“It's happening now”: Middle school students’ thinking about climate change

J. Randy McGinnis, University of Maryland
Wayne Breslyn, University of Maryland
Emily Hestness, University of Maryland

Introduction

There is an imperative need to examine learners’ thinking regarding global climate change. Climate change is an increasingly salient topic in science education in the U.S. and worldwide. Current policy changes in U.S. science education have sought to catch up with the majority of the international science education community by including climate change as a topic that science educators will now need to consider in their practices. The 2013 release of the Next Generation Science Standards (NGSS Lead States, 2013), preceded by the 2012 Framework for K-12 Science Education (NRC, 2012), marks the first set of U.S. national science standards to explicitly address climate change. Since climate change is a potentially sensitive socioscientific issue (Feierabend & Eilks, 2010) it adds complexity to its instruction in differing sociocultural contexts.

Our rationale for our study was to contribute new knowledge of learners’ thinking about climate change that can be used to inform curriculum, instruction, and assessment in climate change education. We viewed learners’ ideas about climate change as being influenced by their disciplinary content knowledge as well as by their prior experiences across varied social and cultural contexts, both within and beyond the world of school. Because science learning transcends contexts (National Research Council, 2000) and because climate change is a topic about which learners may develop ideas both in and out of school – particularly due to its ongoing presence in the media, we believe that understanding climate change learning must take

into account how learners' social and cultural contexts may be relevant to the disciplinary content knowledge they develop related to the topic.

To investigate these issues, we used a case study methodology (Stake, 1995) to examine the following research questions:

1. What informs 6th grade students' ideas about climate change?
2. What do 6th grade students know about climate change (i.e., mechanism, role of human activity, consequences, and mitigation and adaptation strategies)?
3. How do 6th grade students understand climate change as relevant to their lives?

Literature Review

A review of the body of research on student understanding of climate change indicates that while much is known, there remains much to explore. Students may become aware of climate change as a result of its presence in diverse arenas including political discourse (Albe & Gombert, 2012; Boon, 2010), media (Boyes et al., 2008; Hansen, 2010; Svilha & Linn, 2011); school-based curriculum and instruction (Bodzin & Fu, 2014; Boon, 2010; Kılınç et al., 2008; Varma & Linn, 2012); and out-of-school learning environments (Devine-Wright et al., 2004). As a result of such diverse information sources on climate change, learners may come to the classroom with varying prior knowledge and prior mindsets (Feinstein, 2015) regarding climate change.

Researchers examining students conceptual understandings of climate change have explored how students may think about climate change mechanism, the role of human activities in enhancing the greenhouse effect, consequences of climate change, and possible mitigation and adaptation strategies. A number of researchers have explored learners' understanding of the greenhouse effect (e.g., Boyes & Stanisstreet, 1997; Rye & Rubba, 1998; Shepardson et al.,

2009) and the carbon cycle (Jakobsson et al., 2009; Jin et al., 2013; Mohan et al., 2009). This body of research has highlighted a number of concepts that may present challenges for learners, including conflation between the greenhouse effect and the ozone hole, factors that exacerbate the greenhouse effect, and the role of greenhouse gases in increasing global temperatures.

Regarding the roles of human activities in climate change, researchers (e.g., Bodzin & Fu, 2014; Boyes et al., 2008) have suggested that learners may be aware of a number of human activities that contribute to climate change, such as fossil fuel use and deforestation. However, learners may also identify irrelevant human activities as relevant to climate change (Boyes & Stanisstreet, 1993; Boyes et al., 1998). Learners may describe how reducing or stopping certain human activities could serve to mitigate climate change, but may also cite any environmentally-friendly action as helpful for mitigating climate change, without explaining the cause-effect relationship at hand. Similarly, learners may be able to appropriately identify climate change consequences such as ice melt, sea level rise, and threats to plants and animals. However, they may have difficulty explaining why these consequences may occur (Shepardson et al., 2009) and on what scale (Gowda, Fox, & Magelky, 1997).

Finally, some researchers have examined students' levels of concern about climate change. Leiserowitz et al., (2011) reported that a majority of U.S. teen participants in their survey-based study were either *not very worried* or *not at all worried* about climate change. However, studies in other international contexts have reported that adolescents and teens are generally worried about climate change (e.g., Boyes & Stanisstreet, 2001; Chhokar et al. 2011). Byrne et al. (2014) described how students tended to base their concerns, as well as their ideas about climate change mitigation strategies, on potential impacts for people's everyday lives, including their own.

Taken together, the research corpus on learners' thinking of climate change suggests there is need for further exploration of the ideas learners hold of climate change, what sources of information may be shaping these ideas, and how learners may see climate change as relevant to their lives.

Methods

Study Context

Our study took place within the context of a 6th grade science course taught at a suburban blended learning charter school in a Mid-Atlantic U.S. state. The 378 students at the school were primarily middle class, but 17% were eligible for free or reduced-price lunch. The school was highly racially and ethnically diverse. The 6th grade science curriculum, aligned with the Next Generation Science Standards, was comprised of a series of instructional units that were taught partially online. The final unit within the 6th grade science curriculum, *Weather and Climate*, included two days (75-minute sessions) on the greenhouse effect and global warming. These lessons were intended to support students in: describing greenhouse gases, explaining the effects of greenhouse gases on the environment and organisms, and explaining measures for reducing global warming.

In addition to the two blended learning class sessions, our research team co-taught two additional active learning sessions on climate change alongside the 6th grade science teacher. Learning activities were drawn primarily from the GEMS Ocean Sciences Sequence for Grades 6-8 (Lawrence Hall of Science, n.d.). Through these activities, we engaged the 6th grade students in science content related to sea level rise (e.g., ice melt, thermal expansion), climate change evidence (e.g., glacial melt, sea ice cover, sea level change), the greenhouse effect and the

function of heat-trapping gases, and climate change mitigation and adaptation strategies. These activities provided students with an additional 2.5 hours of climate change instruction.

Participants

Participants in this study were 31 6th grade students enrolled in a general science course. Participants represented five different class sections of 6th grade science, all of which covered the same course material and were taught by the same teacher. All participants completed both the pre-instruction assessment and the post-instruction assessment. A subset of participants (n=14) participated in individual content knowledge interviews, and a separate subset of participants (n=15) participated in individual sociocultural interviews (described below).

Data Collection

We collected data related to students' sources of information on climate change, their climate science content knowledge, and their understandings of the relevance of climate change for their own lives. These data were collected using three instruments: 1) a multiple-choice assessment instrument (*Climate Science Knowledge Assessment Instrument (CSKAI))* administered to all students before and after climate change-related instruction*;* 2) a content knowledge interview protocol administered to a purposefully-selected subset of students (n=14); and 3) a sociocultural interview protocol administered to a separate subset of students (n=15).

Multiple-choice *Climate Science Knowledge Assessment Instrument (CSKAI)*. We used a researcher-crafted valid and reliable instrument, piloted and validated over a two-year period prior to this study. Changes were made in an iterative manner between administrations based on student responses. The final instrument consisted of 18 multiple-choice items with distractors for each item based on alternative conceptions found in the literature and in our pilot study (Appendix A).

For multiple-choice items, students were asked to provide written responses explaining the rationale for their selection. During the pilot phase students provided written explanations for all questions. Data from student responses served to provide information on the validity of the questions and to identify necessary modifications. Due to participant fatigue, as well our confidence in the validity of the questions, in the final administration only each student provided explanations for only four questions. These learner explanations provided essential data to further confirm the validity of these items within the context of a different population of students as well as to triangulate responses with interview data.

Climate science content knowledge interviews. We used a researcher crafted interview protocol with a purposively selected subset of students who completed the CSKAI. To probe content understanding, students (n=14) were interviewed before and after instruction. These interviews sought to elicit student thinking on the four primary areas of climate change measured in the CSKAI. Interviews were approximately twenty minutes in duration and were audio recorded.

The interviews followed the sequence of constructs used in the development of the CSKAI. Interviews began with students discussing how human activity was related to climate change. After discussing the mechanism behind climate change, as well as the consequences, we ended the interview with a focus on mitigation and adaptation strategies. To elicit student ideas we asked the open-ended questions:

- Temperature data from the past 100 years show that the earth is getting warmer. How does human activity influence this warming trend, if at all?
- How does an increase in the amount of carbon dioxide (CO_2) cause the earth to become warmer?

- Present students with a drawing of the greenhouse effect without labels. Ask "Based on these drawings, why is the earth getting warmer?"
- What do you think are the effects of a warmer earth for both living and non-living things?
- What do you think can be done to slow or stop the earth from getting warmer?

Our intent was to elicit student ideas on what could be done to slow climate change or to deal with its consequences. In addition, we asked students how certain they believed scientists were about climate change as well as if they personally believed it was taking place.

Sociocultural interviews. With a separate subset of participants (n=15), we administered another researcher-crafted interview designed to provide insight into: 1) students' sources of information on climate change, and 2) students' senses of personal connection to climate change. These individual interviews were conducted prior to climate change instruction only, so that we could capture students' initial thoughts about climate change, as well as information about where they may have heard about climate change other than in school. Interviews were approximately 12-15 minutes in duration. We began by asking students:

- Have you ever heard of climate change?
    - [If yes]: What have you heard about climate change? How did you hear about climate change?
    - [If no]: Have you ever heard of global warming?

Next, we showed students a short video clip (2:47) on an iPad, which we had located on the Climate Literacy and Energy Awareness Network (CLEAN) website (www.clean.org). The video, entitled *Climate Change Basics* (https://www.youtube.com/watch?v=ScX29WBJI3w), was developed by the U.S. Environmental Protection Agency (EPA). The purpose of sharing the

video was to introduce students to (or remind them about) the issue of climate change, since the interview was being conducted prior to classroom instruction on climate change. Following the video, we asked the students:

- How do you think climate change relates to your life (if at all)? (probes: home, school, recreation)
- How do you think climate change relates to other people's lives in your community? (probes: people's jobs, people's lives at home, recreation)

Through this interview protocol, our intent was to gain insight into the sociocultural dimensions of climate change learning for these students.

Data Analysis

Analysis of multiple-choice *Climate Science Knowledge Assessment Instrument (CSKAI)* data. A paired t-test was used in order to measure change between pre and post administrations of the CSKAI. Prior to the paired t-test analysis, normality of score distributions on the pre and post-test were examined and skewness and kurtosis of both distributions were between -1 and 1. Results of Shapiro-Wilk tests were not statistically significant $p > .05$. Findings indicate that both pre-test and post-test scores are normally distributed and that t-test can be conducted in order to determine if there is statistically significant difference between these two data sets.

Analysis of climate science content knowledge interview data. Two researchers independently coded a subset of the interview transcripts to identify emerging themes. Researchers then completed several cycles of coding and came to agreement on a set of codes. A codebook was developed describing each code, including examples and clarifying statements. This iterative process led to a high degree of interrater agreement (83%).

Analysis of sociocultural interview data. We engaged in two separate rounds of structural coding (Saldana, 2012) to inductively code the 15 sociocultural interviews. Our structural coding was guided by the questions: "*What are learners' sources of information on climate change*?" and "*How do learners see climate change as relevant to their own lives and communities?"* Two raters independently coded the data using NVivo software (QSR International), discussing discrepancies in interpretations of the data until consensus was reached.

Findings

In this section, we report our findings related to: 1) learners' sources of information on climate change; 2) learners science content knowledge related to climate change, and 3) how learners made personal connections to the topic of climate change.

Learners' Sources of Information on Climate Change

Our analysis of the sociocultural interviews suggested that learners' interactions with people and artifacts in the media, in school, and - to a lesser extent - in their families appeared to be informing their ideas about climate change.

Media as a source of climate change information. The most common category, media, encompassed a variety of media sources, including the Internet, television, and print media.

Internet. Internet was the most common source of information within the media category. However, five of the 15 participants explicitly stated that they had *not* gotten information about climate change from the Internet. Learners who used the Internet as a source of information about climate change were generally cautious about the reputability of some Internet sites, suggesting that it is also important to confirm information using other sources, such as other people. Learners mentioned using Google, and other reference sites such as Wikipedia, to find

information about climate change. However, they were also aware that these sources are not always trustworthy. As one learner stated:

> I don't trust Wikipedia that much because, you know, people can go on there and edit it themselves. Sometimes if you Google things on Google, like, it'll come up in a little box above the Internet options, and then right below that you can click a website, and it'll give you information on it, where they got that from. (M99)

Such messages related to information literacy were commonly conveyed by teachers at the blended learning charter school, where students engaged in much of their learning online.

Television. Learners citing television as a source of information most commonly talked about stories they had seen on the news. Some of these included locally-relevant information about potential climate change impacts. For example, in describing a story he had heard on the local news, one learner stated:

> I heard that the gases from the factories are killing the atmosphere which is hurting the atmosphere and breaking it, which makes the sun's radiation and heat hurt... I mean melting the polar ice caps and raising the waters and oceans. So it might be dangerous for the East Coast of the United States, [and] who is around the coast.

In a few cases, learners cited TV programs other than the news as informing their thinking about climate change. One learner talked about seeing a documentary on TV, and another mentioned hearing about climate change on the *Disney Channel* show, *Jessie*. The latter case was interesting to us, as the learner described a recurring joke in the show, in which one of the characters would always blame global warming when something went wrong. As the learner described it:

> They keep saying that people blame global warming for bunches of things that, global warming is just an excuse to get out of things. Like, they break something in the balcony,

like, or outside. They blame global warming for it. They throw a shoe out the window, blame global warming. People just blame a bunch of things on global warming. (M89)

In contrast to these examples, four of the 15 learners stated that they had not heard about climate change on TV. Of the learners who had heard about climate change on TV, the few who commented on its trustworthiness all agreed that information they had heard on TV could generally be trusted. As one learner stated: “I usually trust the news and newspapers, because they have a lot of information from scientists” (M38).

Print media. The most common form of print media that learners cited was books. It appeared that these books were not included as part of the science curriculum (e.g., books they had at home, books they selected in the school library). For example, one learner stated: “[I have learned about climate change in] science books. And then when I was little we had this science pop-up book, and that was like a whole chapter about climate change and space” (M95). While learners did not generally speak about books as particularly trustworthy or not trustworthy, in one case, a learner stated that books may have inaccuracies: “And sometimes books aren't even accurate. So I think it's better to learn it verbally” (M8). Other forms of print media that learners mentioned as sources of information about climate change included newspapers and science articles in other periodicals such as *Popular Science*, *Scientific American*, and *Time for Kids*.

School as a source of climate change information. Learners cited school as a source of information on climate change nearly as often as they cited media. At school, they discussed getting information from sources such as teachers, administrators, visitors, and lessons. Most of the comments from learners were general statements like, “I learned about it in school” (M27). However, some specified specific instances of learning about climate change in both elementary and middle school. Although climate change is not included in elementary school science

standards, five of the learners mentioned learning about it in elementary school, though sometimes as a topic they came across in their own independent information-seeking, and not within a formal lesson. For example: “Yeah, once we, in the fifth grade were using computers inside the computer lab and we had to type about something that the world has. Then I just typed in ‘global warming’”(M89). In a few cases, they mentioned experiences that did appear to be part of formal instruction, such as watching videos in class that mentioned the topic.

Learners mentioned specific people at school who had given them information about climate change. Primarily, they mentioned teachers, though one learner mentioned talking with the principal, and another mentioned visitors from the University. Learners rarely mentioned talking to classmates about climate change. Finally, another potential school-based source of information on climate change that became apparent to us was the learners’ participation in the MADE CLEAR research itself. In particular, five learners talked about what they learned from the video that, we (the researchers) had shown them. When they referenced this video, we reflected that had they not been participating in the research, they would not have interacted with this information source. Therefore, we believe that their participation in the research was shaping their ideas about climate change, and also that their interaction with visual media sources communicating climate change information was particularly memorable for learners.

Learners’ Climate Science Content Knowledge

The analysis of responses to the CSKAI multiple-choice items found that there was a significant difference between pre- and post-instruction administrations. A paired t-test was used in order to measure change between pre and post administrations of the CSKAI. Results of the paired-samples t-test show that mean of CSKAI scores differs before instruction ($M = 10.39$, $SD = 3.77$) and after instruction ($M = 11.58$, $SD = 4.30$) at the .05 level of significance ($t = -2.51$, df

= 30, n = 31, p < .05, 95% CI for mean difference -2.17 to 0.-22, r = .79, effect size dz=0.45). On average students scored 1.2 points higher on post-test.

Coding and analysis of interview data also indicated that students' understanding improved after instruction. Interview data, along with students written responses to CSKAI items, provide additional data to add essential detail about student understanding of climate change. Findings are presented individually for each construct, *Human Activity*, *Mechanism*, *Consequences*, and *Mitigation and Adaptation*.

Content knowledge relevant to the *Human Activity* construct. The construct of human activity consists of how human actions contribute to climate change with a focus on a warming earth resulting from the generation of carbon dioxide (CO_2) through human use of fossil fuels. In Table 1, the percentage of students providing the correct response (pre and post instruction) is presented for CSKAI items related to human activity and climate change. The correct response is provided below each item.

Table 1.

Climate Content Knowledge Assessment Data for Human Activity

Item Number and Correct Response	% Correct Pre	% Correct Post
3: Over the past several decades, the Earth has warmed faster than any other time period. What best explains this increase? *c. Humans are generating more air pollution.*	74	81
5: There is strong evidence that there is more CO_2 (carbon dioxide) in the atmosphere now than in the past several hundred years. What is most likely cause of the current increase in carbon dioxide? *d. Humans are using more fossil fuels.*	81	84
*9. Not every action taken by humans contributes to climate change. Which of the following human activities does **NOT** contribute to climate change? *a. Greater use of chemicals that destroy the ozone layer*	10	19
10. How is carbon dioxide (CO_2) removed from the atmosphere? *a. Plants absorb carbon dioxide for food.*	45	61
12. Energy can be obtained from different sources. Which of the following forms of energy production releases the most carbon dioxide (CO_2) into the atmosphere? *c. Oil and coal*	71	74
16. How does the rate that humans produce greenhouse gases relate to how quickly they are being removed by plants? *d. Humans are producing more than can be removed by natural sinks, like vegetation and oceans.*	65	71

* Question 9 is was found to be problematic due to the inclusion of "NOT" in the question.

Prior to instruction, the majority of students held appropriate ideas about human activity and climate change and showed only slight improvement after instruction. However, distractors for several questions identified areas where students held alternative conceptions, even after instruction. These are presented for each assessment item in Table 2.

Table 2.

Climate Content Knowledge Assessment Alternative Conceptions for Human Activity

CSKAI Distractors Frequently Selected by Students	% Pre	% Post
3. *a. The sun is releasing more heat energy.*	19	19
5. *a. There's more toxic chemicals in the oceans and rivers.*	14	14
10. *c. Carbon dioxide escapes into space*	29	26
12. *a. Nuclear plants.*	10	16
16. d. *Scientists do not have enough evidence to compare the rates.*	6	13

Prior to, and after instruction, students were asked to respond to the interview prompt "*Temperature data from the past 100 years show that the earth is getting warmer. How does human activity influence this warming trend, if at all?"* An analysis of interview data produced the frequencies in Table 3. Percentages represent number of students for the code label.

Table 3.

Climate Content Knowledge Interview Themes for Human Activity

Code Label	% Pre	% Post
Human Activity Produces Gases/Pollution	64	43
Humans Create the Heat that Cause Global Warming	36	14
Human Activity Produces Carbon Dioxide (CO_2)	21	86
Fossil Fuel Sources: Coal, Oil, or Gas	21	14
Fossil Fuels Cause Climate Change	14	0
Fossil Fuels Generate CO_2	7	29
Breathing is a Significant Source CO_2	7	14
Methane Contributes to Climate Change/Global Warming	0	14

In analyzing the data relevant to the *Human Activity* construct, we noted that students were able to identify that CO_2 is generated through the use of fossil fuels (Question #5: 81% pre, 84% post) and that coal and oil are the source (Question #12: 74% pre, 81% post). However, in pre instruction interviews, many students did not use the term "CO_2" or "carbon dioxide" and spoke more generally of pollution or gases (64% pre, 43% post). After instruction, most students

(21% pre, 86% post) included carbon dioxide or CO_2 when they discussed human activity and climate change. For example, prior to instruction, one learner stated: *"Sometimes when people use cars, they permit gas and that makes the earth sometimes hotter than it usually is.* (M107-Pre). After instruction, she incorporated CO_2 (rather than gases in general) into her explanation: "*When we drive cars it permits* CO_2 *a lot, smoke and smog"* M107-Post).

We interpreted that prior to instruction, students were able to recognize carbon dioxide in a multiple choice assessment context, but it was not part of their spoken vocabulary. This changed after instruction and many replaced the more general "pollution" or "gases" with the more specific "carbon dioxide" or "CO_2" to describe climate change. Many students (Question #10: 29% pre, 26% post) believed that CO_2 is removed from the atmosphere by escaping into space. This was also found during interviews about the mechanism of climate change. Data on mechanism is presented in the next section. A number of students (Question #3: 19% pre, 19% post) believed the sun "releasing more energy" was the cause of a warming earth. This theme also emerged in pre and post interview data, for example, in responding to what communities might do to slow or stop climate change, one learner stated: *"I don't think so, because I don't think anybody can really control the sun because the sun is big and very hot"* (M26-Pre). It was not clear whether this explanation was due to the influence of a previous unit on the solar system or another source of information.

Content knowledge relevant to the *Mechanism* construct. The construct of *Mechanism* addresses the phenomenon of climate change with an emphasis on the enhanced greenhouse effect and the role of carbon dioxide. Table 4 presents student responses to CSKAI items about the mechanism of climate change.

Table 4.

Climate Content Knowledge Assessment Data for Mechanism

Item Number and Correct Response	% Correct Pre	% Correct Post
1. Which of the following would cause Earth's average global temperature to rise? *c. Changes in the amounts of gases in the atmosphere.*	39	68
8. Scientists believe that global temperatures are rising primarily because of: *b. increases in the amount of carbon dioxide (CO_2) from burning fossil fuels.*	68	84
14. What is the relationship between temperature and the Earth's atmosphere? The earth's atmosphere: *b. holds heat energy from the Sun to warm the Earth.*	77	77
17. Which of the following activities will lead to future intense storms? *a. Heat trapped by increased greenhouse gases*	39	87

Distractors for several questions relevant to the *Mechanism* construct identified areas where students held alternative conceptions, even after instruction. However, these alternative conceptions were less prevalent after instruction (see Table 5).

Table 5.

Climate Content Knowledge Assessment Alternative Conceptions for Mechanism

CSKAI Distractors Frequently Selected by Students	% Pre	% Post
1. *b. Changes in the thickness of Earth's atmosphere*	39	23
1. *d. Changes in the amount of heat from Earth's molten core*	16	6
8. *c. a hole in the ozone layer allowing heat to enter the earth's atmosphere*	19	13
17. a. *Ozone layer depletion*	42	26

Students were asked to respond to the interview prompt "*How does an increase in the amount of carbon dioxide (CO_2) cause the earth to become warmer?*" They were presented with a diagram of the greenhouse effect, without labels, and asked "*Based on these drawings, why is the earth getting warmer?*" Themes that emerged in student explanations are presented in Table 6.

Table 6.

Climate Content Knowledge Interview Themes for Mechanism

Code Label	% Pre	% Post
Greenhouse gases trap sun's energy	36	64
Greenhouse Gases Escape into Space	29	36
Role of Ozone	29	29
Pollution, CO_2 Changes the thickness of atmosphere	7	14

Of the four constructs, the fewest themes emerged in coding for *Mechanism*. *Mechanism* was also the construct where students experienced the largest gains in understanding. Students gained in several concepts central to the enhanced greenhouse effect, changes to the amount of greenhouse gases in the atmosphere (Question 1: 39% pre, 68% post), and the heat being trapped and warming the earth (Question 17: 39% pre, 87% post and Interview: 36% pre, 64% post). For example, as one student stated: "*Because when we burn fuels, it releases CO2. All the CO2 builds up in the atmosphere. The atmosphere gets thicker and it traps more heat and it gets hotter"* (M93-Post).

Although fewer students believed that ozone was a factor in climate change after instruction (Q8, Q17), several students continued to select distractors in Question 8 and 17. A consistent number of students (29% pre, 29% post) discussed a connection between ozone and climate change during interviews, for example: "*CO2 would go into the atmosphere and destroy the ozone layer"* (M44-Post). Another persistent idea was that carbon dioxide is removed from the atmosphere by escaping into space (Question #10: 29% pre, 26% post; interview data: 29% pre, 36% post). We speculate that students held this idea based on their misinterpretation of diagrams of the enhanced greenhouse effect with arrows showing heat energy returning to space. When asked what the arrows pointing away from earth represented, students often provided explanations such as: "*I know that this is the carbon dioxide leaving. And in this one, there's not*

that much carbon dioxide leaving" (M4-Post). It is not clear to us whether such responses were a result of students' interpretation of arrows in the diagram, or a belief that CO_2 was removed from the atmosphere by escaping into space.

Content knowledge relevant to the *Consequences/Effects* construct. The Consequences/Effects of climate change construct, focuses of the impact of climate change on humans, ecosystems, and the physical world (e.g., sea level rise, drought, extreme weather). Also included is scientific uncertainty in relation to climate change and the nature of future predictions. Relevant CSKAI items are listed in Table 7.

Table 7.

Climate Content Knowledge Assessment Data for Consequences/Effects of Climate Change

Item Number and Correct Response	% Correct Pre	% Correct Post
2. A warmer global climate will impact: *d. humans and Earth's ecosystems.*	77	77
6. Likely outcomes of climate change are: *c. Ocean levels will rise, impacting people who live on the coast.*	68	77
11. Where can scientists see evidence of climate change? *d. Evidence can be seen in all of these areas.*	77	77
18. Climate change projections are: *b. based on available data and may actually be lower or higher than estimated.*	35	45

Learners appeared to hold alternative conceptions related to several aspects of the Consequences/Effects of climate change construct (see Table 8), some of which persisted after instruction.

Table 8.

Climate Content Knowledge Assessment Alternative Conceptions for Consequences/Effects of Climate Change

CSKAI Distractors Frequently Selected by Students	% Pre	% Post
2. *a. the temperature at the center of the Earth.*	19	13
6. *b. The temperature will rise equally around the world.*	16	3
11. *b. Evidence can be seen only in the polar areas like Antarctica.*	13	10
18. c. *relatively uncertain because they are based on scientists' opinions, which can be wrong.*	32	32

During interviews, students were asked to describe the consequences or effects of climate change. They were asked "*What do you think are the effects of a warmer earth for both living and non-living things?*" Additional prompts asked about effects on humans and animals, ecosystems, when they thought climate change was taking place, and how certain scientists are regarding whether and when climate change will take place. Emergent themes from the interview data are listed in Table 9.

Table 9.

Climate Content Knowledge Interview Themes for Consequences/Effects of Climate Change

Code Label	% Pre	% Post
Plants and animals affected	93	86
Scientific Certainty	64	71
Extreme Effects	64	36
Sea Level Rise	43	57
Drought	36	21
Differences in Geographic Areas	36	14
Climate Change is Happening Now	29	71
Food Insecurity	29	29
Benefits of Climate Change	29	14
Oceans and Lakes will Dry Up	14	21
CO_2 is Unhealthy/Toxic	0	21

Related to the climate change Consequences/Effects construct, students understood that climate change would affect humans and ecosystems, lead to rising sea levels, and that scientists

were seeing evidence for a changing climate in multiple areas. Interview data showed that students were able to identify a variety of consequences of climate change such as extreme weather events, sea level rise, drought, and food insecurity.

There was little change in pre and post data for both the CSKAI and interviews, with a few notable exceptions. First, in response to question #18, a consistent number of students (pre: 32%, post: 32%) responded that climate change predictions are "relatively uncertain because they are based on scientists' opinions, which can be wrong." This was also seen in question #16, where students (pre: 6%, post: 13%) believed that "Scientists do not have enough evidence to compare the rates." Even though there was little change in students' ideas about scientific predictions and scientific certainty, the number of students stating that climate change is currently taking place increased considerably (Question # 18: pre: 29%, post: 71%). This suggests that students may be relating climate change to more personal experiences as opposed to scientific sources.

Not surprisingly, the number of students citing sea level rise increased in post interview data. This is likely do to the inclusion of sea level rise related activities during instruction. In addition, after instruction more students believed that CO_2 was unhealthy or toxic. Exemplar statements from students include: "*I've heard that the more carbon dioxide is in the air, probably affects more kids that have asthma. Plus, it's more dangerous"* (M10-Post) and *"That would make people not be able to breathe very well"* (M44-Post). Finally, in post-instruction interviews, fewer students cited benefits of a changing climate (29% pre, 14% post).

Content knowledge relevant to the *Mitigation/Adaptation* construct. The previous three constructs, *Human Activity, Mechanisms, and Consequences/Effects*, are necessary components for student understanding of what can be done to mitigate, or lessen the effects of

climate change, as well as strategies to adapt to a changing climate. In this sense, *Mitigation/Adaptation* can be viewed as a culminating construct. Data on student responses to CSKAI items related to the Mitigation/Adaptation construct are presented in Table 10.

Table 10.

Climate Content Knowledge Assessment Data for Mitigation/Adaptation

Item Number and Correct Response	% Correct Pre	% Correct Post
4. If humans continue to release carbon dioxide (CO_2) into the atmosphere at the current rate, ecosystems may be damaged or destroyed. Which of the following actions can reduce the amount of CO_2 released by humans? *b. Drive cars less often.*	84	84
7. Which method below do you think would be the most effective strategy to reduce future damage from climate change to coastal communities? *c. Preserve wetlands along rivers and shorelines to absorb storm surge.*	48	71
13. Data collected by scientists indicate that the average global temperature is rising and will continue to rise in the foreseeable future. What actions could people in your community take to reduce the negative impacts of climate change? *c. Plant more trees or reduce the number of trees being cut down.*	29	42
15. Human activities and technologies are being developed around the world to slow the increasing rate of global climate change. What is one direct benefit of changing human behavior and using technology to reduce the impacts of climate change worldwide? *a. Coastal areas would be less likely to flood.*	42	58

Data on students' alternative conceptions related to the Mitigation/Adaptation construct, both pre- and post-instruction, are presented in Table 11.

Table 11.

Climate Content Knowledge Assessment Alternative Conceptions for Mitigation/Adaptation

CSKAI Distractors Frequently Selected by Students	% Pre	% Post
4. *a. Produce less nuclear power*	10	10
7. *a. Insulate houses and buildings less.*	23	19
7. *d. Do nothing since no idea will work because climate change is outside of our control.*	16	3
13. *b. Prevent litter and pollution from entering rivers and oceans.*	29	23
13. *d. Banning chemicals that break down ozone in the earth's ozone layer.*	35	29
15. *b. Society will become more dependent on fossil fuels.*	19	16
15. *c. Endangered species will be better protected by laws.*	29	19

During interviews, students were asked "What do you think can be done to slow or stop the earth from getting warmer?" They were then asked to respond what they could do as an individual, what their community could do, and what actions governments could take. Responses emerging from the interview data in response to this series of questions are listed in Table 12.

Table 12.

Climate Content Knowledge Interview Themes for Mitigation/Adaptation

Code Label	% Pre	% Post
Drive Less	86	79
Government Actions	50	43
Adapt to Hot Weather	43	29
Alternative Energy	36	36
More Plants	36	36
Public Education Campaign	36	21
Factories	29	43
Use Less Fossil Fuels	29	36
Recycling	21	7
Stop Littering	12	21
Adapt to Sea Level Rise	12	0
No Action Possible	14	0
Relocation	0	21

In general, student CSKAI scores were lower for the construct of *Mitigation/Adaptation* than for the other constructs. We hypothesize that the construct builds upon the understandings

in previous constructs (Human Activity, Mechanism, Consequences/Effects) and is therefore more challenging.

Most students (Question #4: 84% pre, 84% post, Interview: 86% pre, 79% post) saw driving less as an action that would slow or stop the earth from getting warmer. Using fewer fossil fuels is also present in interview data (29% pre, 36% post), often related to the use of coal, rather than driving. Students also suggested a number of actions that governments could take, including offering financial incentives, making more regulations, or better city planning). In addition, a separate code, Public Education Campaign, was added due its frequent mention (36% pre, 21% post). For example, students made statements such as: "*The government can start putting out commercials about stopping it and actually tell the people what can happen if they don't stop"* (M66-Pre) and "*Put commercials out to stop it. People can see it on TV and then maybe persuade some people"* (M66-Post)

After instruction, fewer students believed that there was nothing that can be done to slow or stop climate change. Students selecting the distractor "Do nothing since no idea will work because climate change is outside of our control" in question seven decreased from 16% to 3%. Likewise, the number of students state that no action was possible decreased from 14% to 0%. This suggests that instruction led to students believing there are actions they or others can take to mitigate or adapt to climate change.

Learners' Personal Connections to Climate Change

In examining how learners saw climate change relevant to their lives, we organized our findings into three broad categories: 1) How learners made personal connections to climate change effects, 2) How learners made personal connections to climate change causes; and 3) How learners made personal connections to climate change mitigation and adaptation. We noted

that learners were much more likely to cite climate change effects as relevant to their lives than they were to cite climate change causes or climate change mitigation and adaptation.

Personal connections to climate change effects. When referencing effects of climate change, learners most frequently expressed a personal connection to physical and social impacts. When referencing the physical impacts of climate change, learners expressed concern over the possible results of extreme weather events, for example:

Emily: And how do you think [climate change] could affect you?

M19: It could affect me, like, because storms, and it could ruin, like, my house and other people's homes...

Emily: How do you think it might affect your life at school?

M19: Well, I might not even have a school. But the school could be damaged... and, could be flooded and… ruined.

Learners mentioned events that had impacted the community in the past, such as hurricanes and flooding events. They also referenced weather events and other physical impacts that received large amounts of media attention, such as extreme winters and wildfires.

When referencing possible social impacts of climate change, learners most commonly referenced health and safety concerns connected with food and water shortages, pollution, and safety concerns during extreme weather events. One learner explained:

M1: ...If you're going outside you might not be able to breathe as good because there's so much pollution in the air...

Randy: What would be in that pollution that would hurt you?

M1: Well it would be, like, carbon dioxide too much and then it would be,

> like, too much factories and it would be kind of hard to breathe. And then we're using a little bit too much paper, so when you cut down the trees, it, it creates oxygen for us to breathe, so when you cut down too much it might affect us and breathing, it might get hard.

Learners referenced possible impacts on outdoor recreation activities caused by weather events and seasonal shifts caused by climate change. For example, one learner stated:

> [Climate change could affect my activities like] soccer, because the fields could be flooded, um, basketball, the courts, people might not be able to go on the courts because you can't play on a flooded field or a flooded court (M19).

Finally, learners occasionally made reference to ecological, economic, and infrastructure impacts. Ecological impacts were referenced as the impacts of runoff and pollution, as well as possible future shifts in the environment that would impact the population. When speaking about economic and infrastructure impacts learners spoke about impacts on labor (financial burdens) and building damage (loss of facilities) and the resulting consequences.

Personal connections to climate change causes. When learners cited causes of climate change as relevant to their lives, they cited high energy use, burning fossil fuels, pollution in general, and driving or car use. With the theme of energy use, learners often discussed their own use, as well as their peers' and families' use, of personal electronics at home and school. When talking about their home contexts, learners cited activities like watching TV and playing video games. They saw these activities as using up energy and contributing to climate change, though they rarely discussed an explicit connection to fossil fuels for energy production. When talking about their school context - in a blended learning school - learners often mentioned their use of computers as contributing to climate change. As one learner stated: "We have to use computers

and it prepares us for college, but I don't think that we should be plugging in to charge our laptops 24/7" (M89).

Personal connections to climate change mitigation and adaptation. When learners made personal connections to steps that could be taken towards climate change mitigation and adaptation efforts, they most frequently referenced limiting energy consumption (mostly referencing electricity) and switching to renewable or alternative energy sources. When discussing the topic of limiting energy consumption, there was a consistent theme of learners referencing the acts of turning off lights and limiting use of electronic devices. An example is evident in the following interview excerpt:

> Emily: What do you think people could do [to address climate change]?
>
> M2: Turn off lights, turn off the TV... Like I learned while I was in science class, if you keep your plug, like, for your charger plugged in, it actually takes up energy. So now I know to unplug it off the wall.

When discussing possible sources of alternative energy, learners most commonly mentioned the use of solar panels. One student discussed his family's use of solar energy, stating: "My house, we're going to switch to solar because it's just, it's easy, because the sun is a renewable source which we can keep on using" (M41).

When discussing other topics related to mitigation, learners also discussed decreasing the burning of fossil fuels through changing transportation habits and decreasing waste production through recycling programs. Finally, on the few occasions where learners mentioned topics related to climate change adaptation, they referenced work with community members to increase disaster preparedness and recovery efforts related to extreme weather events.

Discussion

Our synthesis of insights regarding students' sources of information about climate change, their climate change content knowledge, and their senses of personal connection to climate change, suggests the following discussion topics: 1) the value of examining learners' climate change understanding from both a cognitive and a sociocultural perspective; 2) possible linkages between students' in-school and out-of-school climate change learning experiences; and 3) possible linkages between students' climate change content knowledge and their ideas about the relevance of climate change to their own lives.

Multiple perspectives on climate change understanding. First, we noted that examining learners' climate change ideas from cognitive (i.e., conceptual understanding) and sociocultural perspective provided us with a more holistic understanding of learners' climate change ideas than either perspective could have provided in isolation. Our bi-dimensional theoretical approach helped us to position climate change as an issue in science education that is simultaneously scientific - in that it entails understanding a complex system of science processes - as well as social - in that it may be exacerbated and mitigated through human actions and in that it has consequences for human society. Further, the climate change messages communicated about within students' social worlds, both in and out-of-school, appeared to have bearing on students ideas about the science behind climate change and its relevance to society, including for their own lives.

In attending to both in-school and out-of-school learning, we were able to draw on our research team's varied expertise in the realms of formal and informal science education, and we were careful to acknowledge that climate change is a topic that learners are likely to encounter across learning settings. We found that prior to instruction, these learners cited the media -

especially Internet and television - as key sources of their prior learning about climate change, but that school was cited nearly as often. Learners' interaction with climate change ideas across settings may become increasingly the norm as schools begin to incorporate climate change into their curricula in response to the Next Generation Science Standards, and as climate change will likely continue to be a topic that learners encounter in the media.

Linkages between in-school and out-of-school learning. In reviewing information from the sociocultural interviews (administered prior to instruction) and the pre-instruction administration of the CSKAI and content interview, we were able to gain insight into the kinds of climate change ideas students were bringing to the classroom from prior learning experiences. We noted that learners came to the classroom with greater apparent background knowledge for the constructs of climate change consequences and the roles of human activity in climate change. For example, participants were already aware that human use of fossil fuels was contributing to climate change, and that climate change would have impacts for ecosystems and human communities. We interpret learners' pre-instruction understandings of such ideas as possibly attributable, in part, to information they have encountered in the media - such as images of air pollution from factories or cars, and images of ecosystems threatened by climate change (e.g., polar areas, coastal areas).

Learners came to the classroom with somewhat more limited understandings of climate change science content related to the constructs of climate change mechanism and climate change mitigation and adaptation. We suggest learners may be less likely to have encountered detailed information about the mechanism of climate change - including the invisible interactions between infrared radiation and greenhouse gases - through their out-of-school learning experiences, such as in watching climate change news coverage on television. Learners' pre-

instruction understandings of climate change mitigation and adaptation were even more limited. We suggest that mitigation and adaptation might be considered a capstone construct for climate change understanding, in that understanding how to stop or slow climate change requires a foundational understanding of climate change mechanism (i.e., the functioning of the greenhouse effect) and the role of human activities in enhancing the greenhouse effect. Although students came to the classroom with more understanding of some constructs than others, we noted that students were generally able to make gains in their understandings of all of the constructs after school-based instruction.

Linkages between knowledge and personal relevance. Learners connected climate change to their own lives particularly in terms of the climate change consequences they believed were affecting them now, or had the potential to affect them in the future, as well as in terms of the activities in which they were engaged (e.g., use of fossil fuel-based energy) that were exacerbating climate change. We noted that these dimensions of climate change, which learners saw as most relevant to their lives, were aligned with the climate change constructs about which learners came to the classroom with the greatest knowledge (i.e., consequences, human activities). Because we conducted the sociocultural interviews prior to instruction, we did not capture changes in how learners saw climate change as relevant to their own lives after instruction. It would be of particular interest to learn whether participants, after instruction, came to see climate change mitigation and adaptation as relevant to their own lives, or whether they came to see a broader array of actions (i.e., beyond limiting personal daily energy consumption) as possible actions with which they could be involved. If so, it may be the case that increased content knowledge could have a potential relationship with feelings of empowerment. We suggest that such a relationship would be worthy of examination in future research.

Conclusions

Examining 6th grade learners' sources of information on climate change, climate change content knowledge, and senses of climate change as relevant to their lives sheds light on the conceptual and sociocultural complexities that science educators may face in their climate change education efforts. We found that these learners came to the classroom with some scientifically-supported and scientifically-unsupported ideas about climate change, particularly related to its consequences and the role of human activities. They showed gains after engaging in a carefully planned and implemented instructional intervention related to these constructs, as well as less familiar constructs such as the greenhouse effect mechanism, which provided students with essential insight on how and why climate change is occurring. By first developing deeper understandings of these dimensions of climate change, we believe students will subsequently be better prepared to engage with ideas around climate change mitigation and adaptation, including providing cause-effect explanations of why certain practices could help slow climate change or lessen its impacts.

The instructional intervention described here on climate change was relatively minimal (four 75-minute class sessions), though twice in length to typical instruction on the topic over the academic year in US science classrooms (Plutzer et al. 2016). However, we conclude that even short-term engagement with climate change can produce gains in student understanding. However, we would also advocate greater inclusion of climate change throughout and beyond the science curriculum, since there are limits to the gains that might be made through only short-term engagement. In doing so, science educators and their colleagues in other disciplines might find broader opportunities to connect climate change to issues that are relevant to students' lives,

including climate change impacts pertinent to the local environment (or other localities of interest to students) and how students might engage in locally-based activities to help promote climate change mitigation and resilience.

Limitations and Directions for Future Research

We acknowledge several possible limitations to our study. First, we acknowledge the potential impact of assuming participant-observer roles as researchers while engaged in this study. Because we were involved in an instructional capacity alongside the classroom teacher, we note that we developed a different kind of rapport with the participants than we might have in a purely observational role. While this may have increased participants' comfort in participating in interviews with us, it may also have led them to a greater tendency to respond to our questions in ways they believed we desired. Second, we examined one type of instructional intervention - the two blended-learning class sessions that were standard in the curriculum, plus the additional active learning experiences we co-facilitated with the teacher. Future research should examine student engagement with other kinds of instructional interventions around climate change. Of particular interest might be instructional interventions that connect to the climate change ideas or concerns that students bring to the classroom. Finally, we note that we examined the thinking of a limited number of students in one context. Future research should examine the ideas that learners in other kinds of contexts bring to the classroom, and how they see climate change as relevant to their lives. In concert with research on the effectiveness of instructional interventions for producing gains in content knowledge, we suggest that research further examining the potentially contextualized nature of climate change learning would be of value.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. 1043262. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

The authors would like to acknowledge the learners' sixth grade classroom teacher and her school administration for agreeing to serve as a field-based site for our research study. We also would like to acknowledge Sheila Hadley and Emily Freeland for their assistance with the data analyses of the conceptual and sociocultural data, respectively.

References

Albe, V., & Gombert, M. J. (2012). Students' communication, argumentation and knowledge in a citizens' conference on global warming. *Cultural Studies of Science Education*, *7*(3), 659-681.

Bodzin, A. M., & Fu, Q. (2014). The effectiveness of the geospatial curriculum approach on urban middle-level students' climate change understandings. *Journal of Science Education and Technology*, *23*(4), 575-590.

Boon, H. J. (2010). Climate change? Who knows? A comparison of secondary students and pre-service teachers. *Australian Journal of Teacher Education*, *35*, 104-120.

Boyes, E., & Stanisstreet, M. (1997). Children's models of understanding of two major global environmental issues (ozone layer and greenhouse effect).*Research in Science &*

Technological Education, 15(1), 19-28.

Boyes, E., & Stanisstreet, M. (2001). Plus ca change, plus c'est la meme chose? School students' ideas about the "greenhouse effect" a decade on. *Canadian Journal of Environmental Education, 6*(1), 77-101.

Boyes, E., Stanisstreet, M., & Yongling, Z. (2008). Combating global warming: the ideas of high school students in the growing economy of South East China. *International Journal of Environmental Studies, 65*(2), 233-245.

Chhokar, K., Dua, S., Taylor, N., Boyes, E., & Stanisstreet, M. (2011). Indian secondary students' views about global warming: Beliefs about the usefulness of actions and willingness to act. *International Journal of Science and Mathematics Education, 9*(5), 1167-1188.

Devine -Wright, P., Devine children's beliefs about global warming and energy. *Environmental Education Research, 10*(4), 493-506.

Feierabend, T., & Eilks, I. (2010). Raising students' perception of the relevance of science teaching and promoting communication and evaluation capabilities using authentic and controversial socio-scientific issues in the framework of climate change. *Science Education International, 21*(3), 176-196.

Feinstein, N. W. (2015). Education, communication, and science in the public sphere. *Journal of Research in Science Teaching, 52*(2), 145-163.

Gowda, M. R., Fox, J. C., & Magelky, R. D. (1997). Students' understanding of climate change: Insights for scientists and educators. *Bulletin of the American Meteorological Society, 78*(10), 2232-2240.

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

Jakobsson, A., Mäkitalo, Å., & Säljö, R. (2009). Conceptions of knowledge in research on students' understanding of the greenhouse effect: Methodological positions and their consequences for representations of knowing. *Science Education*, *93*(6), 978-995.

Jin, H., Zhan, L., & Anderson, C. W. (2013). Developing a fine-grained learning progression framework for carbon-transforming processes. *International Journal of Science Education*, *35*(10), 1663-1697.

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

Leiserowitz, A., Smith, N., & Marlon, J.R. (2011). *American teens' knowledge of climate change*. Yale University. New Haven, CT: Yale Project on Climate Change Communication. Retrieve from: http://environment.yale.edu/uploads/american-teens-knowledge-of-climate-change.pdf

Mohan, L., Chen, J., & Anderson, C. W. (2009). Developing a multi -year learning p for carbon cycling in socio teens ogical sys *Journal of Research in Science Teaching*, *46*(6), 675-698.

NGSS Lead States. (2013). *Next Generation Science Standards: For states, by state*s. Washington, DC: The National Academies Press.

National Research Council (2000). *How people learn: Brain, mind, experience, and school*. Committee on Developments in the Science of Learning and Committee on Learning Research and Educational Practice. Bransford, J. D., Brown, A. L., & Cocking, R. R.

(Eds.). Commission on Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

National Research Council (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, D.C.: The National Academies Press.

Plutzer, E., McCaffrey, M., Hannah, A. L., Rosenau, J., Berbeco, M., & Reid, A. H. (2016). Climate confusion among U.S. teachers. *Science*, *351*(6274), 664-665.

Rye, J. A., & Rubba, P. A. (1998). An exploration of the concept map as an interview tool to facilitate the externalization of students' understandings about global atmospheric change. *Journal of Research in Science Teaching*,*35*(5), 521-546.

Shepardson, D. P., Niyogi, D., Choi, S., & Charusombat, U. (2009). Seventh grade students' conceptions of global warming and climate change. *Environmental Education Research*, *15*(5), 549–570.

Varma, K., & Linn, M. C. (2012). Using interactive technology to support students' understanding of the greenhouse effect and global warming. *Journal of Science Education and Technology*, *21*(4), 453-464.

Appendix A: Climate Science Knowledge Assessment Instrument (CSKAI)

Name:_____ Date:_____

1. Which of the following would cause Earth's average global temperature to rise?

a. Changes in the length of seasons
b. Changes in the thickness of Earth's atmosphere
c. Changes in the amounts of gases in the atmosphere
d. Changes in the amount of heat from Earth's molten core

Why is your choice the best answer?

2. A warmer global climate will impact:

a. the temperature at the center of the Earth.
b. the shape of Earth's orbit around the Sun.
c. the amount of fossil fuels available.
d. humans and Earth's ecosystems.

Why is your choice the best answer?

3. Over the past several decades, the Earth has warmed faster than any other time period. What best explains this increase?

a. The sun is releasing more heat energy.
b. There's an increase in volcanic activity.
c. Humans are generating more air pollution.
d. The Earth's orbit around the Sun is changing.

Why is your choice the best answer?

4. If humans continue to release carbon dioxide (CO_2) into the atmosphere at the current rate, ecosystems may be damaged or destroyed. Which of the following actions can reduce the amount of CO_2 released by humans?

a. Produce less nuclear power
b. Drive cars less often
c. Use fossil fuel more
d. Decrease littering

Why is your choice the best answer?

5. There is strong evidence that there is more carbon dioxide (CO_2) in the atmosphere now than in the past several hundred years. What is most likely cause of the current increase in carbon dioxide?

a. There's more toxic chemicals in the oceans and rivers.
b. Plants are releasing more CO2 (carbon dioxide).
c. Volcanoes are producing more ash and gases.
d. Humans are using more fossil fuels

Why is your choice the best answer?

6. Likely outcomes of climate change are:

a. Ice sheets will grow larger in the Arctic areas.
b. The temperature will rise equally around the world.
c. Ocean levels will rise, impacting people who live on the coast.
d. Earth's atmosphere will thin, especially in the Southern Hemisphere.

Why is your choice the best answer?

7. Which method below do you think would be the <u>most</u> effective strategy to reduce future damage from climate change to coastal communities?

a. Insulate houses and buildings less.
b. Switch from nuclear power to fossil fuels.
c. Preserve wetlands along rivers and shorelines to absorb storm surge.
d. Do nothing since no idea will work because climate change is outside of our control.

Why is your choice the best answer?

8. Scientists believe that global temperatures are rising primarily because of:

a. an increase in the use of toxic chemicals such as pesticides and aerosols sprays.
b. increases in the amount of carbon dioxide (CO2) from burning fossil fuels.
c. a hole in the ozone layer allowing heat to enter the earth's atmosphere.
d. excess heat given off from energy generation in nuclear power plants.

Why is your choice the best answer?

9. Not every action taken by humans contributes to climate change. Which of the following human activities does <u>NOT</u> contribute to climate change?

a. Greater use of chemicals that destroy the ozone layer
b. Rises in the number of people driving cars
c. Greater rates of deforestation
d. Larger demand for electricity

Why is your choice the best answer?

10. How is CO_2 (carbon dioxide) removed from the atmosphere?

a. Factories need carbon dioxide to run.
b. Carbon dioxide breaks down naturally.
c. Carbon dioxide escapes into space.
d. Plants absorb carbon dioxide for food.

Why is your choice the best answer?

11. Where can scientists see evidence of climate change?

a. Evidence can be seen only in areas that experience droughts.
b. Evidence can be seen only in the polar areas like Antarctica.
c. Evidence can be seen only in coastal areas by the beach.
d. Evidence can be seen in all of these areas.

Why is your choice the best answer?

12. Energy can be obtained from different sources. Which of the following forms of energy production releases the most carbon dioxide (CO_2) into the atmosphere?

a. Nuclear plants
b. Windmills
c. Oil and coal
d. Solar power

Why is your choice the best answer?

13. Data collected by scientists indicate that the average global temperature is rising and will continue to rise in the foreseeable future. What actions could people in your community take to reduce the negative impacts of climate change?

a. Buy organic produce like fruits and vegetables.
b. Prevent litter and pollution from entering rivers and oceans.
c. Plant more trees or reduce the number of trees being cut down.
d. Banning chemicals that break down ozone in the earth's ozone layer.

Why is your choice the best answer?

14. What is the relationship between temperature and the Earth's atmosphere? The earth's atmosphere:

a. blocks light from the Sun make the Earth cooler.
b. holds heat energy from the Sun to warm the Earth.
c. has no influence so Earth's temperature doesn't change.
d. strengthens heat energy to increase Earth's temperature.

Why is your choice the best answer?

15. Human activities and technologies are being developed around the world to slow the increasing rate of global climate change. What is one direct benefit of changing human behavior and using technology to reduce the impacts of climate change worldwide?

a. Coastal areas would be less likely to flood.
b. Society will become more dependent on fossil fuels.
c. Endangered species will be better protected by laws.
d. There would be less cases of skin cancer in humans.

Why is your choice the best answer?

16. How does the rate that humans produce greenhouse gases relate to how quickly they are being removed by plants?

a. Humans are producing an equal amount to what is being removed by natural sinks, like vegetation and oceans.
b. Humans are producing more than can be removed by natural sinks, like vegetation and oceans.
c. Humans are producing less than is being removed by natural sinks, like vegetation and oceans.
d. Scientists do not have enough evidence to compare the rates.

Why is your choice the best answer?

17. Which of the following activities will lead to future intense storms?

a. Ozone layer depletion
b. Changes in the tilt of Earth's axis
c. Variations in the energy put out by the Sun
d. Heat trapped by increased greenhouse gases

Why is your choice the best answer?

18. Climate change projections for the future are:

a. based on available data and predict future temperature with complete accuracy.
b. based on available data and may actually be lower or higher than estimated.
c. relatively uncertain because they are based on scientists' opinions, which can be wrong.
d. not useful because it is impossible to predict what will happen in the future.

Why is your choice the best answer?