weather events are mainly caused by changes in Earth's orbit around the Sun.
A GEOSCIENTIST who supports this model makes the following argument:

The number and strength of extreme weather events varies over time. The amount of sunlight received by Earth also varies over time. Because energy from sunlight is a major contributor to Earth's climate and weather, changes in extreme weather are a result of orbital variations.

Description (optional)

Rate the plausibility of Model B *

	1	2	3	4	5	6	7	8	9	10	
Greatly Implausible (or even impossible)	○	○	○	○	○	○	○	○	○	○	Highly Plausible

Page 2

Figure C.2. Model evidence link (MEL) diagram 2.

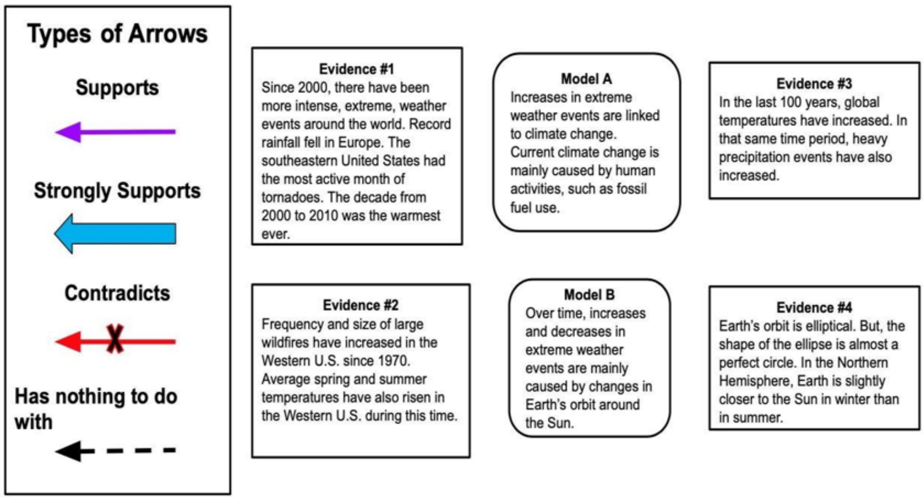
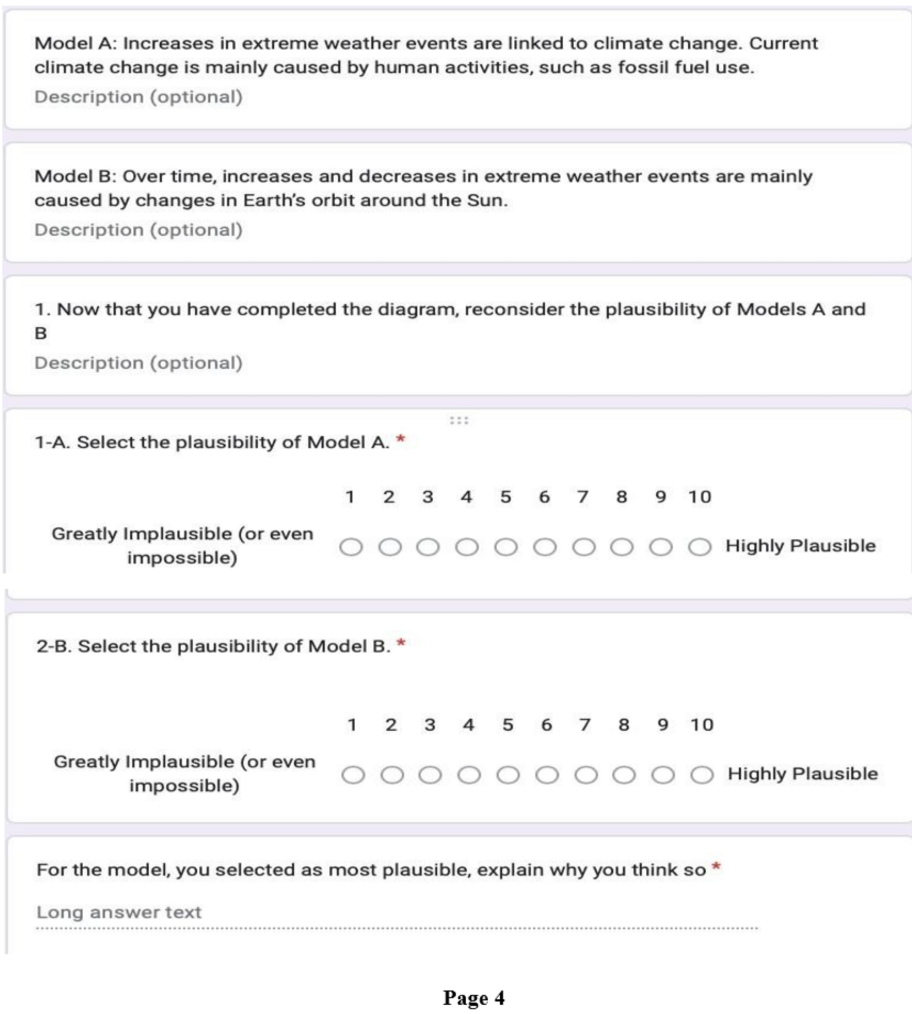


Figure C.3. Model evidence link (MEL) diagram 3.



Model A: Increases in extreme weather events are linked to climate change. Current climate change is mainly caused by human activities, such as fossil fuel use.
Description (optional)

Model B: Over time, increases and decreases in extreme weather events are mainly caused by changes in Earth's orbit around the Sun.
Description (optional)

1. Now that you have completed the diagram, reconsider the plausibility of Models A and B
Description (optional)

1-A. Select the plausibility of Model A. *

1 2 3 4 5 6 7 8 9 10

Greatly Implausible (or even impossible) ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ Highly Plausible

2-B. Select the plausibility of Model B. *

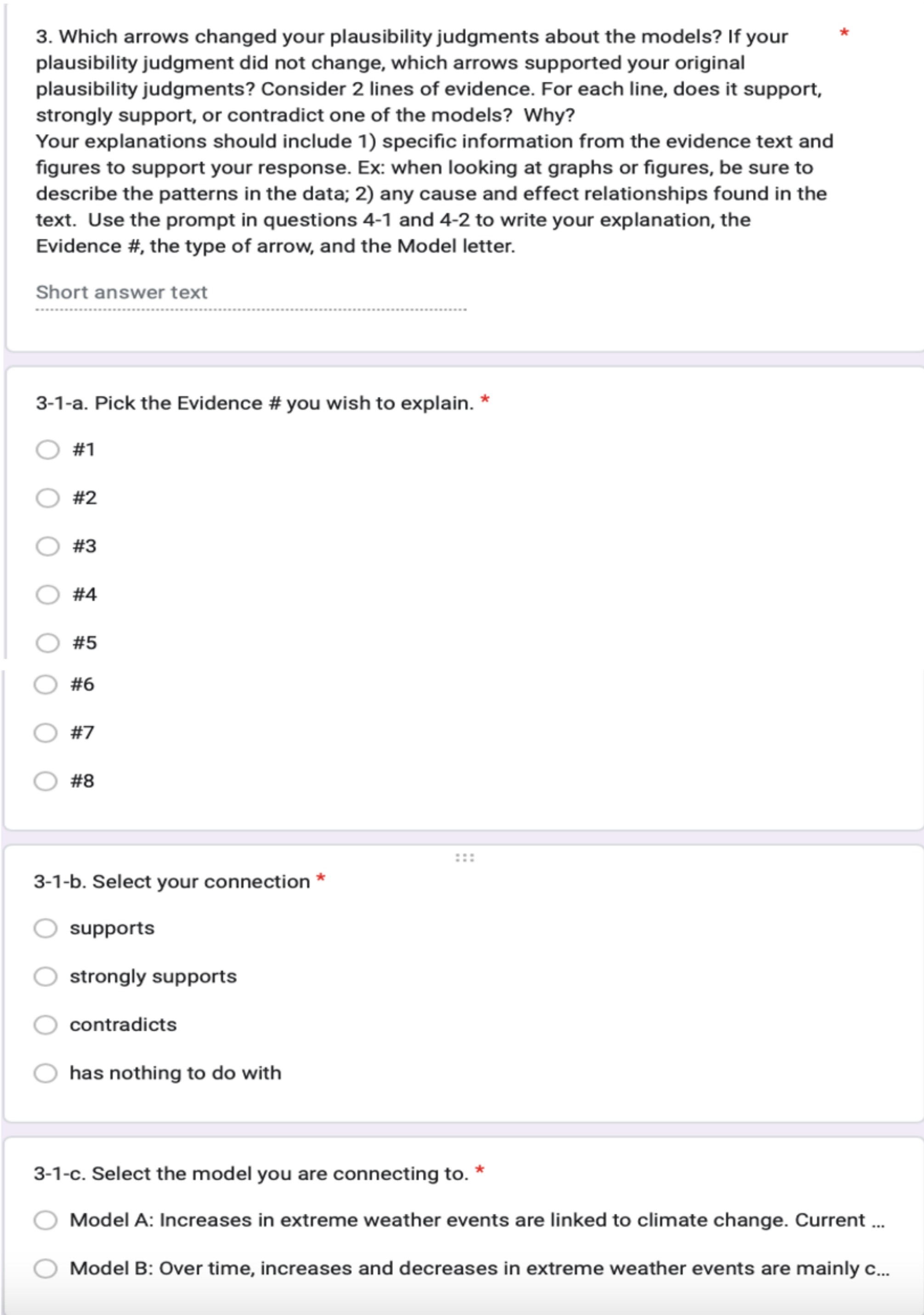
1 2 3 4 5 6 7 8 9 10

Greatly Implausible (or even impossible) ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ Highly Plausible

For the model, you selected as most plausible, explain why you think so *
Long answer text

Page 4

Figure C.4. Model evidence link (MEL) diagram 4.



3. Which arrows changed your plausibility judgments about the models? If your plausibility judgment did not change, which arrows supported your original plausibility judgments? Consider 2 lines of evidence. For each line, does it support, strongly support, or contradict one of the models? Why?
Your explanations should include 1) specific information from the evidence text and figures to support your response. Ex: when looking at graphs or figures, be sure to describe the patterns in the data; 2) any cause and effect relationships found in the text. Use the prompt in questions 4-1 and 4-2 to write your explanation, the Evidence #, the type of arrow, and the Model letter. *

Short answer text

3-1-a. Pick the Evidence # you wish to explain. *

- #1
- #2
- #3
- #4
- #5
- #6
- #7
- #8

3-1-b. Select your connection *

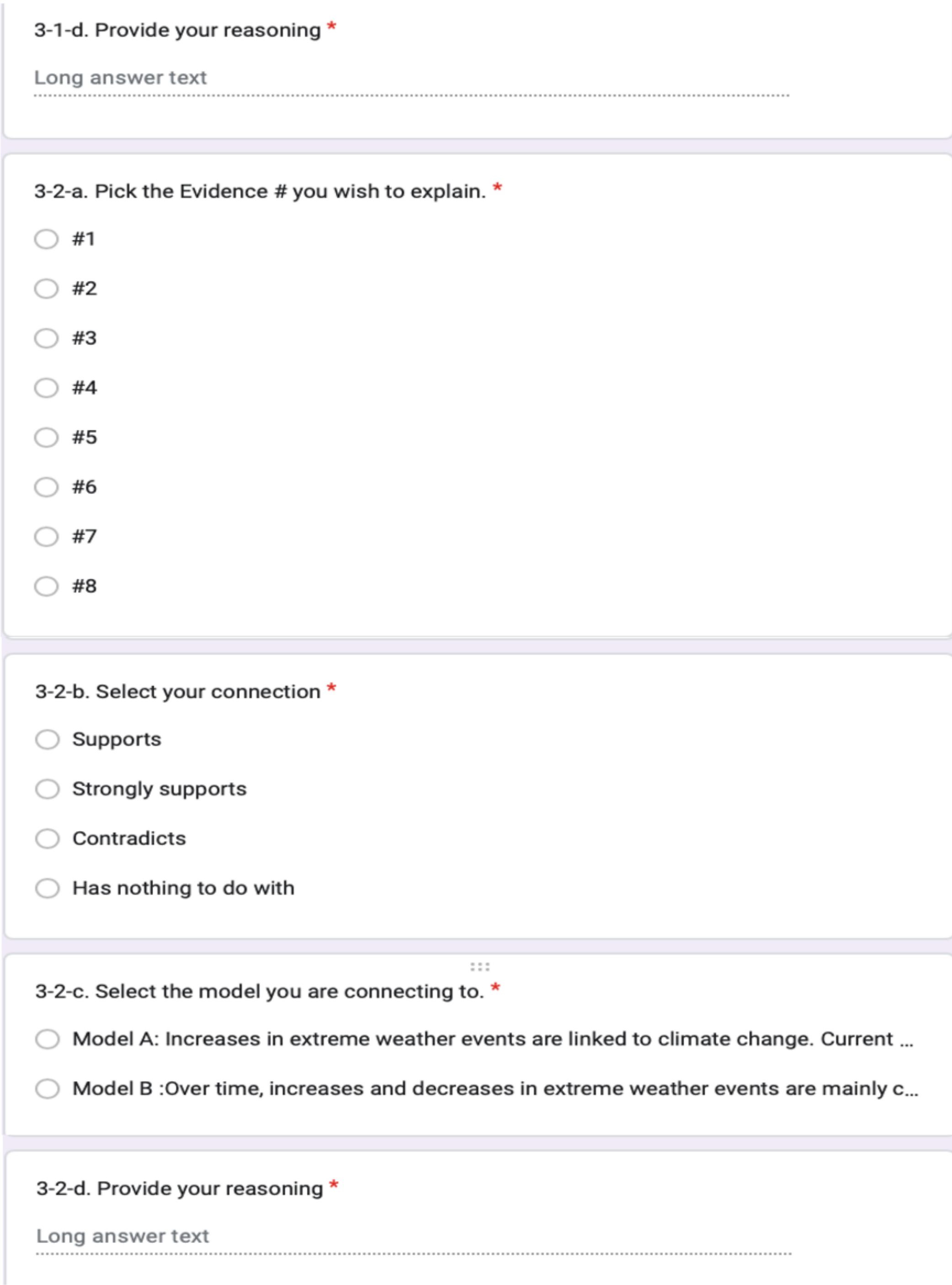
- supports
- strongly supports
- contradicts
- has nothing to do with

3-1-c. Select the model you are connecting to. *

- Model A: Increases in extreme weather events are linked to climate change. Current ...
- Model B: Over time, increases and decreases in extreme weather events are mainly c...

Page 5

Figure C.5. Model evidence link (MEL) diagram 5.



3-1-d. Provide your reasoning *

Long answer text

3-2-a. Pick the Evidence # you wish to explain. *

- #1
- #2
- #3
- #4
- #5
- #6
- #7
- #8

3-2-b. Select your connection *

- Supports
- Strongly supports
- Contradicts
- Has nothing to do with

3-2-c. Select the model you are connecting to. *

- Model A: Increases in extreme weather events are linked to climate change. Current ...
- Model B :Over time, increases and decreases in extreme weather events are mainly c...

3-2-d. Provide your reasoning *

Long answer text

Page 6

Figure C.6. Model evidence link (MEL) diagram 6.

APPENDIX D: ETHICS COMMITTEE APPROVAL

Figure D.1 shows the ethics committee approval.

Evrak Tarih ve Sayısı: 14.03.2023-117669

T.C.
BOĞAZİÇİ ÜNİVERSİTESİ REKTÖRLÜĞÜ
Fen Bilimleri ve Mühendislik Alanları İnsan Araştırmaları Etik Kurulu
(FMİNAREK)

Sayı : E-84391427-050.01.04-117669 14.03.2023
Konu : 2023/09 Kayıt no'lu başvurunuz hakkında

Sayın Dr. Öğr. Üyesi Gaye Defne CEYHAN
Matematik ve Fen Bilimleri Eğitimi Bölüm Başkanlığı - Öğretim Üyesi

"College Students' Plausibility Perceptions About Global Climate Change" başlıklı projeniz ile Boğaziçi Üniversitesi Fen Bilimleri ve Mühendislik Alanları İnsan Araştırmaları Etik Kurulu (FMİNAREK)'e yaptığınız 2023/09 kayıt numaralı başvuru 06.03.2023 tarihli ve 2023/03 No.lu kurul toplantısında incelenerek etik onay verilmesi uygun bulunmuştur.

Bu karar tüm üyelerin toplantıya on-line olarak katılımıyla ve oybirliği ile alınmıştır. Onay mektubu tüm üyeler adına Komisyon Başkanı tarafından e-imzalanmıştır.

Saygılarımızla bilginize sunarız.

Prof. Dr. Tınaz EKİM AŞICI
Başkan

Figure D.1. Ethics committee approval.