Perception and application of climate science by distinct audiences: Impacts of measurement, attention, and credibility

by

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Abstract

Climate change is among the greatest threats to human lives and livelihoods and any efforts to reduce harm by mitigating climate change or adapting to changes will require mass participation. However, the knowledge and perceptions of the public, including policy- and decision-makers, are often not aligned with the knowledge produced by climate scientists. Climate communication is needed to reduce that gap, improving climate literacy across the globe, to allow individuals to make informed choices in their lives and careers. Past research has shown that tailoring climate communication tools and strategies to specific purposes and audiences make communication efforts more effective. In these studies, we advance that research by improving the measurement of use of climate science by decisionmakers, exploring museum visitors' interaction and intake of climate change information, and modeling the relationships between undergraduate students' perceptions of climate change and climate scientists.

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List of Abbreviations

AOI	Area of Interest
CASC	Climate Adaptation Science Center
CFA	Confirmatory Factor Analysis
CFI	Confirmatory Fit Index (usually Bentler's)
EFA	Exploratory Factor Analysis
NMNH	National Museum of Natural History
PETM	Paleocene-Eocene Thermal Maximum
RMSEA	Root Mean Square Error of Approximation
SEM	Structural Equation Model(ing)
SRMR	Standardized Root Mean Residual
STEM	Science, Technology, Engineering, and Mathematics

Chapter 1: Introduction

Global warming, and the associated impacts of climate change, will present increasing risks to human lives and systems of society, infrastructure, agriculture, and many others. Mitigation to reduce global warming and adaptation to reduce harm from it are both critical components to reducing those risks and both require the communication and application of climate science (IPCC, 2018). Social science methods and insights can be used to improve the climate science communication resulting in more effective mitigation and adaptation, especially when climate change information is tailored to the audience and purpose at hand (Bostrom et al., 2013; Harold et al., 2016; IPCC, 2018).

Evidence-based climate communication is critical in efforts to reduce the gap between established scientific knowledge and the knowledge held by non-scientists, especially those who may need to apply that knowledge in their lives or careers. For example, the science of anthropogenic global warming via greenhouse gases has been "certain" since at least 1990 (p. 52, IPCC, 1992) but as of September 2021, 60% of American adults understand global warming is mostly human-caused and only 24% understand that over 90% of scientists agree that human-caused global warming is happening (Leiserowitz et al., 2021). Climate change communication efforts are important to reducing this gap, and are widely implemented in schools (Lawson et al., 2019; Stevenson et al., 2014), higher education (Aksit et al., 2017), on the internet (Goldberg et al., 2021; Ranney & Clark, 2016) and in museums (Hamilton & Ronning, 2020; McGhie et al., 2020), the last of which is explored in greater depth in Chapter 3.

However, we know that the way we perceive, understand, and learn from climate science is impacted by many factors. For example, the same climate change messaging may have different impacts between individuals if they hold different political or cultural affiliations, worldviews, age, or education (Bayes et al., 2020; Hornsey et al., 2016; van der Linden, 2015). Because of that, climate change communication efforts tend to be more effective if they are designed or tailored for a specific audience and context (Bostrom et al., 2013; Goldberg et al., 2021).

The translation of science to action presents challenges beyond the general public and broad policy support. There are many more specific arenas of climate science that require improved communication, such as climate adaptation and conservation science. Broad-scale climate science predictions can be very difficult to apply to the real challenges that decision- and policymakers face due to a variety of factors including mismatches between spatial and temporal scales (Beier et al., 2017). A major contributor to these difficulties is the way in which the science is often produced, that is, without any input from the end-user, in a model often called the loading-dock approach (Cash et al., 2006). Instead, over the last several decades, studies have shown that science produced in collaboration with its end-users is more useful and used to make decisions, likely resulting in more effective climate change adaptation (Cooke et al., 2020; Dilling & Lemos, 2011; Meadow et al., 2015; Wall et al., 2017). There are many models to describe the process and benefits of collaboration between science producers and science users, the most common of which are co-production, user-inspired research, and transdisciplinary science (Evely et al., 2010; Meadow et al., 2015). Science producers include any individuals conducting research, often in federal agencies or at universities, and users include any individuals who need to apply science to decision-making. Authors have also described various types of engagement with information users that vary in activities, level of contact, and likely outcomes. Some examples include contractual, consultative, collaborative, and collegial modes of engagement (Meadow et al., 2015) and inform, consult, participate, and empower engagement approaches (Bamzai-Dodson et al., 2021). Critically, efforts to describe and evaluate collaborative science and measure the impacts of different scientific approaches are still developing and Chapter 2 presents a contribution to this field.

Additionally, there may be benefits of co-developing science communication tools or graphics with their intended audience, even if that audience was not included in the initial research (Bostrom et al., 2013; Courtney & McNeal, in revision; Harold et al., 2016; Morelli et al., 2021). Beyond the benefits of making information more relevant to a specific decision or use, research shows that trust may also play a significant role in the acceptance of new climate science (Dilling & Lemos, 2011; Howe et al., 2019; Kahan et al., 2011) and that trust can be built through collaboration (Cooke et al., 2020; Norström et al., 2020). For example, Americans of varying political affiliations have very different opinions about trustworthy sources of climate change information, such that conservative republicans tend to trust fossil fuel companies more than the Environmental Protection Agency for such information (Leiserowitz et al., 2022). Perceptions of source credibility are important to uptake of scientific information by the public (Cologna & Siegrist, 2020; Druckman & McGrath, 2019; Kahan et al., 2011) and application of climate science by professionals (Bellamy et al., 2021; Cvitanovic et al., 2018). The connections between important drivers of climate change perceptions, including source credibility, are investigated in Chapter 4.

Improving climate literacy is important because reducing harm from climate change, especially while maintaining and improving quality of life around the globe, will require shifts in nearly every aspect of society and thus participation from the public (IPCC, 2018). Specifically, increased awareness of climate science and the consensus among climate scientists increases personal mitigation activities and policy support, likely mediated by climate change risk perception (Dong et al., 2018; Goldberg et al., 2020; McCright et al., 2013; van der Linden et al., 2015). Efforts to reduce harm from climate change will require a variety of communication strategies tailored to various needs and audiences. Further research exploring the possibilities and efficacy of those strategies, such as the studies presented here, is critical to mitigating and adapting to climate change.

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Chapter 2: Development of a survey instrument to assess individual and organizational use of climate adaptation science

Introduction

Reducing harm from climate change will require varied and transformational adaptation responses, and such responses require knowledge and action across social and ecological systems (Fedele et al., 2019; Owen, 2020). In the last few decades, the fields of applied environmental science, especially climate adaptation science, have attempted to meet those needs by producing science that is more useful for decision-making and policy. However, making science more useful and evaluating whether those efforts have been successful are difficult and "messy" tasks (Arnott & Lemos 2021; Nutley et al., 2007). This has inspired active research in both evaluation and improvement of climate adaptation science (Fazey et al., 2014; Louder et al., 2021). Many evaluation efforts have revealed that collaborative research practices, including but not limited to co-production and transdisciplinary science (Evely et al., 2010; Walter et al., 2007), often result in improved outcomes of climate adaptation science (Dilling & Lemos, 2010; Edwards & Meagher, 2020; Meadow et al., 2015; Owen, 2020).

Collaborative research practices contrast dramatically with the traditional method of knowledge exchange in academia, popularly called the loading dock approach (Cash et al., 2006). In the loading dock approach, scientists complete their research in isolation from the end-user and, when they are finished, deliver publications, websites, or (at best) decision-making tools to stakeholders. In this model, researchers seek to inform their stakeholders, however the created knowledge is less often used because it may not be at the spatial or temporal scale the manager needs, may not concern a priority topic, or may not be in a useful format or product, etc. (Bamzai-Dodson et al., 2021; Beier et al., 2017). Instead, co-production is one of many models that facilitates and encourages knowledge exchange, where "both researchers and stakeholders are now seen to have knowledge that is shared…" (pg. 2, Edwards & Meagher, 2020). However, different models and degrees of stakeholder involvement may be appropriate for different research efforts depending on the goals and constraints involved, especially since such involvement may require significantly more time, effort, and resources (Bamzai-Dodson et al., 2021; Meadow et al., 2015).

Understanding how research practices may lead to favorable results requires reliable methods for evaluating and measuring those results. There are a variety of outputs, outcomes, and impacts of climate adaptation science that can be measured, with some authors describing up to 16 types of outcomes and impacts (Wall et al., 2017). Usage of each term varies widely in the literature (Louder et al., 2021), but as commonly used in program evaluation, outputs include direct products delivered by the program; outcomes are changes in individuals' knowledge, skills, and behaviors; and impacts are larger changes in systems (W.K Kellogg Foundation, 2004). Previous efforts to evaluate climate science projects have employed qualitative coding structures (Edwards & Meagher, 2020; Koontz et al., 2020), surveys (Walter et al., 2007), and citation metrics (Evely et al., 2010). Others have used literature reviews and interviews to build frameworks for measuring the use of collaborative climate science by resource managers and stakeholders (Edwards & Meagher, 2020; VanderMolen et al., 2020; Wall et al., 2017). In just the last few years, multiple authors have even meta-analyzed climate science evaluation literature to learn about research characteristics most often studied (Karcher et al., 2021; Koontz et al., 2020) and the evaluation frameworks applied (Louder et al., 2021; Reed et al., 2021).

One finding of those studies is that the usability of research may be the most frequent goal and evaluation metric used in climate adaptation science (Karcher et al., 2021). A common definition for usable science is that of Cash et al. (2003), wherein research that is credible, legitimate, and salient is more usable. However, Karcher et al. (2021) found that actual use of the science, rather than the theoretical usability of it, is less often mentioned as an explicit goal, claimed outcome, or topic of evaluation. This could be because the construct of use of science can be notoriously difficult to measure in any field, including climate adaptation science (Arnott & Lemos, 2021; Dilling & Lemos, 2011; Schwandt, 2015). In this study, we add to the literature by developing and testing a new tool for measuring the use of climate adaptation science.

Context and Objectives

Many of the evaluation approaches mentioned above use qualitative methods which are useful for understanding research projects in depth. However, in some cases, it may be of interest for funders, policymakers, or organizations to compare many projects in less detail, for which there are few methods available in the literature. To address that absence, Hyman et al. (2022) conducted a study to develop a quantitative summative evaluation strategy for climate adaptation science projects and examine the relationships between project inputs, processes, and outcomes of 28 projects funded by the Southeast Climate Adaptation Science Center (SECASC). In that study, the authors sought to compare project characteristics that influenced two outcomes, scientific impact and use by partners. Scientific impact was measured via scientometrics including number of publications and citations. However, there was not a quantitative instrument available to measure stakeholder use of climate adaptation science. Thus, the present study was initiated to develop a survey to quantify use of climate adaptation science across many projects which was subsequently applied by Hyman et al. (2022) to understand the characteristics of climate adaptation science projects that may lead to greater use. We included use of any result or product of the project including publications, web tools, capacities built from engagement with the research process, workshops, etc.

The objectives of the current study were first, to develop a valid and reliable survey instrument to measure use of climate adaptation science, and second, to explore and examine any internal structure or sub-types of use that the instrument may reveal. We addressed these objectives by conducting a thorough and iterative survey development process, distributing the survey to a deliberate sample of partners, and analyzing the results of the survey.

This survey was not developed to measure any absolute degree of use of the projects. Instead, we sought to develop an instrument that could detect variation in use of research outcomes or products relative to other projects. In the future, the survey could be modified or used as-is for other research evaluation efforts, particularly by funding agencies that want to understand differences between large portfolios of projects using fewer institutional resources than qualitative methods would require (Bisbal, 2019). Better understanding of varying impacts of completed projects can then inform future requests for proposals, funding decisions, and facilitation practices. Future applications of the survey could also be followed or accompanied by qualitative methods that would provide better understandings of why and how a project was used.

Methods

Survey Development

To address our first objective, we designed the survey following the systematic, seven-step process outlined by Artino et al. (2014), which includes several iterations of construct- and item-defining informed by literature review and interviews with the intended audience. Following an intentional process such as this one, which includes considerations from multiple perspectives and information sources, can provide greater evidence for the validity of a survey instrument (Artino et al., 2014; Libarkin et al., 2018). Throughout this process, the research team met monthly to discuss the developments and challenges at each step, and a smaller team met weekly for several months. Below, we summarize the seven steps of survey development and how we approached them (Table 1).

Table 2.1

Survey development summary, adapted from Table 1 in Artino et al. (2014).

Survey design step	Summary of process and findings in this study
1. Conduct a literature review	Literature showed that no comprehensive quantitative instrument existed currently and that a new quantitative instrument was needed
2. Conduct group and individual interviews	Conducted interviews both at a scientific meeting and online via videocall afterwards, qualitative analysis and research group discussion were used to process and contextualize findings
3. Synthesize the literature review and interviews	Findings of step 2 roughly paralleled those of VanderMolen et al. (2020) so both were used to define indicators
4. Develop items	5-level Likert-style questions and examples were developed with input from the research team, data, and previous literature
5. Conduct expert validation	Items were reviewed, discussed, and refined by the research team and stakeholder advisory group
6. Conduct cognitive interviews	Respondents were interviewed while taking the survey to inform language and ordering adjustments
7. Conduct pilot testing	The 22-item survey was distributed to identified partners resulting in 81 complete responses
Additional follow-up interviews (not in Artino et al., 2014)	Interviews with survey respondents provided further insights into participant response interpretations, processes, and decisions; some results presented below

The first step of the process is to conduct a literature review, both to inform the survey development and to ensure there are not existing instruments that could be tested or adapted instead of creating a new instrument. Towards this end, we read relevant literature and compiled a list of items previously used in similar science evaluation efforts (Appendix 2.1). Of the items that were explicitly provided in the literature, many addressed other constructs such as broad benefits, satisfaction, and partnerships. Of those that addressed use, usefulness, and effectiveness, the items were often open-ended or addressed the usability of one specific product. Thus, we decided there was a need for a new instrument to quantitatively measure the use of climate adaptation science projects, though the survey could likely be applied to or modified for other natural science uses.

The second step is to conduct interviews and/or focus groups to compare how the construct of interest is described and conceptualized by the potential survey respondents to how it is described in the scientific literature. To gather data for this step, we conducted group and individual interviews throughout a climate adaptation-focused scientific meeting. The interviews were separated by individuals' roles as either a science user, mostly including cultural and resource managers, or a science creator, including government and university researchers. For those who work in both capacities, we invited them to participate in multiple group interviews sharing from one perspective at a time. Because we were recruiting participants between and during meeting events, the interviews varied in length (from 10-40 minutes) and size (from two to six participants), with most group interviews lasting about 20 minutes with two to four participants. In total, we conducted eight group and two individual interviews with science producers and seven group and one individual interview with science users. Moving forward, we will use the term "partners" to describe the science user audience, acknowledging that individuals who use climate adaptation science hold a variety of professional and volunteer positions. At this stage, we asked participants how they have used climate adaptation science to reach their professional goals, what characteristics made the projects useful, and how their involvement and/or deliverables of the projects impacted their use (Courtney et al., in preparation). The recordings of the interviews and notes taken by the research team were transcribed and uploaded into qualitative analysis software (Dedoose). These data were inductively analyzed, primarily using content analysis, to identify major themes and concepts mentioned by participants and to examine the prevalence and connections between those themes (Krippendoff, 1989).

Given results in the first two steps, we chose to build upon the sub-constructs presented by Vandermolen et al. (2020) as a framework for our measurement of use. Specifically, those authors adapt the three most commonly described types of use (conceptual, instrumental, and justification) to stakeholder use of climate information. The coding criteria that Vandermolen et al. (2020) used to distinguish between types of use are: “information was reported to enhance knowledge base or to inform process or planning” (conceptual), “information was reported to influence decision-making directly with respect to action, process, or plan…” (instrumental), and “information was reported to justify an action, process, or plan…” (justification; p. 182, 2020), with examples corresponding to each. We developed operational definitions of each sub-construct which describe how the construct might be measured and are used to develop indicators for each construct, or a measurable occurrence that would indicate the presence or absence of the construct (Cox, 1996).

At this time, we conducted six more virtual individual interviews with natural and cultural resource managers involved with the SECASC to ensure our construct definitions were still compatible with our audience of interest. In this and following couple of stages, we did not intentionally include individuals in our final survey sample pool to avoid fatiguing those individuals. These interviews ranged from 20 to 40 minutes, and the questions focused on how climate science is used in participants' jobs, including questions centered on each of the three sub-constructs adapted from Vandermolen et al. (2020). These interviews were recorded, transcribed, and analyzed in the Dedoose software. The results of this stage were synthesized with previous literature review to develop indicators of each type of use, representing step three of the process. The indicators derived from our analysis paralleled the findings of Vandermolen et al. (2020).

For step four, the indicators were used to develop survey items (questions) to measure participants' degree of each use. Following the guidance of Artino et al. (2014) and previous survey experience, we chose to use quantity-based response options and varying operative verbs (e.g., influence, impact, been used to). For example, the item response options for questions about the project's influence on a particular decision were: 1. No influence, 2. Little influence, 3. Some influence, 4. Quite a bit of influence, and 5. A great deal of influence. For each question, we also compiled a short list of examples, which were presented with the questions, drawn from our own experiences and previous interviews (Table B.1).

The fifth step of survey development is to subject the preliminary questions to expert review. Toward this end, the questions were shared with our wider research team and stakeholder advisory group, whose members are experts in climate adaptation science, natural resource management, and climate science evaluation. After these changes were implemented, the survey was uploaded to the platform Qualtrics to confirm the visual design and for final review by the broader research team (Figure B.1).

Going forward, the survey items will be referenced by codes that begin with a letter where the letter refers to the theoretical construct the item was intended to represent. Thus, items that begin with a *C* were intended to represent conceptual use, *I* for instrumental use, *J* for justification use, and a number referring to their sequential ordering in the block. As the items were discussed in-depth by the research team, some that we initially assigned only to the conceptual use sub-construct became boundary items (i.e., we were no longer confident which sub-construct they would match best). Those items included one concerning monitoring efforts and two concerning education efforts, because each involves acting (instrumental) to gather or spread information (conceptual). Thus, we decided they were relevant to both conceptual and instrumental uses and created the *CI* combined sub-construct. Additionally, after the expert review stage, we added another response option to all but the first four items (C1-C4) that read *not applicable – my organization doesn't do this or I don't know*. Future users of this survey may want to change this language or separate the causes for selecting this response to receive more helpful information for their context.

Next, we recruited three individuals to interview while they took the survey for the sixth step. The goal of this step is to examine how the respondents "interpret the survey items and if their interpretation matches what the survey designer has in mind" (p. 470) to check for evidence of response process validity (Artino et al., 2014). We changed some of the question language and formatting of the items based on participant responses during this stage. The participants also noted that some questions were difficult to understand, specifically item J1 ("affirmed what you already know about environmental change and your job"). However, we retained the question because it is best survey practice to include imperfect items while testing a survey to gather more evidence for the deletion or inclusion of each.

Survey Distribution

We then distributed the survey to possible users of one or more of the 28 research projects of interest, fulfilling the seventh step of the survey design process (pilot distribution).

The research projects examined were all funded beginning in the fiscal years from 2011 to 2016 with project durations ranging from one to five years. Each project was funded by the SECASC based on proposals from the research teams, who consisted primarily of university and federal scientists. We identified possible users of these research projects through project reports, publications, workshop attendance records, SECASC staff, the principal investigators of each project, and individuals named by other survey participants (snowball sampling). In the survey of principal investigators, we asked for the contact information of partners who would be able to comment on the use or usefulness of the research project and for the products, terms, or descriptors that partners would most likely associate with the project. Because we wanted to understand use of the projects relevant to decision-making, we excluded named partners who held research positions at universities. These partners held a variety of positions in settings including universities, non-governmental organizations, local, state, and tribal governments, and federal agencies such as the U.S. Fish and Wildlife Service. Some of the projects of interest involved stakeholders during research process (i.e., collaborative practices) and some did not; similarly, some of the stakeholder respondents were involved during the projects and many were not. This was a source of variation that was included in Hyman et al.'s analysis (2022).

In total, we identified 234 possible respondents and invited them to take the survey via email. In the survey invitation emails, we included a reference to the project which we believed them to be familiar with along with a webpage with the details of each project in case they were unaware of the formal titles or principal investigators associated with any project information they had used. The first page of the survey then prompted participants to select the project they were answering about, and on each page of the survey, instructions were included that read, "Please answer each question about the research project you selected and how you or the organization/agency you work for may have used information from it" (see Appendix 2.3 for survey visual design and complete instructions).

We sent two brief follow-up messages, spaced 1-2 weeks apart, to individuals who had not yet begun the survey by using the personalized link option. We received 81 complete responses (35%) which were used for the analyses described below.

We also invited participants to provide their contact information at the end of the survey for follow-up interviews to further understand and improve the instrument. In total, six participants provided their emails and were contacted following the survey completion. Only three participants responded to our follow up request and were interviewed to discuss their response process and understanding of the questions.

Analysis

Though *not applicable* responses will be meaningful and useful to future applications of the survey, they are not compatible with factor analyses. Thus, the *not applicable* responses in these data were deleted, treated as missing values, and imputed. The data were treated as ordinal for all analyses and imputed in MPlus software with the default settings for ordinal items (multiple imputation, polychoric correlations, and robust weighted least squares estimation; Asparouhov & Muthén, 2010; Jia & Wu, 2019; Muthén & Muthén, 2017). The use of polychoric correlations can reduce the chances of over-dimensionalizing ordinal survey data in factor analysis (van der Eijk & Rose, 2015). This was important because the survey is meant to measure one overarching construct (use) with possible sub-constructs.

The survey was designed with a theoretical underlying structure in mind (conceptual, instrumental, and justification uses, as described above), meaning confirmatory factor analysis could have been used to test the fit of that structure. However, because this survey is one of the first attempts to quantify this structure, we instead decided to use exploratory factor analysis to address our second objective. Toward that end, we used parallel analysis with polychoric correlations (*random.polychor.pa* package in *R*; Presaghi & Desimoni, 2020) to determine the appropriate number of factors.

Exploratory factor analysis was conducted using the *psych* package in *R* version 4.1.1 (R Core Team, 2021; Revelle, 2021; RStudio Team, 2021). Once the appropriate number of factors was determined, we used oblimin rotation (a type of oblique rotation) to conduct the factor analysis. Because the survey was meant to uncover relationships within the overarching construct of use, any existing sub-factors should be correlated, making factor analysis and oblique rotation most appropriate (as opposed to principal components methods or orthogonal rotation). The factor analysis process was conducted iteratively, removing one item at a time, to simplify the structure (Watson, 2017). Specifically, items retained had one pattern coefficient (loading) at or above 0.60 and all others below 0.30 (the 0.6/0.3 rule; Matsunaga, 2010). Thus, retained items had strong loadings on only one factor and could be assigned to that factor with confidence. Although many authors use 0.40 as a minimum threshold for item retention, we decided it was appropriate to use stricter cut-offs because of our small sample size (Fabrigar & Wegener, 2012; Knetka et al., 2019; Watson, 2017). Once the final factor model was found, the *R* packages *lavaan* and *semTools* were used to calculate multiple measures of reliability for each scale (Jorgensen et al., 2021; Rosseel, 2012).

Though most of the qualitative data were used to generate and refine survey items and examples, some excerpts and results will be presented to contextualize our quantitative results. Additionally, the qualitative data were critical to improving the content validity and response process validity of the instrument while the quantitative analyses provide evidence of reliability (Artino et al., 2014; Libarkin et al., 2018).

Results

Survey Results and Factor Analysis

The survey item median responses ranged from 1 to 4 (*little use* to *quite a bit of use*). Specifically, twelve items had a median of 3, six items with a median of 2, three items with a median of 1, and one item with a median of 4, each spread across constructs. All of the items were positively correlated with every other item, something to be expected given that we opted not to use any reverse response options, following recommended survey design practice (Artino et al., 2014). The polychoric (comparable to Pearson) correlation values ranged from 0.304 to 0.875 in the raw data and from 0.224 to 0.852 in the imputed data. The Kaiser-Meyer-Olkin factoring adequacy (KMO test) values ranged from 0.81 to 0.91 for each item with an overall value of 0.87, and Bartlett's test of sphericity was significant, which all indicate that the data were suitable for factor analysis (Watson, 2017).

In preliminary analyses, the parallel analysis showed that three factors best explained the variance in the dataset. However, the third factor was driven solely by J5 (support from lawmakers), the item with the second highest *not applicable* responses (30%). Thus, after more data exploration showing the influence of the imputed data, those items with >25% imputed data (*not applicable* responses) were removed from the dataset, which included items I6, J5, and I2 (Table 2). After these items were removed, the parallel analysis showed that only two factors were needed to explain the variance of the survey responses (initial model in Table 2). Exploratory factor analysis was run repeatedly in *R* using the .6/.3 rule, as described above, removing one item at a time. Once the items retained all satisfied the .6/.3 rule, analyses revealed that the data were still suitable for factor analysis and that two factors best explained the variance, so this model was retained as the final model (Table 3). The factors were named (individual and organizational use) based on the items that loaded onto them and findings from the qualitative data, discussed below.

Table 2.2

Survey items by factor (retained items) or reason for removal

	Item	Item text: To what degree has this project…
Factor 1 Individual Use	C1	…impacted any of your professional skills?
	C2	…impacted your knowledge relevant to your job?
	C3	…influenced your professional network?
	C4	…changed your awareness of informational resources?
	C5	…influenced long-term planning documents?
	J2	…been used to encourage support from or collaboration with peers and/or partner organizations?
Factor 2 Organizational Use	C6	…influenced organizational/departmental objectives or priorities?
	C7	…influenced broad-scale or general policy?
	I3	…influenced decisions to change how time or labor are spent in your organization/agency?
	I4	…influenced decisions to change how money is allocated in your organization/agency?
	I5	…influenced decisions to change internal/organizational policies or procedures?
Removed: No loadings larger than or equal to 0.60	I1	…influenced decisions to change any habitat or species management practices?
	J4	…been used to encourage support from your supervisors?
	J1	…affirmed what you already know about environmental change and your job?
	J6	…been used to support a funding request?

Removed: Both loadings between 0.30 and 0.60	CI3	…influenced monitoring or research efforts in your organization or department?
	CI2	…impacted education efforts focused on resource managers or local landholders?
	CI1	…impacted public education efforts in your organization?
	J3	…been used to encourage support or cooperation from the public or local landholders?
Removed: over 25% *not applicable* responses	J5	…been used to encourage support from lawmakers?
	I6	…influenced decisions to change external policies, regulations, or enforcement?
	I2	…influenced decisions to change how infrastructure is managed?

Table 2.3

Exploratory factor analysis results for initial and final (retained) models.

Item (topic)	Initial Model Factor Loadings			Final Model Factor Loadings		
	Factor 1	Factor 2	h^2	Factor 1	Factor 2	h^2
C1 (skills)	**0.78**	-0.1	0.52	**0.74**	-0.02	0.53
C2 (knowledge)	**0.76**	-0.02	0.55	**0.76**	0.04	0.61
C3 (network)	**0.91**	-0.18	0.66	**0.85**	-0.09	0.64
C4 (information)	**0.82**	-0.16	0.54	**0.8**	-0.08	0.58
C5 (planning)	**0.68**	0.09	0.55	**0.74**	0.12	0.65
C6 (objectives)	0.24	**0.61**	0.61	0.25	**0.63**	0.63
C7 (policy)	0.18	**0.68**	0.64	0.16	**0.69**	0.62
CI1 (public ed.)	0.57	0.29	0.62			
CI2 (peer ed.)	0.56	0.34	0.66			
CI3 (monitoring)	0.36	0.48	0.58			
I1 (management)	0.48	0.19	0.38			
I3 (labor)	-0.04	**0.88**	0.73	-0.04	**0.86**	0.71
I4 (money)	0.05	**0.79**	0.67	0.04	**0.81**	0.69
I5 (procedure)	-0.08	**0.88**	0.7	-0.09	**0.88**	0.69

J1 (affirmation)	0.56	0.02	0.32			
J2 (partners)	**0.85**	-0.02	0.70	**0.62**	0.11	0.42
J3 (public)	0.59	0.32	0.67			
J4 (supervisor)	0.49	0.22	0.41			
J6 (funding)	0.53	0.19	0.45			
Note: Both models exclude items with >25% not applicable responses. Bold denotes pattern coefficients >0.60, h^2 is the communality of each item, and the empty boxes correspond to those items removed from the model.						

Factor 1 (individual use) explained 33% of the data variance, and factor 2 (organizational use) explained 30%, resulting in a total R^2 of 0.63. The correlation between factors was 0.53. The Tucker-Lewis index of factoring reliability was 0.874; the model $\chi^2 = 75.7$ with $p < 0.001$; and the root mean square error of approximation was 0.122 (95% CI: 0.078 to 0.168). These values all fall outside of often-used thresholds for acceptable fit, which is a limitation of the model; however, improving global fit is not the goal of exploratory factor analysis, and the use of strict fit cut-offs has been criticized in recent years (Fabrigar & Wegener, 2012; Kline, 2016). Reliability analyses revealed that Cronbach's α was 0.90 for both factors and McDonald's ω was 0.92 for factor 1 and 0.93 for factor 2 (Hayes & Coutts, 2020; Kline, 2016).

Context from Qualitative Data

Each round of interviews we conducted had distinct prompts, purposes, and referenced different versions of the survey. Thus, while earlier rounds of interview were used to develop these survey questions, here we present context and quotes only from the last round of interviews, which referenced the survey in the form it was distributed, providing clarity in interpretation. While there were only three participants for this stage of interviews, the conversations with each ranged from 40-60 minutes, resulting in helpful information about participants' interpretations of and experiences with the survey.

One of the primary goals of the last round of interviews was to identify any difficulties participants had in answering the questions. The difficulties most often identified by the participants concerned language used in the questions. These language difficulties most often arose from mismatches between the questions and the reality of individuals' positions and uses of climate science. For example, one individual held a full-time volunteer position, so any mention of their job, professional skills, etc. did not technically fit their position. The same participant also found the question concerning infrastructure, which was ultimately removed due to high rates of *not applicable* responses, too vague ("You know, are we talking about physical infrastructure, but you could think maybe financial infrastructure or organizational infrastructure."). In actuality, we intended to measure impacts in any of these categories, so several questions were intentionally broad. Language disconnects like these demonstrate the challenges of developing a survey that is understandable to respondents in a wide range of positions, contexts, and backgrounds, which was also recognized by the same participant ("I don't really think you can get too much more specific just because of the really wide-spread audience that you're going to be applying the survey to. This comes along with a lot of gray area"). Only one participant highlighted a question where the question language did not align with their duties, which they described by sharing: "It was interesting, 'been used to encourage support or collaboration', I think I did struggle with the way that was worded a little bit. Because I didn't have to use anything to encourage support or collaboration, it's a constant thing to be involved with these groups."

Last, the project that one participant was responding about was completed less than a year before they took this survey, which influenced their response context. For some questions this made responding more difficult for them ("I'm pretty confident that within my [unit] it will influence some allocations, so I would've been torn at guessing at some impact versus I don't know, because it didn't actually happen yet. So it was a recurring problem through all the questions"). Notably, though, other questions with different operative words (though all in the past tense) were easier for this participant:

> "…they were all easy to answer because of the stage of the project and the verb tense. If not for the verb tense issue it would've been difficult to answer the last two because of the limited sphere that I can see. I don't know if it has been used for J5, or there might be an org using it for J6 that I don't know about. The way I answered them all was no impact because of the timing of the project."

Though unclear because only one participant mentioned it, differences in verbs between blocks could reduce the validity of the instrument which would present a limitation. However, this participant only drew a contrast between the use of "been used to" in the justification questions and all other verbs, which isn't a major concern for the final instrument, because only one justification item (J2) was retained. Of the items retained in the final instrument, there are commonalities in the terms used by assigned factor, but the commonalities are not so uniform as to imply they are the reason for the factor loadings.

In contrast, other difficulties associated with question language may indicate complications that are inherent to measuring use of climate adaptation science. For example, all three participants described difficulties in deciding how to consider use at various scales and hierarchies of their organizations and in the context of their own positions, described by two of them in the quotes below (note: parenthetical text within excerpts represents interviewer speech and bracketed text represents edits made to maintain participant anonymity):

> "I struggled with the term organization. That's probably a bigger struggle for me than most people in my agency. My paycheck comes from one place where my job is to coordinate a

> multi-organization partnership, federal and state and private. I answer to the [partnership] more than the agency that pays me. I'd like to say I answered consistently but I can't promise I did. I tried to answer from the [partnership] perspective because that's how I was related to this project."

> "It's interesting, any federal agency is a juggernaut. To change course or even influence internal policies or organizational policies takes a thermonuclear weapon sometimes. Climate change is impacting the [agency] and we're seeing those changes happening slowly. So it kind of depends on what we're talking about. Did this particular project affect any changes to the internal policies or internal organization of the agency, nah, probably not. But it's one of many that are contributing to change, recognition, and options, what we need out here."

To some degree, these quotes describe dynamics common to large organizations, i.e., operations at multiple scales where information needs and applications vary. Additional quotes from participants seemed to show that there were two primary factors making it difficult for them to answer the questions about each of these scales. The first was, understandably, a single individual not knowing what information is useful or used at other locations or hierarchical levels of their organization, as described by the participants below:

> "There are some of these things that you don't know for sure, we've talked and hit upon this, the influence decisions in a larger perspective kind of questions – you can guess at it, maybe you know if you're involved with some of the larger groups in climate change or you get a call from the director in D.C. so you have an idea then, but otherwise you just don't have the foundation to answer about the larger organization."

> "This would be true of any of those projects on the list, there are influences we can identify and influences that we don't know about. I have a sphere that I can see and can answer about, but there are lots of influences outside that sphere, so that makes it hard to answer these."

> "I don't know how anyone could answer those last two besides I don't know, because anyone could do those and you wouldn't necessarily be aware. You could add 'funding request by my department' or 'that I know of'."

In designing the survey, of course we only expected participants to answer from their knowledge and perspective and would not expect them to know how information is used across the entirety of large organizations or federal agencies. These quotes illustrate that our expectation that participants respond from their perspective may be clearer, as the last quote suggests, by explicitly asking about use "that they know of."

In addition to not having full awareness of how information is used at different scales of an organization, participants also described variation in the importance of one piece of information across scales. This variation complicated the response process for at least one of the participants, largely because the survey asked participants to try to quantify use via the Likert-style response options, as described below:

> "If I had to re-answer now, I'd say the study in itself probably did not have a tremendous impact, probably would've said little or some. Here at the [site], lots. So when it's broad like that it's harder to answer… I would say, if this had said "locally," at the [site] level, I would've without fail said that there was a great deal of impact… I think it's important to look at where the impacts occurred, especially if you're looking at how the study impacted the broader spectrum of things, or any study – for local managers and people with local

> knowledge, something like this can be huge. On a Washington-level scale, this is just one piece of many studies and many pieces of work that have gone into painting the whole climate change picture."

Participant responses also seem to indicate meaningful differences in how climate science is used across organizational scales, beyond the differences in awareness and importance described above. Two of the participants explicitly described this contrast by both separating use by an individual and organization and by comparing the conceptual items that were eventually assigned to the first factor (C1-C5) versus the second factor (C6-C7):

> "So when I answered J1, I would've been thinking about the whole process and not just outcomes. (Why J1?) Similar to the first three or four questions, how they impacted me, J1 is also a very personal questions, about me and my job. So that's why I thought about how the project impacted me, which was throughout the course of the whole project. It didn't impact my organization throughout the whole project except through me and my skillsets."

> "…like C5 – when it's completed I know it absolutely will influence those documents. I don't need it to be finished to know how influential it will be in our planning documents. It's harder to say how it will play out for C6. (Why?) Because I get to decide what goes in planning documents and a whole bunch of other people get to decide what impact they have. (So is it about your position?) Yes. And that's even more true with C7 – policy for my organization is set at a very high level and not by me or my boss."

> "C's seem more personal now that I compare them, where the second chunk are more similar to the last few questions of the previous chunk. The early C's are personal, then moved to organizational influence, and these all seem like organizational influence questions."

Participants also mentioned possible explanations of such differences across levels of an organization such as differences in funding structures and the breadth of factors under consideration ("I don't know that there's any level above that that people are thinking about climate change… So that's probably the broadest that we're going to get"). When asked if the survey left out any ways that they use climate science, only one respondent had an answer which was use for media relations including applications to broadcast, print, and social media, a topic that could be added to the survey in the future.

Discussion

Evidence of instrument validity and reliability

We followed a systematic development process to ensure we had multiple opportunities to examine and improve the validity and reliability of the survey instrument. There are multiple definitions and types of validity described in the literature, but here we are using the definition provided by the *Standards for Educational and Psychological Testing*: "Validity refers to the degree of which evidence and theory support the interpretations of the test score for the proposed use" (AERA, APA, and NCME, 2014, p.11). The content validity was bolstered by the use of multiple rounds of interviews with the intended audience and including input from previous literature and content experts (Knekta et al., 2019; Libarkin et al., 2018). Because instrument validity is also reliant on the audience and context of use, repeatedly checking in with our intended users, natural and cultural resource managers engaged with the Southeast Climate Adaptation Science Center, was also important.

The last two sets of interviews which used preliminary and final versions of the survey questions provided evidence of response process validity by assessing how respondents interpreted and answered the questions (Artino et al., 2018). Exploratory factor analysis was conducted to evaluate construct dimensionality and validity based on internal structure, though the factor structure did not represent the initially intended sub-types of use. However, multiple participants in two of the last three rounds of interviews, where we were asking about ways that they use climate adaptation science, described differences in use that were very compatible with our factor structure. We used conservative factor analysis methods (e.g., >0.6 factor loadings) to ensure that there was solid evidence for the survey structure despite our middling sample size, and the resulting factors had high reliability coefficients.

Additionally, the results of Hyman et al. (2022) provide evidence of the validity of the survey via relationships to other variables. Those authors found significant causal relationships showing that the frequency of meetings between researchers and users significantly predicted one sub-type of use which then predicted the other type of use. Their analysis also found important relationships between other project characteristics (e.g., project budget and duration) and research publications. These findings, specifically the relationship between team meetings and use, align with previous research demonstrating the crucial role of consistent stakeholder engagement in collaborative science approaches for increasing use (Djentonin and Meadow, 2018).

Survey structure and implications

We developed the survey based on three sub-types of use (conceptual, instrumental, and justification; CIJ) which have been applied throughout previous literature in evaluation and often applied in climate adaptation science evaluation (e.g., Arnott & Lemos, 2021; Louder et al., 2021; Reed et al., 2014; in combination with other sub-constructs, also Edwards & Meagher, 2020). These authors all found additional evidence of the applicability of the CIJ sub-constructs, unlike the present study; however, we note that each of these examples have relied on qualitative analyses.

It is therefore possible that organizing structures of use (i.e., CIJ versus individual and organizational) are related to the methods of investigation and evaluation. That said, these findings are not the first, qualitative or quantitative, to reveal differences in use of climate science based on institutional level or position of use. Cvitanovic et al. (2018) conducted a case study evaluation of an applied environmental science program and found distinctions between impacts on individuals, the host university, and policy and decision-making. Notably, some quotes the authors provide describing types of individual impacts (learning opportunities, expansion of social networks) and university/organizational impacts (relevance of research to policy) parallel those described by participants in this study.

There are likely important connections between the CIJ and individual-organizational (IO) structures. For example, VanderMolen et al. (2020) posit that their findings may be a result of organizational cultural factors, specifically that conceptual use of information may predominate in government agencies. In the present study, we found that the survey items we intended to represent conceptual use largely loaded together, except for the last two items which some participants said represented different uses (less "personal"). Additionally, the participant descriptions of individual and organizational use, or use higher up the chain of command, highlighted some differences congruent with the CIJ structure. For example, because instrumental use involves changes in practices, institutional positionality would be very relevant to any individuals' capacity to change practices based on new research. In this study, participants noted that they considered setting priorities and policies (C6 and C7) to be broader tasks only carried out "at a very high level." Finally, the items that we placed in the boundary category, CI, had three of the five smallest differences between loadings on the two factors (cross-loadings) and thus were boundary items in the factor model as well.

Because this was one of the first efforts to quantify use of climate adaptation science, each step of the process was needed to build evidence for the validity of the survey. There are many organizations with similar research projects and partners, however, who may find it useful in its current form. Future implementations of the survey as presented could bolster the evidence of the reliability and validity of the instrument. Additionally, future studies could apply analyses such as a confirmatory factor analysis comparing the CIJ and IO models to enhance our collective understanding of how climate adaptation science is used and how to quantify that use. Alternately, the relationships between the models could be used to examine whether a combined or nested model might best explain use of climate adaptation science (i.e., conceptual organizational use vs. conceptual individual use). Regardless, understanding the finer details between types of use and when they emerge will likely require a much larger sample size than our 81 participant responses. Additionally, while we chose participants based on project documentation and researchers' recommendation, testing other sampling methods may provide different kinds of information about use of the projects, such as deliberate sampling of individuals at different managerial or authoritative levels of an organization.

Combining this survey with other evaluation methods and frameworks, for example those centered on stakeholder engagement (Bamzai-Dodson et al., 2021; Meadow et al., 2015) or on qualitative data which could provide more details about nuances and mechanics of use, could reveal how to increase use of climate adaptation science.

The development process we followed was helpful for building an instrument to fit our needs and respondents, but future implementations may benefit from making some adjustments to the survey based on the goals and context at hand. For example, practitioners could repeat some steps of the development process, especially step 6 (Table 1), to tailor the instrument to specific respondents. Second, items that were removed from the survey in this study could still be used in future implementations. In particular, items that were removed only for weak loadings (Table 2) or items that are highly relevant to the research being evaluated could be valuable additions. Lastly, based on our qualitative findings, it may be appropriate to change some of the language of the questions in the future. For example, evaluators could provide explicit definitions about the time and organizational perspectives that respondents should answer from (i.e., use by only you or including use by your coworkers, use in the last year, use that you are aware of, etc.) depending on the survey purpose and context. Of course, any of these modifications are also dependent on the time and labor available to dedicate to additional review, interviews, and/or data analysis to inform the changes.

This instrument and both models of use may be important for better understanding the impacts of climate adaptation science. Specifically, this quantitative survey can be useful for comparing larger suites of projects with less institutional time and funding than in-depth qualitative evaluations. Better understanding large suites of projects using faster evaluation methods may be important for improving climate adaptation science more broadly. To name a few examples, funding agencies and organizations can develop uniform and transferable evaluation protocols; alter requests for funding proposals (RFPs) to better represent their missions and priorities; find consistent project weaknesses to improve facilitation procedures; or tailor their research portfolios to be more targeted or more diversified (Arnott et al., 2020; Bisbal, 2019; Karcher et al., 2021).

Conclusions

We have presented a robust and thorough process for developing a survey which measures use of climate adaptation science. The results from the first distribution of the survey show that quantitative measures of use may not fit the previously theorized structures. Instead, the survey items seemed to covary depending on whether the item described use for individual purposes or at broader organizational scales. Interview data, collected throughout the survey development process, further illustrate this difference. Enhanced understandings of how climate science influences policy and practice allow funding agencies to build more efficient and deliberate actionable science research portfolios. Ultimately, by understanding and improving the connections between science on society, we can more effectively and efficiently adapt to climate change to reduce harm to ecosystems and society.

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Chapter 3: Our choices matter: Museum visitors' perceptions of modern climate change

Background

The renovated David H. Koch Hall of Fossils – Deep Time exhibit was unveiled in June of 2019 with a reinforced focus on the connections between our Earth's past, present, and future, especially what paleoclimatology can tell us about modern climate change. Considering this exhibit is the home to T. Rex and Triceratops, Deep Time will likely be visited by most of the National Museum of Natural History's visitors, who numbered 4.2 million in 2019. Mitigating and adapting to the effects of future climate change will require participation from many of those millions of visitors making this exhibit a crucial opportunity for impacting the climate change knowledge and perceptions of the general public. These visitors may bring their improved knowledge and perceptions of science and scientists back home where they will talk to their friends and families about climate change and make decisions that affect their impact on and vulnerability to climate change.

The goal of this research project was to better understand visitor perceptions of climate change and their experiences learning about modern climate change in the Deep Time exhibit. The exhibit is book-ended by two displays explicitly comparing modern climate change to past climate events, specifically the Paleocene-Eocene Thermal Maximum (PETM display) and periods of much hotter climates throughout the Phanerozoic Eon (Polar Forest display). Each uses a variety of representations including temperature graphs to draw parallels between past periods of dramatic climatic change and current global warming. By examining visitor experiences with these displays and identifying potential improvements to the displays we can better understand how the museum can achieve its educational goals in the future.

Climate change is a complex problem which will require participation, whether through personal actions, support of government policy, or other action, across societies to solve. In fact, two U.N. treaties and their Sustainable Development Goals all call for taking action to combat climate change which include public education and training (McGhie et al., 2020). However, many people (including American adults) know little about climate change and do not see it as a major risk (Ranney & Clark, 2015). Both of these factors, in addition to many other complex socio-cultural dynamics, may reduce widespread support for climate change solutions and policy (Goldberg et al., 2021).

Though climate change is being integrated into K-12 education (McNeal et al., 2014), it is often difficult to engage the general public, especially adults, in Earth and climate sciences. Even once they are engaged, individuals of varying backgrounds may interpret climate information differently for a variety of reasons including their judgements of credible and trustworthy information sources (Kahan et al. 2011; McCright et al., 2013). However, even political conservatives and climate skeptics may still trust scientific authority and value scientific input on matters of environmental policy (Courtney & McNeal, in revision; Sarathchandra & Haltinner, 2020). This is one reason communication of the high level of scientific consensus around anthropogenic climate change can be effective for increasing risk perception and support for action on climate change (Kahan et al., 2011; van der Linden et al., 2015). Museums can act as a direct conduit from scientists to the public especially because they are trusted information sources (Cameron et al., 2013).

However, the modest levels of climate action and engagement by the American public is likely not a result of lacking climate literacy or awareness of scientists' positions alone. Instead, research has shown that individuals' perceptions of climate risk and willingness to support climate policy are impacted by many other factors (Hornsey et al., 2016; van der Linden, 2015). For example, museum exhibits that connect visitors with other times and places (exemplified by Earth history exhibits such as Deep Time) may reduce visitors' psychological distance from climate change (McGhie et al., 2020). Reducing this psychological distance from climate change and its impacts can increase visitors' intentions to take climate-combatting actions (Jones et al., 2017; Loy & Spence, 2020). The panels also provide information about the causes, context, and consequences of climate change, and improved knowledge of climate change can increase climate change acceptance and risk perception regardless of political leanings (Aksit et al., 2017; Courtney & McNeal, in revision; Libarkin et al., 2018; Ranney & Clark, 2016; Stevenson et al., 2014). This is even true of communications using visualizations and graphs specifically, which are very important to the relevant climate panels in Deep Time (Courtney & McNeal, in revision; Harold et al, 2016; van der Linden et al., 2014). However, research and evaluation are important to understanding the effectiveness of such climate change communication efforts, especially as museum missions and public perspectives of science and scientific authority are shifting (Jones et al., 2020).

We collaborated across institutional and disciplinary boundaries to design this study to address the priorities of the exhibit, displays, and research team members. Guided by those priorities, the research questions for the project were:

1) What are visitors' opinions of climate change and climate scientists, and what are the relationships between their perceptions and identities?

2) How do visitors understand and interact with the panels, especially the climate change graphs?

3) How could the displays be changed to improve visitor comprehension?

Methods

This study was approved by both the Auburn University IRB and the Smithsonian Institution IRB. The specific methods, interview questions, and survey items for this study were co-developed with two museum employees, one involved in exhibit design and one in collections research in paleobotany. During the planning process, other exhibits, evaluation, and education experts attended planning meetings and provided input which was integrated into the research questions and topics of study. For example, many of the items on the survey were identical to those used by an evaluation firm contracted to collect data in the same exhibit several months earlier so the participants of this study could be compared to their broader efforts once made available. By collaborating with some representatives of each of these departments and perspectives, these findings can be much more relevant and applicable than if it were conducted without input from these experts, especially because of the unique role museums play in education (Hamilton and Ronning, 2020; Meadows et al., 2015).

Eye-tracking

Eye-tracking technology describes any system used to record where an individual looks and for how long. In this study, Tobii eye-tracking glasses were used, which consist of a headset not much larger than standard glasses and an attached processing unit which is about the size of a portable cassette player. The glasses use infrared light to record the position of the participant's cornea relative to the camera, and another camera recording the scene in front of the participant to connect the eye-tracking data to the real world. In the analysis software, the captured video and eye-tracking data are used to map each participant's attention to an uploaded image of the feature of interest, in this case the museum displays.

Though there are many kinds of eye movements and patterns, the majority of cognitive processing is accomplished during fixations, when an individual's gaze pauses on one place or piece of information. Thus, in this study, the primary metric used to understand visitors' attention is their total duration of fixations, or the total amount of time they spent fixating on the entire display or on one feature of the display designated as an area of interest (AOI).

Data Collection

The data were collected during a 3-week period in the Deep Time exhibit in Spring of 2022. The researchers alternated between the two displays of interest on each day of data collection. Participants were recruited from the general visitor pool by typical random sampling methods in museum studies, specifically by inviting participation from every third visitor who deliberately looked at the display of interest (at least 2 seconds). Visitors aged 13 and older were included in the study and participants ages 13 to 17 required parental consent to participate in addition to their own assent. After each participant consented and read their information letter, they were asked to put on the eye-tracking glasses which were then calibrated to their eyes in accordance with the device manual and software. Participants were then interviewed about their perceptions of the display of interest including: the big idea or take-away message of the display, where they saw the message, and how it was relevant to their life; the hardest part of the graphs on that display to understand; three factual comprehension questions about the information displayed in that display; and any suggested changes that might make the display easier to understand. The participants were free to spend as much or as little time responding to each interview question as they wanted and could walk to different parts of the display to read additional information during that time. After they were finished answering the interview questions the participants were given a short paper survey. The survey included questions about their identities and demographic information, their perceptions of climate change (items used to measure the Six Americas Short Survey, SASSY; Chryst et al., 2018) and climate scientists (abbreviated source credibility instrument based on the work of McCroskey and Teven, 1999). The lead researcher was responsible for the recruitment, consent process, eye-tracking set-up, interviewing, and survey distribution with each participant, but a museum employee assisted each day to take live notes during the interview portion of the study. Data collection was concluded after each display of interest had 33 participants with acceptable eye-tracking data (complete recordings with over 75% of gaze samples recorded). We did not record the number of participants who declined to participate.

Exhibit displays used in the study

The display of interest closer to the exhibit entrance compares the 56-million-year-ago PETM event to modern climate change, especially using temperature graphs with identical axes for each event (Figure 3.1). Comparing these graphs, which is encouraged in panel text, shows that warming over the PETM took thousands of years whereas, with continued high CO_2 emissions, modern day warming would take only hundreds of years to increase an equal number of degrees. However, the modern climate graph on the right-hand side shows both a high- and low-emission future temperature curve, emphasizing that "our choices matter" in determining which of these future scenarios occur.

The second display comparing past and current climate change is the "polar forest" panel which shows temperature change across the last 500 million years of Earth history (product of the PhanTASTIC project, Wing et al., 2018) and across the 20,000 years since the last ice age. Both graphs have some highlighted events, namely high-CO_2 warming events and events in human evolution (Figure 3.2). Additionally, both graphs use trend-line color to denote whether there were polar ice caps during that period (blue line) or none (red line), showing that all of human evolution has only taken place during periods with polar ice, relatively cooler than average climates throughout the Phanerozoic Eon. The right-hand-side graph of recent climate also shows the same two potential future paths as the PETM display, showing that human activities determine whether polar ice caps will continue into the near future or if Earth's climate will warm to the point of complete polar ice melt.

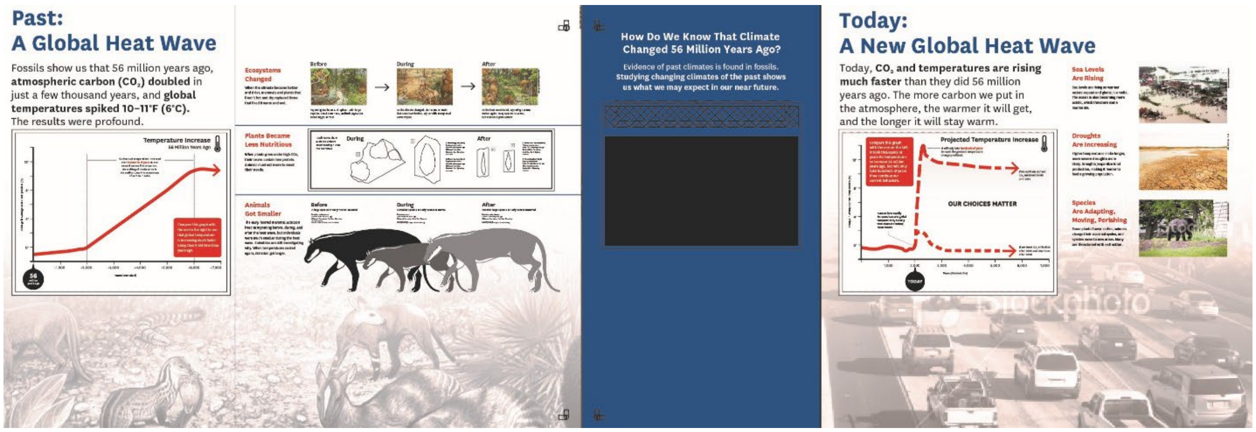

Figure 3.1. Proof of the PETM panel in the Smithsonian National Museum of Natural History exhibit Deep Time, including graphs of global average temperature change over the PETM event (left) and modern to future times (right)

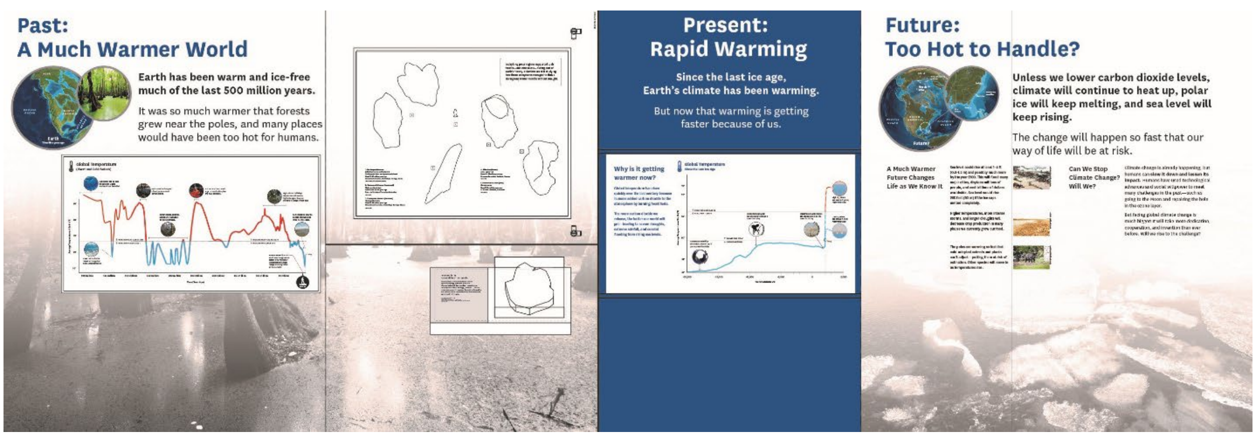

Figure 3.2. Proof of the Polar Forest panel in the Smithsonian National Museum of Natural History exhibit Deep Time, including graphs of global average temperature change over the last 500 million years (left) and the last 20,000 years (right)

Interview protocol

The comprehension questions for each display (Table 3.1) were designed to be answerable from either the graphs or text and to be relevant to the intended messages of the displays.

Additionally, the questions were written to parallel each other, meaning that the first comprehension questions concerned temperature change in the far past, featured on the left sides of the displays; the second question involved comparing the rate of temperature change between two time periods; and the third question asked participants to predict the Earth's average temperature in the next millennium/a, discussed on the far right-hand side of each display. These parallels were intended to make comparison between the results of each display more meaningful. Specifically, we chose to ask about the "big idea" first to understand what messages may be apparent to visitors who only spend a few seconds looking at the display (most visitors). We next wanted to explicitly direct visitor attention to the graphs and understand their first impressions of the graphs. Thus, when they answered the comprehension questions next, they would have the opportunity to compare their initial impressions of the display to their experience extracting information from it. Last, we asked about any changes that may make the display easier to understand, an opportunity to reflect on any difficulties they may have experienced during the comprehension questions and for museum staff to better understand possible improvements.

Table 3.1

Interview questions by display

	PETM display	Polar Forest display
Big idea	What is the big idea or take-away message of this display? Can you show me where you see that message? How is that message relevant to your life?	
Graphs	What is the hardest part of the graphs to understand and why?	
Comprehension 1: Historical	How much did the Earth warm during the past event and how long did it take?	On average, has the Earth been warmer or cooler over most of its history compared to today?

Comprehension 2: Comparison	How does the rate of warming during the past event compare with current warming?	How does the speed of current warming compare to the last 30,000 years or so?
Comprehension 3: Projection	How much warmer will the Earth be in the year 3000?	Are the polar ice caps going to melt in the next few thousand years? Why or why not?
Suggested changes	What changes might make any part of this display easier to understand?	

Analysis

We used the survey data to better understand visitor perceptions of science and scientists, including the relationships between those variables (research question 1). Quantitative analyses were completed in jamovi version 1.6 (The jamovi project, 2021). Interview data, in the form of notes taken based on participants' verbal responses, were uploaded into Dedoose for qualitative analysis using inductive coding. Where statistical tests are used, parametric and non-parametric equivalents were selected for each comparison based on the number of levels of the variables involved (i.e., non-parametric comparisons for binary variables such as international residence).

Eye-tracking data were analyzed quantitatively using the fixation metrics in different areas of interest on the display and qualitatively by comparing the spatial distribution of attention by different groupings of participants. Both of these assessments can be compared to participants' demographics, identities, and correct or incorrect responses to comprehension questions. We conducted statistical comparisons on these quantitative measures to better understand contrasts between the displays. Each of these analyses highlight the pieces of information that visitors are using to form opinions about the information and about climate change.

We also analyzed the content of participants' responses to the interview questions. Specifically, responses to the "big idea" and relevance questions were qualitatively coded to look for common themes and references to specific pieces of information in the panel to better understand how visitors are interpreting the exhibit information. Because the factual comprehension questions were open-ended and verbal, additional information about these responses beyond their factual correctness was recorded and analyzed. Additionally, interview responses about possible barriers to comprehension were asked in order to make recommendations regarding potential improvements to the displays in the future.

Results

Participants

Data were retained for 66 total participants including 33 at each panel. In total, 28 of the participants identified as women (42%), 38 were men, and none were other genders; 10 lived outside of the United States (15%); and 39 were visiting for the first time (59%). The mean age was 33.8, the median age 31, and participant ages ranged from 13 to 71. 13% of participants did not have a high school diploma (mostly adolescents; 15 individuals), 8% had a high school diploma, 11% had an associate's degree, 24% a bachelor's degree, and 35 had an advanced degree. 65% of participants identified only as white while 12% were multiracial, 14% were Asian, 11% were Latine (Carbajal, 2020), 9% were Black, and two had other racial identities. Participants at the two panels were statistically equivalent in gender distribution, formal education, age, whiteness, climate change perceptions, and eye-tracking data sampling. Additionally, our sample was very similar to a larger exhibit-wide evaluation conducted a few months earlier (personal communication).

Quantitative results

Using the Six America's Short Survey (Chryst et al., 2018) we found that three of the participants were in the cautious segment of climate change beliefs (4%), 19 were concerned

(29%), and 44 were alarmed (67%), the grouping with the highest activation and concern about climate change. None of the participants were in the three segments associated with lower concern about climate change. There were no statistically significant differences in demographics or climate change perceptions between the groups who used each display (Table 3.2). Additionally, the SASSY distribution and demographic characteristics of these participants were very similar to those measured in a recent external evaluation of the entire exhibit with over 1,5000 participants (personal communication). We used ordinal regression to see if other important characteristics measured in the survey were appropriate predictors for their SASSY grouping, since climate change perceptions are often related to cultural factors (Hornsey et al., 2016). The statistically significant predictors were formal education (Z = 2.34, p = .019) and whiteness, which was negatively related to climate concern (Z = 2.48, p = .013; Baldwin & Erickson, 2020). Statistically insignificant predictors included perception of climate scientist credibility, age, gender, and international or domestic current residence.

Table 3.2
Basic demographics and characteristics of participants by museum display

	Age (*M*, *S.D.*)	Women (*n*, %)	Interna-tional (*n*, %)	Only white (*n*, %)	Education (*Median*)	SASSY category (*Median*)	Credibility rating (*M*, *S.D.*)
PETM *n* = 33	31.4, 15.2	12, 36.4	3, 9.1	21, 66.7	4 (Bach. degree)	5 (Alarmed)	6.2, 1.0
Phan *n* = 33	36.2, 16.0	16, 48.5	7, 21.2	22, 63.6	4 (Bach. degree)	5 (Alarmed)	6.1, 1.3
Total *n* = 66	33.8, 15.7	28, 42.4	10, 15.2	43, 65.2	4 (Bach. degree)	5 (Alarmed)	6.1, 1.1

Note. Items on the credibility instrument had seven measurement levels, so mean values can be interpreted as a rating out of 7. PETM row contains data for those participants who saw the PETM-focused display, Phan indicates participants who saw the Polar Forest display with Phanerozoic temperature data.

Bivariate correlations were used to compare relationships between other demographics and identities since, at this time, we do not have enough evidence to predict causal relationships. Participants' age was strongly related to their formal education experience (Spearman's $\rho = .527$, $p < .001$), but otherwise none of the demographic or identity items were significantly correlated. Among perception constructs, participants' SASSY grouping was significantly correlated with their perception of climate scientists' credibility ($\rho = .285$, $p = .021$).

Total eye-tracking measures were compared next, showing that women spent more time on the interviews on average ($\rho = .283$, $p = .021$), more time viewing the text about past climate ($\rho = .274$, $p = .026$), and more time viewing the text about present and future climate ($\rho = .414$, $p < .001$). International visitors spent less time viewing the present/future text than participants who lived in the U.S. at the time of the study ($\rho = .295$, $p = .016$). Individuals who spent more time attending to the past text also attended more to the past graph ($\rho = .507$, $p < .001$) and the same association was observed between the present/future text and graph ($\rho = .286$, $p = .020$). However, time on each of these features was also strongly related to the display the individual viewed, possibly because there was a slight difference in where the most relevant information was for each question. Specifically, the answer to the first comprehension question could be found in the past text or past graph of both displays; the answer to the third question could be found in the present text or present graph of both displays; but the answer to the second question could be found only in the present section in the Polar Forest display but required comparing both the past and present graphs for the PETM display. Thus, relationships between attention to specific features could be affected by which display the individuals saw.

Next, we looked for correlations between performance on the comprehension questions and other measures, including eye-tracking metrics, to better understand how participants reached correct answers. Participants' total score was significantly correlated only with whiteness (ρ = .245, p = .047) and not any other demographics (including formal education) or overall attention metrics. Correct answers on comprehension question 1 were negatively correlated to time spent on that question (ρ = .407, p <.001) and time spent on both the present/future text (ρ = .348, p = .004) and graph (ρ = .450, p < .001), which were also related to each other (ρ = .665, p < .001). Correct answers on the second comprehension question were only significantly correlated with whiteness (ρ = .270, p = .028).

Correct answers on the third comprehension questions, which concerned global temperature in the next few centuries to millennium, were measured as participants' explicit acknowledgement of the uncertainty of future warming and/or the role human decisions play in shaping future climate. However, we also recorded whether participants, when they suggested a higher likelihood of one or the other, described a high-warming and therefore high-CO_2 future or a future with a stable climate and therefore lower CO_2. 24 total participants (36%) mentioned uncertainty in some way, which included participants who made any "if" statements in response to the questions or read relevant sections of text aloud. For statistical analyses, we only included participants who emphasized the role of human decisions and future uncertainty or expressed the ideas in their own words (not reading panel text aloud). Acknowledgement of future uncertainty was related to time spent viewing the present/future graph (ρ = .262, p = .034), younger participants (ρ = .254, p = .039), and less concerned SASSY group membership (ρ = .257, p = .037), and somewhat associated with whiteness (ρ = .224, p = .071). Participants who assumed a high-temperature future were more often men (ρ = .308, p = .032) and tended to be slightly younger (ρ = .247, p = .087).

Panel comparisons

There were several differences in participants' attention and answers between the two displays (Table 3.3). Specifically, participants who used the Polar Forest display tended to spend more time viewing both sections of text and the past graph and had more correct answers on the second comprehension question. Individuals using the PETM display spent more time viewing the present graph on the third comprehension question and throughout the interview time period.

Table 3.3

Significant contrasts in participant attention and performance between panels

	Past Graph	Past Text	Present Graph	Present Text	Answered correctly
Comprehension Q2 (comparison)	Phan $t = 2.24$^*			Phan $t = 2.63$^*	Phan $\chi^2 = 5.35$*
Comprehension Q3 (projection)	Phan $t = 3.30$^**	Phan $t = 2.13$^*	PETM $t = 3.74$**	Phan $t = 4.29$^**	
Entire interview	Phan $t = 5.88$^**	Phan $t = 4.86$^**	PETM $t = 5.10$**		

Note. The display named in each cell is the one that was more attended to, i.e., PETM refers to those participants who saw the PETM-focused display and Phan indicates participants who saw the Polar Forest display with Phanerozoic temperature data. There were no significant contrasts for question 1 or any of the empty cells. Student's t was used unless the metrics were found to have unequal variances via Levene's test, in which case Welch's t was used, denoted by ^; * $p < .05$, ** $p < .005$

Because many of the metrics examined above had strong correlations to the display that participants used, we decided to investigate partial correlations in which the display was controlled for. Controlling for the display used did not affect most of the correlations, but there were some contrasts including differences in graph use. Once the display was controlled for, there was a strong relationship between attention to each of the graphs ($\rho = .517$, $p < .001$) which was not detectable in the bivariate correlations above. Additional relationships only detectable in the partial correlations include greater attention to the present/future graph paid by individuals with less concerned SASSY group memberships ($\rho = .269$, $p = .030$); women paying more attention to the present/future graph ($\rho = .292$, $p = .018$); and white people paying less attention to the past text, on average ($\rho = .262$, $p = .035$).

Qualitative Findings: Heatmaps

Additional qualitative analysis of eye-tracking data by visual examination of heatmap images allows for attention comparisons between finer details of the panels since quantitative methods which rely on defined areas of interest cannot reliably distinguish between fixations on small features very close together. For example, the heatmaps of total attention to each display (Figure 3.3) shows that the majority of attention paid even within the graph AOIs were on small

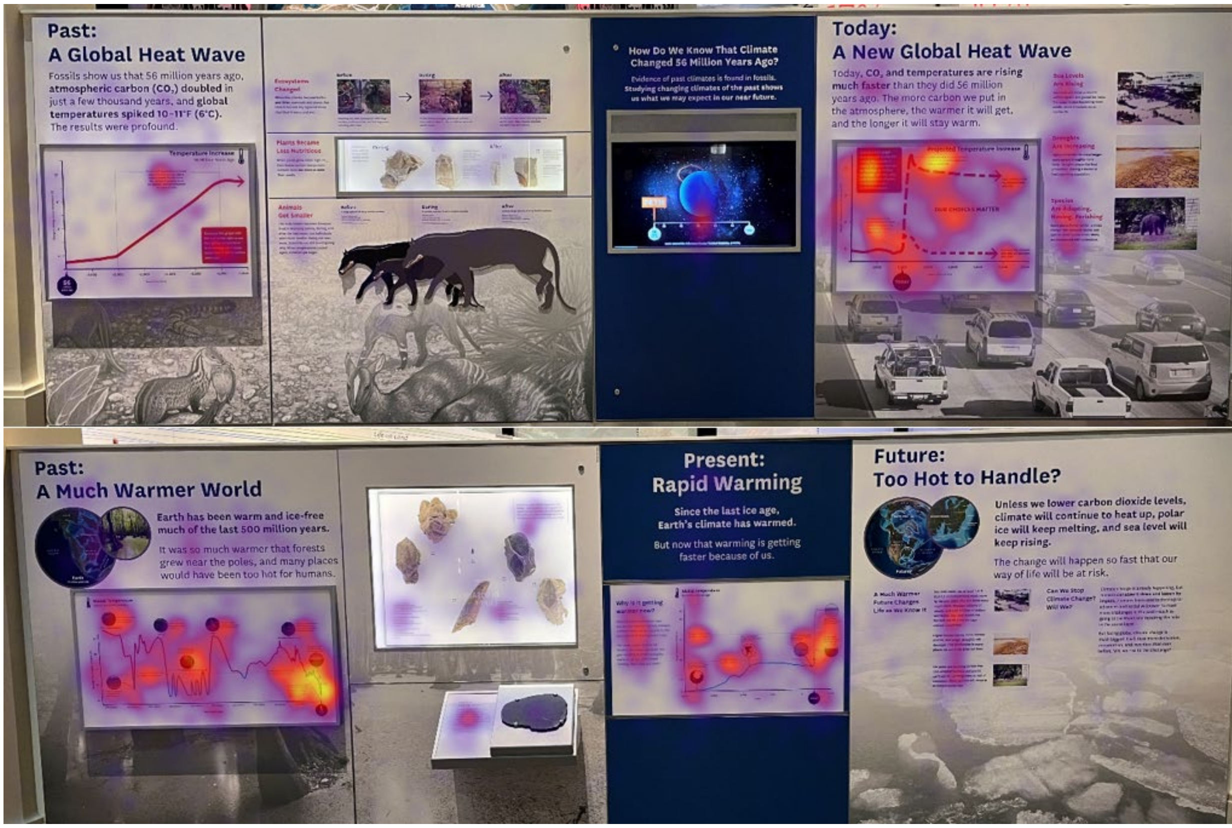

Figure 3.3. Heatmap of all participants' attention on the PETM display (top) and Polar Forest display (bottom) during the entire interview, with yellow areas representing the highest total fixation duration (view time).

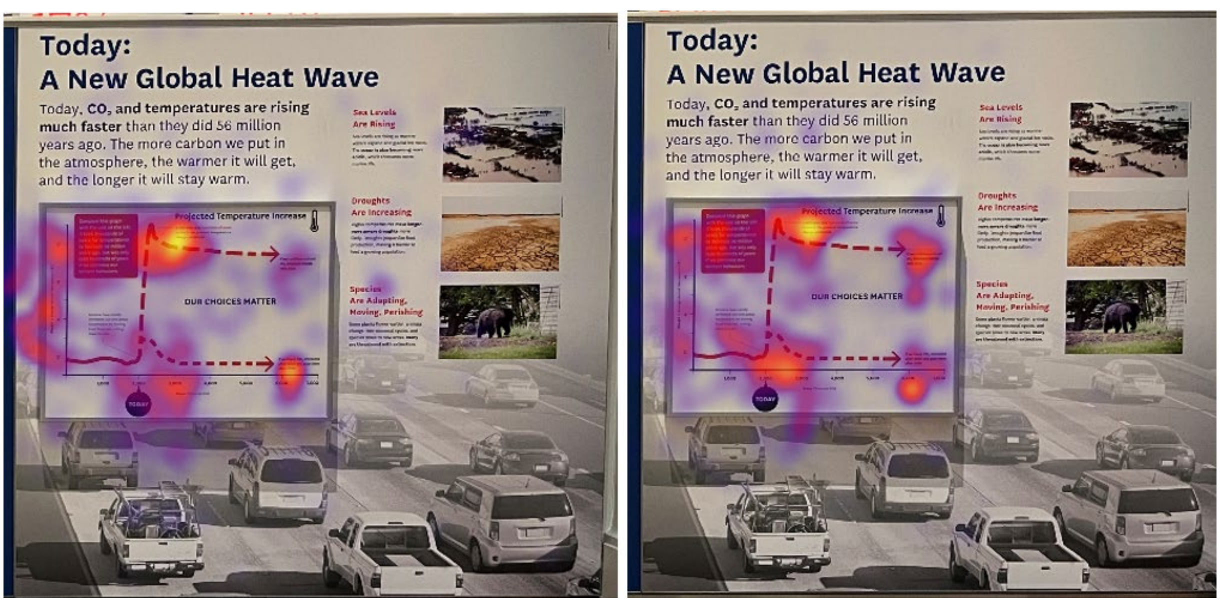

Figure 3.4. Heatmaps comparing attention of participants who did not (left, n = 24) and did (right, n = 9) emphasize the uncertainty of or role of human decisions in future climate during the time they spent answering the third comprehension about the PETM display.

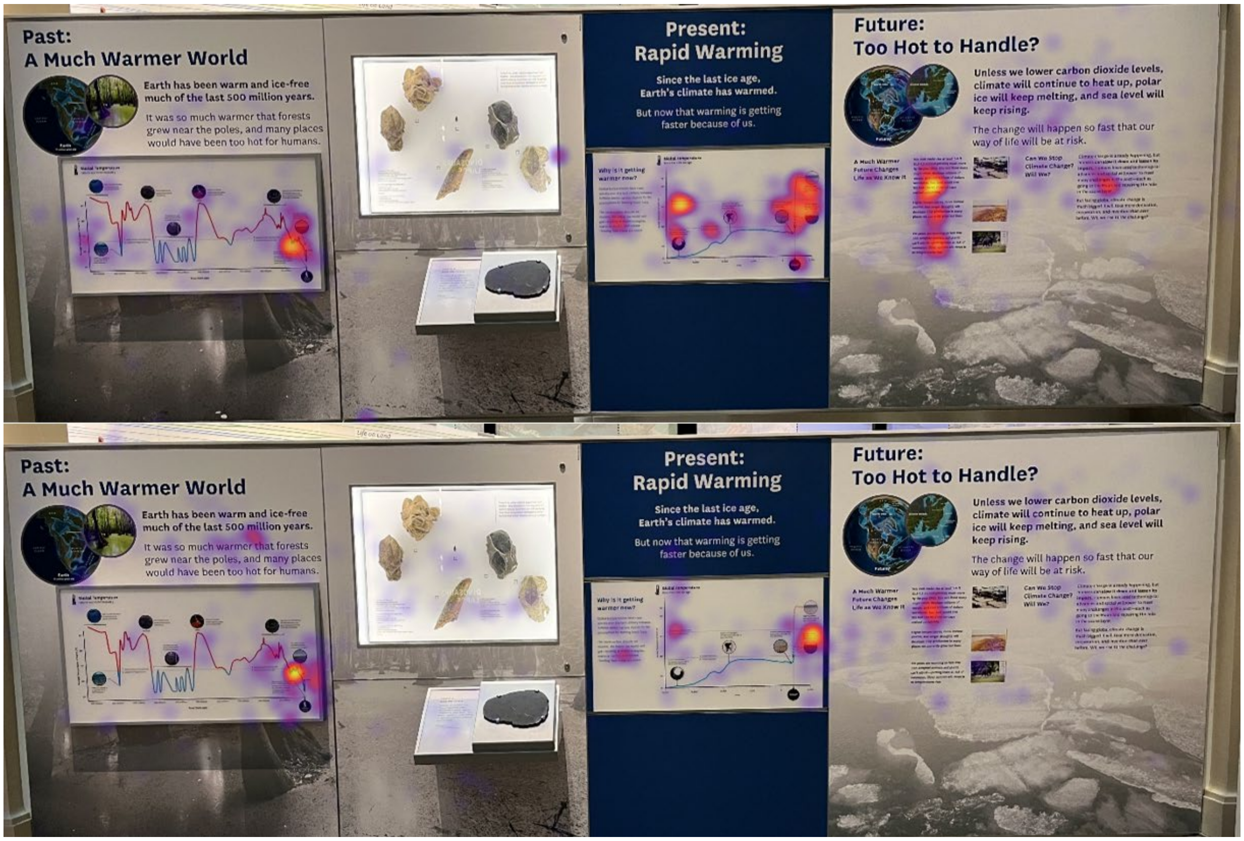

Figure 3.5. Heatmaps comparing attention of participants who did not (top, $n = 28$) and did (bottom, $n = 5$) emphasize the uncertainty of or role of human decisions in future climate conditions during the time they spent answering the third comprehension question about the Polar Forest display.

were generated comparing similar tasks between panels and comparing attention on the same panel between groups of participants.

Because one of the most important intended messages of both panels concerned our ability to control (i.e., improve) future climatic conditions, we paid special attention to this contrast. Figure 3.4 shows small differences in the attention patterns of participants separated by whether they did or did not refer to uncertainty in future climate conditions while answering the third comprehension question about the PETM display. The heatmap shows very similar attention patterns but seems to show that participants who successfully referenced the uncertainty of future conditions paid more attention to the text accompanying the high-CO_2 future projection. Notably, neither group of participants spent much time viewing the relevant text in the graph stating, "our choices matter." While the heatmaps provide more of a starting point for investigating these differences in responses than explanations of their causes, the findings can still be useful for considering options to change the display design in the future (see recommendations below).

Similarly, the differences in attention between participants who did and did not reference future climate uncertainty while viewing the Polar Forest display (Figure 3.5) could provide more guidance for future changes in or user testing of the displays. For example, explanatory text relevant to the question ("Can we stop climate change? Will we?") is found on the far-right side of the display, which was hardly viewed by either group of participants, especially in comparison to the text nearer the graph about impacts of climate change ("A much warmer world changes life as we know it"). Thus, moving the text relevant to the choice between possible futures closer to the graph may increase attention to it, possibly increasing comprehension of this important message. Additionally, correct participants spent time reading the text accompanying the low-CO_2 future trendline on the graph whereas incorrect participants spent similar amounts of time reading text throughout the graph, so increasing the prominence of that text may also improve comprehension.

Though such analysis is even more tedious and subjective, participants' eye-tracking videos contain qualitative clues about their information processing. Specifically, we took note of five participants who tilted their heads to the side when reading sideways axis labels, a possible sign of high cognitive load (Harold et al., 2016). Additionally, at least one participant estimated a future temperature that was in the middle of the low- and high-CO_2 futures and we observed that their gaze often fixated in the spatial center between the two trendlines during that question, possibly implying that they interpreted the high and low future trendlines as the edges of a confidence interval rather than separate scenarios. Since these observations are more examples than results, they are not discussed below, but illustrate the value of employing multiple metrics for understanding visitor experiences.

Qualitative Findings: Interview responses

Participant responses to the interview questions, especially more open-ended questions such as those about the "big idea" of the panels, revealed important connections between participants' perceptions of climate change and climate science. Tables 3.4 and 3.5 summarize these findings for each of these displays by listing the most frequently associated topics with each question as revealed by qualitative coding.

Other topics important to the displays and their main messages were the influence of human activities on future climatic conditions, which was mentioned 26 times by 19 participants; any expressed aversion to graphs, since they are an important part of displays, which was only expressed by two participants; and controversy surrounding the realities of modern climate change, which was mentioned a total of four times by three participants. None of the participants expressed any skepticism about the occurrence or severity of modern climate change.

Table 3.4

Summary of qualitative findings by interview question: Polar Forest display

Question	Frequently associated codes	Example excerpt
Big idea	Global warming/temperature (21), Climate change (9), Human activities/emissions (6)	I assume the message is humans are causing climate change and it's quite recent

Relevance	Impacts on environment (11), My life (10), Behavior change (9), Impacts on humans (8), High concern (8), Children/future generations (8)	We love animals. We see what it's doing to polar bears. I'm a mom and a grandmother, I want the Earth to be great for my children and grandchildren and their children.
Graphs*	Past graph (10), Data representation (8), Present graph (6), Axes and units (6)	Bring up a question is that we are still below the line. I see if I look closely that we are going up quickly. But if I was denying climate change, I would say what's the big deal, we are still below the line.
Suggested changes	Emphasis/salience (13), Continuity and connections (9), Font size (9), Pictures (9), Content (9)	Left plot: A lot of information. Add a take-away message in bold? Lots of small text. Make the "world without polar ice" text bigger, take-away message or point to big idea

Note. Interview responses were recorded as live-typed notes rather than audio recordings, so excerpts are likely summarized versions of the original responses.
*The "graphs" code was primarily used for the interview question about graph difficulty but was also applied when a participant spoke generally about both graphs in the display.

Table 3.5

Summary of qualitative findings by interview question: PETM display

Question	Frequently associated codes	Example excerpt
Big idea	Global warming/temperature (17), Climate change (15), Comparison to past (14), Impacts on environment (10)	How climate change is not just a normal temperature changing like it was in the past and how it's an actual problem
Relevance	Impacts on environment (13), My life (11), High concern (9), Global warming/temperature (8)	We see it happening and lots of changes in the environment, the relevance coupled with the fact that there's not much I can do as an individual is kind of scary.
Graphs*	Data representation (9), Axes and units (9), Emphasis/salience (8), Present graph (8), Continuity and connections (7), Distance between graphs (7)	In the today graph, the two separate lines and the dotted versus solid parts – I think I got it that the dotted starts when they separate out.
Suggested changes	Graphs (15), Images (12), Content (7), Emphasis/salience (7), Axes and units (6), Distance between graphs (6)	I think that the main message is contained in the two graphs. Those aren't what I looked at first though. But that's what it's about I guess, it's about making people aware of

		how we can change things but only those two lines make us understand how our behavior can change things.

Note. Interview responses were recorded as live-typed notes rather than audio recordings, so excerpts are likely summarized versions of the original responses.
*The "graphs" code was primarily used for the interview question about graph difficulty but was also applied when a participant spoke generally about both graphs in the display.

In total, when asked about the "big idea" of the displays, 38 individuals mentioned global warming, 24 mentioned climate change, 19 mentioned the comparison to past climates, 14 mentioned impacts to the environment (including non-human animals), and 11 mentioned human activities or emissions. When asked about the relevance of that message to their lives, 24 mentioned impacts to the environment, 21 mentioned their own experiences of climate change ("my life" code), 17 mentioned concern or worry about climate change, 15 referenced humans doing something about it by changing lifestyles or behaviors, 13 mentioned global warming, 12 mentioned impacts on humans, and 11 mentioned their children or future generations of humans.

Discussion

In this study, we used a variety of data sources to better understand visitor experiences with information about modern climate change at a major American museum. Despite the relatively small sample size, due both to the intensity of our methods and restrictions imposed by the ongoing COVID-19 pandemic, we found evidence of important relationships between visitors' perceptions of climate change and experiences learning about climate change in the museum. Additionally, many of these findings will help to inform future exhibit programming and modifications to the displays via distribution of the de-identified and summarized data with museum exhibit staff.

RQ1: Visitors' opinions of climate change and climate scientists

The participants in this study were all concerned, to some degree, about modern climate change and its current or future impacts. This may be representative of the visitor population at large [comparison to exhibit evaluation demographics coming soon], but there was likely some effect of self-selection, due both to the sampling method relying on initial attention to the display and participation requiring visitors to sacrifice time they intended to be spent in the museum without any financial incentive. Overall concern about climate change, measured by a participants' belonging in a more activated Six America's group (SASSY; Chryst et al., 2018), was further predicted by participants' level of formal education and racial identity, consistent with previous literature (Finucane et al., 2010; Leiserowitz et al., 2021). Participants' judgments of climate scientist credibility were correlated with their SASSY group belonging but was not a significant predictor in the regression analysis. Though we did not ask any interview questions about visitors' trust in the museum or displays, other authors have found important contrasts in science museum visitors' understanding of trustworthiness based on their SASSY segmentation (Jones et al., 2020). For example, those authors found that members of the "alarmed" group trusted academic and empirical research and museums inherently, whereas "concerned" and "cautious" visitors more often connected judgements of trust to visible sponsorship or political positions. Overall, none of the findings of visitors' perceptions were surprising or contradictory to previous literature, but low variation in beliefs may be an artifact of a relatively homogenous sample [also needs comparison to general exhibit data].

RQ2: Visitors' experiences with climate change information

Much of our analysis of visitor experiences interacting with the exhibit displays of interest relies on findings from eye-tracking and factual comprehension questions asked about the displayed information. Interestingly, performance on these comprehension questions was not strongly related to formal education or age. Instead, the only visitor characteristic that predicted correct answers was racial identity. Participants who identified as white alone (no other racial identities) tended to have more correct answers on the second comprehension question, a higher total score, and more often acknowledged the uncertainty of future climate conditions. We did not collect enough qualitative data to explore why this may have happened, but two possible explanations are the white participants' lower levels of concern about climate change (consistent with previous research; Finucane et al., 2010) or the presence of cultural bias in the questions, scoring, and/or displays. This finding deserves further investigation in future studies, especially as the importance of uncertainty in future climate change due to human decisions is highlighted even more in policy contexts, such as the shared socioeconomic pathway model used in the newest IPCC assessment report (IPCC, 2021).

Though participants' gender did not predict performance on the comprehension questions, women tended to spend more time answering the questions and more time viewing the present/future graphs and both sections of text, even after controlling for the effect of the different displays and questions. This is another topic where this study cannot provide an explanation, but a recommendation for further investigation, since longer view times can indicate either greater engagement with the information or greater difficulty answering the question. Interestingly, other demographic characteristics had very little predictive power of climate change concern or performance on the comprehension questions, which was somewhat contrary to our expectations, i.e. expectations of younger individuals being more concerned about climate change (Leiserowitz et al., 2021; Libarkin et al., 2018). Additionally, though there were only 10 visitors who did not live in the U.S. at the time of the study, those participants did not perform significantly differently than domestic participants except for spending more time reading the present text sections of the displays.

Individuals' tendencies to use certain features of the displays have interesting implications. Specifically, there were strong positive relationships between attention to the two graphs and attention to the two sections of text, implying that participants may have had preferences for using one or the other. However, total attention to any of these features was not strongly correlated with summed scores. Thus, we were seemingly successful in designing questions that could be correctly answered using either the graph areas or bodies of text, which is an important factor in the interpretability of attention data.

Interestingly, contrasts in attention between the two displays did not vary only with the differences in questions between the displays. Specifically, comprehension question two was the only one where the answer could be found in different areas of interest between the two displays (comparison of past and present on PETM, comparison of information within present on Polar Forest). Thus, if attention on the tasks were related only to locations of the answers, PETM participants would have greater fixation durations on the past graph and text. However, participants using the Polar Forest display instead viewed the past graph significantly longer on comprehension questions 2 and 3.

The qualitative data can suggest possible explanations, like the fact that out of 7 excerpts from Polar Forest participants coded for both "past/left graph" and "hard to understand", three participants mentioned difficulties in understanding the connection between the two graphs; two mentioned apparent incongruity between global warming being worrying and the graph showing that we're still in a much cooler climate than most of the history shown; and two mentioned difficulties drawing conclusions from the graph because it showed many variations in temperature rather than one clear trend. The last could be an indication that the excess, mostly task-irrelevant data hindered participants' data processing (Strobel et al., 2018). A caveat, again, is that more viewing time is not a definite indicator of more difficulty understanding a stimulus; but in this case, only one PETM participant explicitly mentioned a difficulty understanding that past graph, as opposed to the 7 mentioned by Polar Forest participants, providing additional evidence of the increased difficulty.

RQ3: Suggestions for improved comprehension and engagement

The interview questions were designed to guide participants to think critically about their comprehension of each part of the graphs on the display, and their responses revealed some successes of that. The participants had suggestions for changes in organization and layout that they thought could improve the displays, often concerning the amount of information presented, the size of features, and connections between the graphs at each display. They also explained some difficulty in understanding certain aspects of the graphs, specifically the sections of future projected temperature, and included some suggestions for those difficulties like color-coding each of the trend lines differently (observed and each projection). Eye-tracking metrics and heatmaps can also be used to compare participants' attention to their expectations or priorities for features that are most salient or interesting to museum visitors. Last, any user testing information, whether user-reported or observed through other means, can be contextualized using the wealth of evidence-based best practices for data visualizations available in previous literature, including those specific to climate change visualizations (Harold et al., 2016; Harold et al., 2017). Other participant- and researcher-generated suggestions which may be more generalizable include:

- Minimizing the distance between features/graphs if they're intended to be compared, relevant in this case to the greater number of mentions about distance between graphs from

PETM participants (10 versus 1 using Polar Forest display). However, distance between visuals and any text that is helpful or necessary to understand them can also create unnecessary cognitive load and reduce comprehension (Harold et al., 2016);

- Providing ample information and context if using graphs with multiple concurrent trends (i.e., multiple possible futures), since they are known to be difficult for novices to comprehend and may be mistaken for scientific uncertainty rather than sociopolitical uncertainty (McMahon et al., 2015);
- Minimizing information on a display in total, which may be aided by removing redundant information. For example, in these displays some information was present in text in both the stand-alone paragraphs and text within the graphs, which may be superfluous and thus add to visual clutter, which can reduce comprehension (Strobel et al., 2018);
- Ensuring that the main message of any graphic or display is a highly salient feature can ensure that the message is not only viewed but also processed. This was illustrated by participants using the PETM panel where, despite the message being in all-capital black text near other features that were highly viewed, less attention was paid to the message "our choices matter" than many smaller sections of text. In this case, there is not clear evidence to suggest why that feature was not highly attended to, so such improvements may require further testing of its position, language, etc.

While these results and suggestions were not the primary focus of this manuscript, since most are quite specific to the displays at hand, we did provide all of them to museum staff. We hope that this study can serve as an example of the kinds of findings that can be gained from user testing of museum displays with the combined approach of deploying surveys, interviews, and eye-tracking.

Conclusions

Educating the public about climate change, including its dangers, possible solutions, and the Earth science context, is an important component of making systemic changes that will reduce harm from climate change. Museum visitors who agreed to participate in this study generally had a high regard for climate scientists and were concerned about climate change with slight variations related to participants' age and racial identity, consistent with previous literature. We investigated participants' attention and comprehension of two museum displays related to modern climate change including the information on each related to the uncertainty of future climate conditions depending on human emissions. However, the majority of participants did not explicitly acknowledge this uncertainty, and instead predicted a hot, polar-ice-free Earth in the next thousand years. Qualitative and eye-tracking data provide opportunities to understand what information visitors are using to draw conclusions about museum displays and how the intended messages and relevance can be communicated in a more accessible way.

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Chapter 4: Perceptions of climate scientists predict conservatives' climate change beliefs

Abstract

Two of the most researched predictors of climate change acceptance and risk perception are political affiliation and the role of scientific knowledge. There are also complex relationships between the two, demonstrated by previous work that has found both increases and decreases in political polarization from education. Further, individuals' intake of climate science is likely impacted by their judgements of the credibility and consensus among climate scientists. In this study, we add to this discussion by testing the influence of each of these factors on climate change belief and risk perception among undergraduates in the Southeast U.S. using structural equation modeling. We did not find direct impacts of broader STEM experience or specific climate change knowledge on climate change belief or risk perception across participants. However, the direct and indirect impacts of knowledge vary by political ideology, such that increased knowledge is an important predictor of liberals' risk perception but not conservatives'. Instead, awareness of scientific consensus may predict up to 75% of conservatives' belief that climate change is happening which more reliably predicts their risk perception compared to other groups. Additionally, we found evidence of STEM gender gaps among liberals, but not conservatives, that may lead to disparities in climate change knowledge and beliefs. Our findings further highlight the need for evidence-based climate change communication strategies tailored to specific audiences.

Background

Though the science surrounding climate change predictions, impacts, and solutions has been robust for decades, members of the American public have widely varying knowledge and opinions of climate change (Howe et al., 2015). Most well-known is the discrepancy in climate change opinions between members of differing political parties, which in September 2021 showed a 62-point gap in the frequency of liberal Democrats versus conservative Republicans who think global warming is caused mostly by human activities (Leiserowitz et al., 2021). Though there are many possible strategies for climate change communication, many education and communication efforts intended to reduce this gap focus on conveying climate change data and facts. Therefore, understanding how knowledge and fact-based education efforts, in additional to political factors, impact climate change beliefs and risk perception is critical.

Past studies have used measures of either subjective or objective knowledge of climate science or broader topics (e.g., Dong et al, 2018; Hornsey et al., 2016; Kahan et al., 2012; Libarkin et al., 2018) with relatively fewer experimenting with fact-based interventions (e.g., Courtney and McNeal, in revision; Ranney & Clark, 2016), and the results of these studies have been varied. Some researchers claim that educating the public about climate science may not impact climate change acceptance or could even increase polarization between cultural and political groups (Bolsen & Druckman 2018; Kahan et al., 2012). However, other studies have found significant gains from fact-based climate communication approaches, especially with younger audiences (Aksit et al., 2017; Courtney & McNeal, in revision; Ranney & Clark, 2016; Stevenson et al., 2014). Some authors have even implied that ineffective or polarizing outcomes may result from differences in measurement methods (Guy et al., 2014; Motta et al., 2019; Ranney & Clark, 2016; Shi et al., 2016).

However, there are many more factors that impact individuals' opinions, risk perception, and behavior related to climate change, which have been synthesized by several recent studies and meta-analyses. Goldberg and colleagues surveyed 2,063 registered voters and found that worry about global warming, risk perceptions, certainty that global warming is happening, belief that global warming is human-caused, and general affect toward global warming best predicted individuals' climate policy support. They also found that pro-climate injunctive norms and global warming risk perceptions caused the largest differences between Republicans and Democrats (2020). Hornsey and colleagues found in a 2016 meta-analysis that political affiliation is a strong predictor of climate change belief which then influences individuals' pro-environmental intentions, behaviors, and policy support; but other factors such as trust in scientists, perceived scientific consensus, experience of local weather change, and free-market ideology were equal or stronger predictors of climate change belief than political affiliation. In another study, van der Linden reviewed several empirical studies of climate change risk perceptions to develop and test a comprehensive model with predictors separated into categories of cognitive factors, experiential processing, socio-cultural influences, and socio-demographics (2015). These findings each have important implications for efforts to communicate climate change science to the public as a means of working towards mitigation and adaptation.

Credibility and Consensus

As described above, individuals with different cultural backgrounds may have varied reactions to the same climate change information. However, there are varying theories about the mechanisms that produce these varied reactions, and one that is becoming more prominent in the literature is motivated reasoning (Akin et al., 2020; Bayes et al., 2020; Bolsen & Druckman, 2018; Druckman & McGrath, 2019). Motivated reasoning describes the motivations or goals an individual might have when processing information that may lead them to draw different conclusions (Bayes et al. 2020; Druckman & McGrath, 2019). Possible motivations, whether the individuals are fully aware of them or not, include partisan, identity-protective, accuracy, and values-driven motivations. The direction and degree of motivation can depend on the information presented, whether the individuals are primed or the information framed to encourage a certain motivation, or possibly the individuals' prior knowledge and values (Akin et al., 2020; Bayes et al., 2020; Bolsen & Druckman, 2018; Druckman & McGrath, 2019; Kahan et al., 2011). Thus, the intake of any climate change information is likely affected not only by cultural context but also the information itself and context in which it is presented.

In the case of scientific information in particular, then, individuals who are motivated to draw accurate conclusions (accuracy motivation) should be more impacted by and accepting of scientific climate change communication than those without any priming or with inconsistent priming (Bayes et al., 2020). However, information assimilation and acceptance in these cases may be heavily impacted by another factor, source credibility (Druckman & McGrath, 2019). That is, because the individuals are trying to draw accurate conclusions, they will accept information coming from sources that they perceive to be more trustworthy and their perceptions of credibility may be impacted by cultural and political factors (Akin et al., 2020; Dong et al., 2018; Jamieson et al., 2014).

This effect is exemplified by the work of Kahan and colleagues showing, among other effects, that individuals' perceptions of expert opinion is driven by their cultural worldview (2011). Additionally, self-described conservatives and people living in rural areas may trust federal science programs less than urban liberals, though American trust in scientists remains relatively high compared to other groups (Krause et al., 2019; Myers et al., 2017). Additionally, an individual's worldview can predict their perception of scientific consensus, i.e., whether "most expert scientists agree" or not (Kahan et al., 2011). These findings are important especially because awareness of the high consensus among climate scientists has been shown to increase risk perception and predict support for climate policy (Bolsen & Druckman, 2018; McCright et al., 2013; van der Linden et al., 2015). Thus, it is important to consider the effects that an audience's worldview and politics may have on their perception of who climate change experts are, what experts believe, and thus how the audience should interpret information from specific information sources.

In this study, we will build on these previous efforts by testing predictors of climate change belief and risk perception using a structural equation modeling approach. By using structural equation modeling, rather than correlation or regression, the relationships between predictors and multiple outcomes can be explored and tested in greater detail, and measurement of complex constructs such as risk perception is improved. Risk perception is often studied as an outcome in addition to belief in climate change because it is more directly tied to intentions to take climate action (Dong et al., 2018; Stevenson et al., 2014; van der Linden, 2015). Though there are many relevant relationships that would be beneficial to examine with a structural model, we are guided by the following research questions:

1. What is the effect of climate change knowledge on climate change belief and risk perception?
2. What are the direct and indirect effects of political ideology on climate change belief and risk perception?
3. Do perceptions of climate scientist credibility and consensus impact the effects of knowledge and politics on climate change belief and/or risk perception?
4. Does political ideology moderate the impacts of other factors on climate change belief and/or risk perception, especially impacts of scientific knowledge?

Methods

Participants

Undergraduate students at a large public university in the southeast U.S. were recruited via emails sent to large introductory classes and flyers around campus. Participants were most actively recruited from May to November of 2018 and June to July of 2019, but there were also responses between those recruitment periods. Respondents were offered a chance to win one of several $50 online gift cards, in accordance with the approval for this project from the Auburn University IRB (#18-085 EP 1803). 1,059 participants began the survey, but only the data from the 722 participants who completed the survey were retained since the incomplete responses each lacked data for at least one entire construct. Additionally, data exploration revealed that the 18 individuals who did not pass the attention check question had significantly different responses than other participants, specifically a much higher proportion of zero scores on the knowledge assessment, so their data was also removed. Last, there were several questions throughout the survey that had *I don't know* options, which cannot be analyzed ordinally and were not relevant to our research questions. Thus, we excluded the data of 24 individuals who had 4 or more *I don't know* responses (out of six possible) and an additional 5 who answered *I don't know* to half or more of the questions measuring any given construct. However, excluding all participants who decline to answer or provide *I don't know* or *not applicable* responses can bias survey samples (Holman et al., 2004). Thus, the final sample included 675 participants and the remaining *I don't know* responses (n=56 participants) were marked as missing and statistically imputed. Multiple imputation was completed in MPlus software using a Markov Chain Monte Carlo resampling method and the WLSMV estimator, both appropriate for ordinal data (Asparouhov & Muthén, 2010; Jia and Wu, 2019).

Measurement and Analysis

The survey included instruments to measure climate change knowledge, source credibility, risk perception, scientific consensus, and background items such as STEM class experience and demographics including political ideology and gender (Appendix 4.1). Climate change knowledge was measured using a 21-item climate change concept inventory and we also included several items used by previous authors alongside the concept inventory including questions about belief in climate change, perception of scientific consensus on climate change, and participants' opinion of "the environmental movement" (Aksit et al., 2017; Libarkin et al., 2018; other items also used by McCright et al., 2013). Source credibility was measured using an 18-item instrument from McCroskey and Teven (1999) by inserting "climate scientists" as the information source of interest. We used items often deployed by the Yale Program on Climate Change Communications to measure risk perception (6 questions) and perception of scientific consensus surrounding anthropogenic global warming (1 question; Leiserowitz et al., 2017). Most of the survey items were Likert-type multiple choice questions with three to five response options and many had high skew and kurtosis, so the items with six or fewer response options were treated as ordinal variables (Table 4.1). Initial frequencies, crosstabs, and zero-order correlations were reviewed to ensure that the variables were coded correctly (including reverse-coding) and the relationships between variables were reasonable.

Where possible, latent variable analyses were used, which can provide more reliable measurements of abstract constructs by accounting for both measurement error and multiple dimensions of a construct of interest. Latent variable methods include any analyses where multiple observed variables, or indicators, are used to estimate the value of an unobserved construct. For the climate change knowledge construct, instead of using summed scores on the problems, we used item response theory which treats each question as an indicator of participants' latent ability.

Table 4.1

Survey questions used and measurement summary

Construct	Item(s) or instrument	Item measurement level
Climate change content knowledge	21-item concept inventory reduced to logit scores	Logit scores are continuous

Perception of risk from global warming	6-item instrument	Ordinal, 4 to 6 levels
Perception of climate scientists' credibility	18-items reduced to scores on 3 sub-constructs	Original items had 7 levels, factor scores are continuous
Perception of scientific consensus	2 items	One ordinal (4-level), one continuous
STEM class experience	2 items	Ordinal, 4 to 5 levels
Belief climate change is happening	1 item	Ordinal, 4-level
Relationship to the environmental movement	1 item	Ordinal, 4-level
Religious/worship activity	1 item	Ordinal, 5-level
Gender	1 item	Text-entry coded into "woman" or "other genders" (binary)
Racial identity	1 item	Multiple choice and text entry coded into "only white" or "additional identities" (binary)

We followed the example of previous authors by running a single-parameter Rasch analysis on the concept inventory which produced log odd unit (logit) scores for the performance of each individual (Aksit et al., 2017; Libarkin et al., 2018). Since the other constructs concerned perceptions and identities rather than knowledge, confirmatory factor analysis was used to estimate participants' risk perception of climate change, perception of scientific consensus surrounding climate change, perception of climate scientist credibility, and STEM experience, which was used to predict climate change knowledge. The credibility instrument had a two-order structure, where 18 survey questions were indicators of three sub-types of credibility, which themselves measure the broader construct of credibility. To ensure the final models remained interpretable and consistent, the first-order measurement model was run separately to generate each participant's score for each sub-type of credibility (competence, trustworthiness, and goodwill). These factor scores were then used to estimate the overarching construct of credibility in final models. Before any structural (causal) models were investigated, the full measurement model was analyzed, including all indicators of latent variables and correlations between the latent variables.

However, some constructs were represented by only one survey item (single indicators), specifically belief in global warming, relationship to the environmental movement, political ideology, gender, and frequency of religious service attendance (worship). For these items, a small random error term of 0.10 (10% of each item's variance) was added to simulate measurement error which provides more realistic results than presuming the items have no measurement error (Kline, 2016). The final model was also tested by setting the error levels of each single indicator variable to 0.0, 0.5, 0.15, and 0.2 to evaluate the sensitivity of the model to measurement error. This test showed that the structure and fit of the model were robust to measurement error with no detectable variation in the global fit estimates recorded (robust CFI and RMSEA). Higher error levels resulted in some change in path coefficients and the R^2 value of outcome variables which is to be expected since higher error terms allow for over-fitting of the data (modeling error in addition to relationships between variables). Of the key paths compared, the one that varied the most from the 0.0 to 0.2 error had a 0.068 change in its standardized estimate (0.145 to 0.213) and the path that varied the least had only a 0.002 difference between estimates. This variance was judged to be acceptable and the .10 error level was maintained for analysis.

The final structural equation model (SEM) was developed using a model-building approach rather than hypothesis-testing approaches which are more common for regression and mean-comparison methods. Model-building approaches can be used to examine complex phenomena in much greater detail than univariate methods or modeling approaches that seek only to confirm or deny the plausibility of single models (Kline, 2016; Rodgers, 2010). In this case, the model-building approach was informed by the outcome variables and causal relationships of interest such that model complexity was increased over time to examine the impact of new variables and paths to the overall model. Causal relationships between variables were added based only on theory and findings from previous climate change communication research. *R* version 4.2.0 was used for all analyses, the package *lavaan* was used for latent variable modeling, the package *eRm* for item response modeling (Rasch analysis), and functions from additional packages for data exploration and visualization (Mair et al., 2021; R Core Team, 2022; Rosseel, 2012). The *lavaan* defaults for ordinal variables were retained, including diagonally-weighted least squares (DWLS) estimation and printing both standard and robust fit statistics (often combined as WLSMV estimation).

Models were assessed by examining their local fit, i.e. the factor loadings on latent variables and path coefficients between variables, and global fit, i.e. commonly used statistics for overall fit. Statistics softwares often print the results of significance tests alongside factor loadings and regression coefficients, so evaluation of local fit will include some consideration of coefficient *p*-value ($\alpha = .05$) but focus primarily on the result of the standardized estimate, i.e., whether each variable predicts a sizeable change in another. Additionally, the R^2 value for the important outcome variables, belief and risk perception, will be compared between models to understand whether certain variables and structures best explain the total variance in those constructs. Last, the change in regression and factor coefficients between models, including direct and indirect effects of predictor variables and variance explained in key outcomes, will be compared across models to better understand underlying causal structures.

The global fit statistics and reference values for acceptable fit were determined before modeling was begun, though these values were not intended to serve as strict binary thresholds for acceptable or unacceptable model fit, especially because most make comparisons to unrealistic baseline models (Kline, 2016). We chose to use: the standardized root mean squared residual

(SRMR) with better fit indicated by values lower than 0.08; the root mean squared error of approximation (RMSEA) with better fit indicated by values lower than 0.06 and the 90% confidence interval lower than 0.1; and the comparative fit index (CFI) with better fit indicated by values greater than 0.95 (Hu & Bentler, 1999). Notably, most of these statistics penalize model complexity, so in general we expect the statistics to worsen with the addition of new variables, but the values may still assist in comparison of similar models.

The results below include some comparisons between models but the majority of our presented results describe the final model chosen based on a combination of global and local fit. In addition, the accepted model was used as the basis for the moderation analysis which was completed using multi-group SEM, since the moderator of interest, political ideology, was ordinal. For this analysis, the political ideology variable was completely removed from the model, and the model was instead run separately for three separate groups of participants based on their political ideology. The contrast between the unstandardized model estimates was then tested statistically with a one-way analysis of variance (ANOVA) between the liberal and conservative groups.

Results

Participants and measures

The final sample of 675 individuals included 554 individuals (82.1%) whose racial identity was only white or caucasian, compared to 121 individuals (17.9%) of multiple or additional identities, and 381 (56%) who identified as women, compared to 294 men and individuals of other genders (43.6%). 57 described themselves as very conservative, 226 as conservative, 260 as middle-of-the-road, 98 as liberal, and 34 as very liberal (8.4%, 33.5%, 38.5%, 14.5%, and 5%, respectively). Because the number of participants in the extreme groups was too small for separate model runs, for the moderation analysis the participants were collapsed into three groups such that very conservative and conservative participants (n = 283) and liberal and very liberal (n = 132) participants were combined (middle-of-the-road participants stayed in their own group). 55 participants (8.1%) were *not at all sure* that climate change is happening, 210 (31.1%) were *somewhat sure*, 201 (29.8%) were *very sure*, and 209 (31%) were *extremely sure*. On average, the participants estimated that 78.3% of climate scientists think that human-caused global warming is happening (*SD* = 16.2). The median score on the concept inventory was 10 correct questions out of 21 (*M* = 10.18, *SD* = 3.0) which corresponded to logit scores ranging from -4.78 to 3.80 (*M* = -0.10).

The measurement model, which included the latent variables of STEM experience (2 indicators), perception of scientific consensus (2 indicators), risk perception (6 indicators), and climate scientist credibility (3 second-order indicators; see above) fit the data well. One of the indicators of STEM experience was not statistically significant ($p = 0.152$), but the standardized loading was large enough that the indicator was retained (0.541). All of the other indicators had *p*-values <.001 and standardized coefficients ranged from 0.517 to 0.984. After the measurement model was accepted, structural models were run iteratively with the addition or subtraction of one to three variables, covariances, or causal paths at a time, based on both theory and empirical observations of previous models. The global and local fit statistics were recorded for each model run and select models are compared on that basis below (Table 4.2). When it was determined that additional changes to the model did not meaningfully improve model fit, the final model was selected.

As summarized in Table 4.2, all of the models tested had good fit according to the reference values chosen for SRMR and CFI for both standard and robust calculations of the statistics. All of the models also had suitable standard RMSEA values and 90% C.I. RMSEA values for both standard and robust calculations, though a few of the models had robust RMSEA values up to 0.076 (above the reference value of 0.06). However, no models were rejected based on RMSEA alone and every model was evaluated by the criteria discussed above. Because all of the models had high global fit statistics, our model building focused on increasing the variance explained (R^2) of the key outcomes of risk perception and belief while not greatly increasing the complexity of the model. Towards the end of the process, it became clear that additional paths and covariances increased the R^2 value only marginally and resulted in poor local fit (small regression and covariance estimates). The final model chosen was therefore selected by the researcher to balance of global fit statistics, R^2 of risk perception, coefficient estimate significance and strength, and interpretability (Figure 4.1).

Table 4.2

Model comparison summary

Model description	SRMR	CFI	RMSEA	R^2		Total effect of politics on	
	(Robust)	(Robust)	(Robust)	Belief	Risk	Belief	Risk
Measurement model	0.034	.992	0.067	N/A	N/A	N/A	N/A
Initial model	0.035	.996	0.062	0.319	0.408	0.479	0.474
Demographic and cultural predictors added	0.034	.994	0.062	0.421	0.479	0.361	0.327
Consensus and credibility added	0.050	.980	0.072	0.574	0.500	0.525	0.471
Final model (Figure 4.1)	0.036	.989	0.054	0.595	0.517	0.457	0.391
Multi-group SEM for moderation analysis	0.044	.962	0.035	varied	varied	N/A	N/A

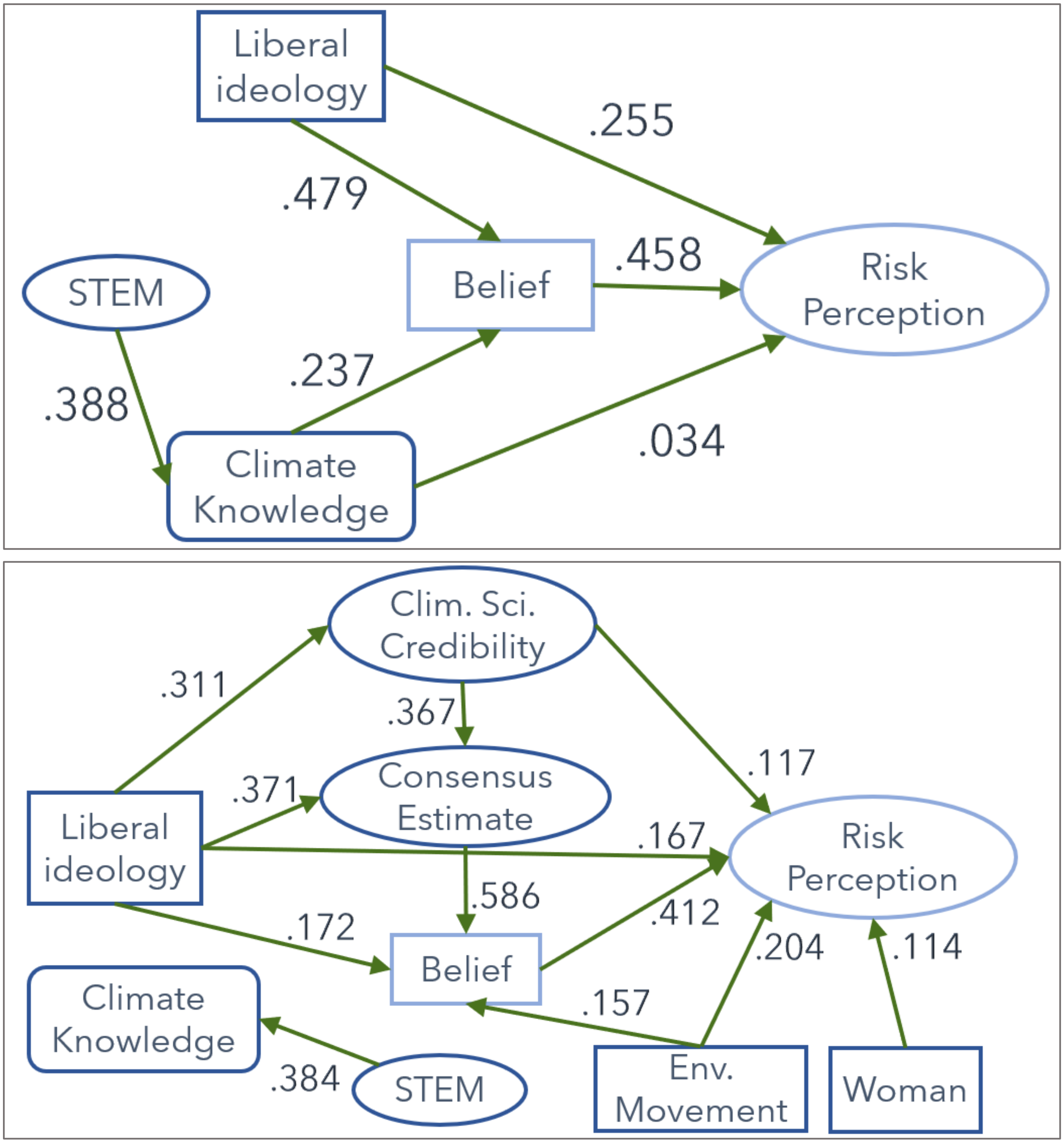

Figure 4.1. Diagrams of the initial (top) and final (bottom) structural models used in this study. Included are predictors (green boxes) of belief in and perception of risk associated with climate change (yellow boxes). The standardized path coefficients are overlain on each regression path (arrows) and model covariances are not shown. All paths are p <.005 except risk perception regressed on climate knowledge in the initial model which is p > .1

Research question 1: Impacts of climate change knowledge

In models with fewer predictors, such as the initial model, the effect of climate change knowledge on belief were significant (0.291 using standardized coefficients) and reduced only slightly when additional demographic items were added. However, the effects reduced dramatically when scientific consensus and credibility were added, to total effects of 0.037 and 0.002, respectively. Because causal paths from climate change knowledge or STEM experience were removed during model refinement and there was not a theoretical basis for adding more, the constructs appear separate from the main regression structure in the final model. However, climate change knowledge has high correlations to other constructs in the model, many of which are direct predictors of global warming belief and/or risk perception (Table 4.3).

Table 4.3

Correlations (standardized covariances) included in final structural model

	1	2	3	4	5	6	7	8
1. Risk P.								
2. Belief								
3. Credib.								
4. Consen.								
5. Knowl.	.033		.123**	.318**				
6. STEM				.226*				
7. Liberal					.133*	.069		
8. Enviro.			.260**	.209**	.203**	.012	.362**	
9. Woman			.078	-.300**	-.108*	-.132*	.085*	.197**

Note. * indicates $p < .05$, ** indicates $p < .005$

Research question 2: Impacts of political ideology

In contrast, the indirect and total effects of political ideology on the outcomes stayed relatively stable between tested models; however, the distribution of effects changed greatly with the addition of new variables and paths. The total effect of political ideology (using standardized coefficients) on risk perception is 0.391 in the final model compared to 0.474 in the initial model, and the direct effect fell from 0.255 to 0.167. The total effect on belief in the initial model was .479 (direct only) compared to 0.172 direct and 0.457 total effect in the final model. Notably, in the final model, political ideology has greater indirect effects on both belief and risk perception than direct effects and larger direct effects on both climate scientist credibility and consensus than on belief or risk perception. Much of the shared variance of ideology and risk perception is spread throughout different paths in the model, but the strong relationship between participants' estimate of scientific consensus and belief in climate change (0.586 coefficient) is a large contributor. There is also a significant correlation between ideology and participants' relationship to the environmental movement, which in turn has significant effects on belief and risk perception. However, there was no apparent theoretical basis for adding a causal path that could have clarified the relationship between environmentalism and political ideology.

Understanding these relationships, as well as possible dynamics of the moderation analysis below, may also be enhanced by comparing participants' scores on different components of the survey by political ideology. Like in the moderation analysis, ideology was collapsed to three groups from five (conservative, moderate, liberal; Table 4.4).

Table 4.4
Means and standard deviations of scores by political ideology

Observed Variables	Range	All	Con.	Mod.	Lib.
Number of participants		675	283	260	132
Women (proportion of participants)		0.56	.052	0.57	0.64
Belief / Certainty that C.C. is happening	1 – 4	2.84 (0.96)	2.41 (0.88)	2.92 (0.91)	3.59 (0.68)
Relationship to the enviro. movement	1 – 4	2.77 (0.68)	2.57 (0.71)	2.78 (0.61)	3.17 (0.56)

C.C. knowledge (adjusted logit scores)	-2.78 – 5.80	1.90 (0.95)	1.79 (0.91)	1.94 (0.99)	2.07 (0.91)
Latent Vars. (factor scores)					
Risk from climate change	-1.84 – 1.40	-0.01 (0.66)	-0.32 (0.63)	0.07 (0.59)	0.47 (0.52)
Climate scientists' credibility	-3.16 – 1.34	0.00 (0.86)	-0.23 (0.82)	0.05 (0.75)	0.38 (0.90)
Climate scientists' consensus	-0.69 – 0.53	0.00 (0.25)	-0.13 (0.22)	0.02 (0.22)	0.22 (0.20)
Recent STEM experience	-1.49 – 0.94	0.00 (0.38)	-0.02 (0.37)	0.00 (0.37)	0.05 (0.40)

Note. C.C. is short for climate change;

Research question 3: Credibility and consensus

Perceptions of climate scientists' credibility and consensus surrounding human-caused global warming are important predictors of both belief and risk perception. The total effects on risk perception in the final model are 0.206 from credibility and .241 from consensus (indirect only), and the total effects on belief are 0.215 from credibility (indirect only) and .586 from consensus. Consensus is by far the strongest predictor of climate change belief and the most powerful direct predictor in the entire model. Additionally, both constructs have strong correlations to other variables in the model, largest among them the relationships between consensus and climate change knowledge ($r = .318$, $p < .005$) and gender ($r = -.300$, $p < .005$), where women in this sample had significantly lower estimates of scientific consensus than participants of other genders. Perceptions of climate scientists' credibility and consensus are also strongly predicted by political ideology. Out of the total effects of political ideology on belief (0.457) and risk perception (0.391), over half of the effect on belief (0.284) and over a third of the effect on risk perception (0.154) come from a path including consensus and/or credibility in this model.

Research question 4: Moderation by political ideology

The effects of political ideology as a moderator of other relationships was tested with multi-group SEM, where participants were separated into groups based on their conservative, moderate, or liberal political ideologies (Table 4.4). The final model was used as the basis for the multigroup model, however climate change knowledge was added back as a predictor on both belief and risk perception in order to test whether there were differences between groups. Though the statistical power was reduced due to smaller sample sizes and estimates vary between groups, most of the predictive relationships were still statistically significant within each group. Climate change knowledge was not a significant predictor of belief for conservatives or liberals or a significant predictor of risk for conservatives or moderates, and gender was not a significant predictor of risk perception among liberals ($p \geq .10$). For the conservative group, the model explained 56.1% of the variance in belief and 42.6% of risk perception; for the moderates, 37.6% of the variance in belief and 35.6% of risk perception; and for the liberals, 32.9% of the variance in belief and 44.8% of variance in risk perception was explained.

The largest predictor of conservative and moderates' perception of risk from global warming was their belief that climate change was happening, whereas the largest risk perception predictor for liberals was their relationship to the environmental movement (though there may have been some ceiling effects with belief since 69% of liberals chose the highest category). One notable difference is the effect of participants' awareness of scientific consensus on their belief in climate change. While the coefficient is large in all three groups and across groups in the main model, the standardized regression coefficient of 0.716 for conservative participants is the highest observed in this study. Other coefficients had different predictive power in different ideological groups. Being a woman positively predicted risk perception among conservatives and moderates but was not a strong predictor for liberals, and liberal women had less STEM experience than liberal men (-0.370), where there was not a statistically significant difference among conservatives (0.040). Last, there were some estimates that were more similar between liberals and conservatives than either with moderates, including their slightly higher predictive power of credibility on consensus (0.492 and 0.513 compared to 0.354) and their climate change knowledge being predicted less by general STEM experience than moderates (0.310 and 0.336 compared to 0.560). The ANOVA results showed that all the regression and covariance estimates were significantly different between the liberal and conservative participants ($p < .001$).

Table 4.5

Moderation analysis results from multi-group SEM

Regressions	Conservatives (n = 283)			Moderates (n = 260)			Liberals (n = 132)		
	B	S.E.	β	B	S.E.	β	B	S.E.	β
Risk ~ Belief	**.646**	**.098**	**.441**	**.376**	**.090**	**.373**	.219	.133	.203
Risk ~ Cred.	.193	.082	.141	.146	.076	.130	.236	.109	.304
Risk ~ Gender	**.409**	**.148**	**.163**	.268	.126	.146	-.008	.133	-.006
Risk ~ Env.	**.395**	**.111**	**.226**	**.361**	**.134**	**.243**	.326	.184	.260
Risk ~ Know	.032	.075	.025	-.032	.063	-.036	.212	.088	.288
Know ~ STEM	**.671**	**.244**	**.310**	**1.174**	**.436**	**.560**	**.506**	**.189**	**.336**
Belief ~ Cons.	**2.354**	**.690**	**.716**	**1.293**	**.378**	**.439**	.748	.311	.410
Belief ~ Env.	.186	.129	.155	.258	.142	.175	.254	.165	.218
Belief ~ Know	-.045	.109	-.051	**.164**	**.061**	**.186**	.063	.076	.092
Cons. ~ Cred.	**.140**	**.037**	**.492**	**.135**	**.046**	**.354**	**.202**	**.063**	**.513**
Covariances	Est.	S.E.	Std.	Est.	S.E.	Std.	Est.	S.E.	Std.
Know & Cred.	**.169**	**.060**	**.223**	-.006	.060	-.010	-.069	.127	-.099
Know & Cons.	**.082**	**.029**	**.440**	**.050**	**.019**	**.225**	**.145**	**.044**	**.613**
Know & Env.	.048	.046	.082	.075	.054	.159	.090	.057	.209
Know & Gender	-.055	.028	-.134	-.027	.035	-.071	-.071	.043	-.188
STEM & Env.	.032	.032	.112	.032	.042	.120	-.020	.037	-.064
STEM & Cred.	-.001	.037	-.003	.070	.038	.198	.126	.084	.254
STEM & Gender	.008	.016	.040	-.042	.024	-.190	**-.099**	**.038**	**-.370**

Note. Gray lettering represents statistical insignificance ($p \geq .10$), plain text represents $p < .10$, bold represents $p < .01$.
Tilde (~) reads as "regressed on", and thus comes between the outcome (left) and predictor (right) variables.
Included are all regressions and only those covariances that included either STEM Experience or climate change knowledge (CI score). Estimates of regression and covariance coefficients are from a model standardized with respect to the variance of latent variable indicators whereas standardized estimates are fully standardized to latent and observed variables.

Discussion

In this study, we used an online survey and structural equation modeling to better understand the complex relationships between climate change knowledge and perceptions among undergraduate students in the Southeast U.S. We were motivated to investigate the impacts of scientific knowledge and perceptions of climate scientists based both on our own expertise and on prominent theories presented in the literature. By using a model-building approach, which allows for testing multiple theoretically-justified relationships and reliable measurement methods, this study may present an important contribution to this field of research, especially since some authors have attributed contradictory findings to measurement differences (Motta et al., 2019; Shi et al., 2016).

Indirect influences of STEM experience and climate change knowledge

When tested across ideological groups, we did not find evidence of direct impacts of climate change knowledge on belief in or risk perception of climate change. We only evaluated direct effects on the outcome variables because we did not have a specific theoretical basis for regressing other constructs on climate change knowledge, i.e., on awareness of scientific consensus or perceptions of climate scientists' credibility. However, the covariances between these constructs, which were included in the final model, demonstrate strong relationships that deserve future investigation. The multi-group analysis found evidence for some direct impacts of specific climate change knowledge as a predictor of belief for political moderates and the second-largest predictor of risk perception for liberals. This implies that climate change knowledge is important to some climate change perceptions depending on the individual's political ideology, which is discussed in further detail below. Since our study is correlative rather than experimental or longitudinal, we cannot confirm the causality of these relationships, but many other studies have found direct effects of scientific knowledge and instruction on climate change belief and risk perception (Aksit et al., 2017; Ranney and Clark, 2016).

Gender was not initially a variable of interest in this study, but by closely examining the impacts of STEM experience and climate change knowledge, the related impacts of gender became unavoidable. Specifically, the data showed that the women in our sample tended to have significantly less STEM experience than people of other genders, and since STEM experience strongly predicted climate change knowledge, this dynamic could account for women's lower performance on the climate change concept inventory. Further, though we did not test these relationships causally, covariance with STEM experience could also explain women's relatively lower awareness of the scientific consensus surrounding climate change. Therefore, women's relatively lower participation in STEM could have impacts down the causal chain of climate change beliefs. The moderation analysis provides further of evidence of this possibility because the liberal grouping shows the largest STEM gap by gender and is the only group where gender is an insignificant predictor of climate change risk perception. In the whole-group model, gender is a positive predictor of risk perception, but to a smaller degree than shown in either of the partitioned groups of conservatives and moderates. The dynamics between gender and specific climate change knowledge is less clear, where both liberals and conservatives have a significant gender gap but moderates do not or at least have a far smaller gap. Women's higher rates of environmentalism and liberalism may contribute to their climate change risk perception, but further investigation into possible differences is needed. In particular, a better understanding of women's participation in STEM and the Earth sciences should be a goal of future research to advance climate change action across genders.

Culture to credibility to consensus to correct conceptions

The impacts of source credibility and scientific consensus have been discussed widely in climate change communication literature. Specifically, the work of Kahan et al. (2011) and van der Linden et al. (2015) on the role of scientific consensus in climate change perceptions have been debated and tested since their publishing (among many other authors). In this study, we hoped to investigate the theories advanced by these authors and found evidence that supports both of their claims. Van der Linden et al. proposed that awareness of the high scientific consensus surrounding human-caused climate change serves as a "gateway belief" that significantly increases individuals' acceptance of climate change, concern about it, and support for public action to address it (2015). Our findings greatly aligned with theirs and showed that awareness of scientific consensus is a much better predictor of climate change belief than political ideology or relevant knowledge alone. In addition, both studies found an increased impact of consensus effects on individuals with conservative political ideologies, which could be important for engaging new audiences with climate change policy and action. Though our study cannot speak to the effectiveness of any active messaging, authors including Bolsen and Druckman (2018), van der Linden et al. (2014), and Chinn et al. (2018) have provided evidence of the reliability of consensus communication.

We also hoped to understand what factors might influence and result from an individual's perception of scientific consensus, so we based the causal paths in this study on the theory of cultural cognition of risk advanced by Kahan et al. (2011). This theory connects discrepancies often observed in opinions on scientific risks between members of differing political parties to their information assimilation and resulting perceptions of scientific consensus. Specifically, the authors posit that individuals' ideologies influence their perceptions of source credibility which leads to greater information assimilation from sources who they believe share their worldview. Thus, someone's awareness of "what experts think," important to the formation of their own beliefs and risk perceptions, depends on their perception of who the experts are. Our study provides evidence for this by showing that the impact of political ideology is greater on individuals' perceptions of climate scientists, both credibility and consensus, than on their belief or risk perception of climate change directly. Specifically, out of the total effects of ideology, over half of the influence on belief in this study results from paths that include perceptions of climate scientist credibility and consensus. Last, our study validated the relationship between individuals' judgements of credibility and consensus, at least concerning climate scientists.

Few statistical studies before ours have included each of these factors in one model, but many others have provided consistent evidence for each path of our final model. For example, there is plentiful evidence that individuals with liberal ideologies, usually including Democrats, tend to have greater overall trust in science (Hamilton et al., 2015; Myers et al., 2017; Visschers, 2018) and governments, which fund the majority of climate science (Pechar et al., 2018). Trust in science has been shown to moderate the impact of scientific consensus messaging (Chinn et al., 2018) and predict perceptions of multiple kinds of uncertainty in climate science (Visschers, 2018). As discussed above, awareness of climate scientists' consensus is reliably demonstrated to have large impacts on climate change beliefs (Hornsey et al., 2016; McCright et al., 2013). Additionally, our study and others have found large influences from individuals' environmental ideologies and identities, especially on risk perception and support for policy (Aksit et al., 2017; Hornsey et al., 2016; McCright et al., 2013).

Ideology moderates relationships between climate change perceptions

Political ideology and affiliation are known to impact a variety of climate change perceptions including belief and risk perception (Hornsey et al. 2016; Libarkin et al., 2018; McCright et al., 2013). However, there is disagreement in the literature about the moderating power of politics on other climate change belief and perception formation, especially knowledge and education. Some authors have found that political ideology moderates the effect of education and science literacy on climate change perceptions, such that more educated people have more polarized views by political party than less educated or knowledgeable individuals (Bolsen and Druckman, 2018; Hamilton et al., 2015; Kahan et al., 2012). Others have found that education and climate literacy can decrease political polarization (Guy et al., 2014; Ranney and Clark, 2016), especially with adolescent (Lawson et al., 2019; Stevenson et al., 2014) and college-aged groups (Aksit et al., 2017; Bedford, 2016; Courtney & McNeal, in revision). Science interest in adolescence may even be associated with greater trust in climate scientists in adulthood (Motta et al., 2018).

Our multigroup analysis provides evidence that political ideology moderates the impacts of STEM experience and climate change knowledge on other perceptions. However, we did not find any clear evidence of polarization. Polarization, as described in previous works, would be indicated by negative effects of knowledge on belief or risk perception among conservatives. Instead, climate change knowledge positively predicts risk perception, but only among liberals, and belief that climate change is happening, but only among moderates, and has insignificant direct effects on both among conservatives. The coefficient describing the effect of knowledge on belief for conservatives is technically negative; however, the error term of the estimate is larger than the estimate itself, so this effect does not appear meaningful ($p > .5$). That coefficient, however, is also part of the reason that the indirect and total effects of knowledge on risk perception are also negative for conservatives, but these effects are very small (-0.032 and -0.016, respectively). In contrast, the direct, indirect, and total effects of knowledge on risk perception for liberals are all positive. Thus, while we did not find compelling evidence of polarization, the data doesn't rule it out, either.

The relationships between STEM experience and climate change knowledge and other predictors show that knowledge could have other positive indirect effects that we did not test in this study. Though conservatives had a small negative effect of knowledge on belief, their climate change knowledge was positively associated with their perceptions of both climate scientists' credibility ($r = .223$) and scientific consensus ($r = .440$). There were not theoretical grounds to test these relationships causally, but it is possible that climate change knowledge (or experiences that increase such knowledge) could impact conservatives' perceptions of climate science and scientists, which are both shown to have large positive effects on their belief and risk perception of climate change. Additionally, specific climate knowledge was correlated with conservatives' judgments of credibility (not true of moderates and liberals), and conservatives tended to have lower specific climate knowledge, showing an opportunity for improved education and communication. These findings highlight the possibility for STEM experience, perhaps especially Earth and climate science experience, to advance climate change risk perception and motivation regardless of individuals' political affiliations.

Though the moderation analysis focused on comparing conservatives and liberals, the results concerning political moderates could also inspire important future research. For example, the relationship between moderates' general STEM experience and specific climate change knowledge was far larger than conservatives' or liberals' ($\beta = .560$ as opposed to .310 and .336, respectively). While our study did not address any possible causes of this contrast, it could be related to variations in the individuals' knowledge seeking or avoidance, which are related to a variety of relevant social and cultural factors (Yang & Kahlor, 2013). Additionally, because we did not find evidence of polarization related to STEM experience or climate change knowledge, these results reinforce the potential of scientific communication for increasing climate change awareness and risk perception, especially from sources like NASA who tend to be trusted even by political conservatives (Akin et al., 2020; Leiserowitz et al., 2022).

Our comparison between individuals of varying political ideologies revealed other important findings concerning the effects of gender and relationships to the environmental movement. As discussed above, the conservatives had no detectable gender gap in STEM experience whereas liberal women had significantly less STEM experience than their peers, and moderate women fell in between. The above discussion illustrates how this gendered STEM gap could negatively influence women's acceptance and worry about climate change, which may also be evidenced by the neutral to negative direct effect of gender on risk perception seen only among liberals (statistically insignificant negative direct effect). However, women and liberals were more likely to sympathize with the environmental movement, which was also a greater predictor of climate change risk perception among liberals. Ultimately, each of these findings, and this study in general, clearly demonstrate the importance of climate change communication strategies that are tailored to specific audiences.

Conclusions

Our study emphasizes the importance of broader perceptions of climate science and scientists to individuals' perceptions of risk associated with global warming which other studies have shown to predict climate change action and policy support. Further, different perceptions were more important to climate change belief than risk perception, and vice versa, showing that future research and communication efforts must thoroughly address both. Communication efforts tailored toward distinct audiences including women, scientists, environmentalists, etc. may want to consider how individuals of varying identities form their perceptions of climate change risk and reality differently. For example, this study and others have implied that communication of the scientific consensus surrounding climate change could be especially important to the engagement of political conservatives. Conservatives were also the largest political group represented in our sample and in the region where this study took place, the Southeast U.S., where climate change acceptance and risk perceptions tend to be lower than the U.S. average (Howe et al., 2015).

We also wanted to add to existing literature concerning scientific source credibility and consensus in relation to risk perceptions. The results of our model-building process and excellent fit of our data to the model are consistent with theory of cultural cognition of risk advanced by Kahan et al. (2011). Our findings show that, within and across political groups, judgements of climate scientists' credibility predict an individual's judgement of climate scientist consensus, which in turn predicts up to 71.6% of the variance in climate change belief depending on the group. Future work can elaborate on our findings by using qualitative or experimental methods to better understand how these perceptions are formed, what interventions and experiences can facilitate them, and therefore how improved climate communication can reduce harm from climate change.

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Chapter 5: Conclusion

Education efforts among the general public are a critical component of reducing harm from climate change, especially when tailored to specific audiences and contexts (IPCC, 2018). Tailored information is especially important because individuals' climate change perceptions and opinions are related to their worldviews, cultural affiliations, subjective and objective knowledge, perceptions of climate scientists, and social norms (Goldberg et al., 2021; Hornsey et al., 2016; Leiserowitz et al., 2021). Many of these factors also influence individuals' perception and intake of new information, which is important for implementing effective communication strategies (Bostrom et al., 2013; Chinn et al., 2018; Kahan et al., 2011; Ranney & Clark, 2016).

Some communication strategies, therefore, have been shown to be more effective than others, within and across audiences. One such example is the communication of scientific consensus surrounding climate change, or the fact that 97 to 100% of climate scientists agree that human-caused climate change is happening and poses a threat to human lives (Cook et al., 2016). Communicating this scientific consensus has repeatedly shown effectiveness in increasing belief in climate change and support for climate policy (Bolsen & Druckman, 2017; Chinn et al., 2018), enough that some researchers call it a "gateway belief" (van der Linden et al., 2015; Zhang et al., 2018). However, the effectiveness of this messaging strategy still requires audience awareness and nuance, as the acceptance of it may rely on perceptions of source credibility, including trust in climate scientists (Chinn et al., 2018; Kahan et al., 2011), which was addressed in chapter 4.

These points are reiterated to illustrate the value of specific and applied climate change communication research. Described above are studies which examine the interaction of defined audiences with defined units of climate change information which, because of the role of audiences' prior perceptions and the context of new information, are critical to drawing accurate conclusions about the impact of climate change communications which use climate science. This is one possibly reason why previous authors have found conflicting results in similar studies of climate change communication and perceptions, especially in relation to scientific knowledge (Shi et al., 2016). Specifically, there is conflicting evidence of whether science and climate science knowledge and instruction tend to increase (e.g., Bolsen and Druckman, 2018; Hamilton et al., 2015; Kahan et al., 2012) or decrease (e.g., Bedford et al., 2016; Guy et al., 2014; Ranney & Clark, 2016; van der Linden et al., 2018) discrepancies in climate change beliefs between individuals of varying political ideologies and worldviews. There is also evidence that some of these discrepancies can be attributed to variation in measurement methods and contexts (Kahan, 2015; Motta et al., 2019).

Thus, the studies described above contribute to previous literature in providing examples of robust measurement (chapters 2 and 3) and analysis (chapter 4) methods with respect to deliberate real-world audiences. Each study concerns the use of climate change science for forming opinions or making decisions, though the studies varied in whether science knowledge was assessed as an existing characteristic of participants (chapter 4), a tool to be applied by participants as professionals (chapter 2), or a public informal educational exposure (chapter 3).

The study which most examined possible mechanisms by which scientific knowledge has varying effects on individual opinions was chapter 4. This study revealed that specific climate change knowledge tended to increase liberals' risk perception of climate change and moderates' belief in climate change, but likely only affected conservatives' perceptions indirectly through their perceptions of climate scientists. Specifically, the finding that perception of scientific consensus was by far the primary determinant of conservatives' belief in climate change out of the influences studied furthers the existing body of literature about the importance of consensus communication. The connections to climate scientist credibility perceptions may also advance research on possible mechanisms of such differences, for example the theory of cultural cognition (Kahan et al., 2011) and studies of motivated reasoning (Druckman & McGrath, 2019). While our study did not include considerations of motivation, our findings in chapter 4 were aligned with the theory of cultural cognition, where individuals' cultural groups (political ideology) predicted both their ratings of climate scientists' source credibility and their awareness of climate scientists' consensus. Regardless of mechanism, political divides in climate perceptions including trusted sources of climate science, blame for global warming, and expectations of harm from either continued warming or government climate action are severe and thus important to understand (Leiserowitz et al., 2022).

Chapters 2 and 3, instead, concerned applications of climate science by individuals in their real lives rather than an online survey setting. This contextual difference has obvious benefits by elaborating on possible measurement methods for understanding the impact of climate science as it is already being funded, facilitated, and disseminated in the world. However, the limited topical scope of these projects also highlights some limitations of highly applied research. For example, other authors have written about the critical roles of source credibility and social trust in both of these fields as well, climate adaptation science (Dilling and Lemos, 2011; Schneider et al., 2019) and informal education (Hamilton & Ronning, 2020; Jones et al., 2020). The studies in chapters 2 and 3 were limited in participant time and attention, leading to increased focuses on perceptions of the science in both studies rather than possible mechanisms leading to those perceptions. Future work should undoubtedly continue to investigate the role of trust in increasing the use of climate adaptation science and the motivation and learning of museum visitors.

Another important limitation of chapters 2 and 4 is the lack of a specific connection to climate action. The value in climate change communication and studies of it is the possibility for reducing harm and saving lives from climate change. While both studies concerned risk perception of climate change, which is a predictor of climate action, including some measure of intention to take climate action, to talk about it with friends or family, to join a relevant community organization, etc., could have made these studies more valuable to the ultimate goal of mitigating and adapting to the climate crisis. Additionally, because so many of an individual's perceptions, understandings, and identities may be relevant to their motivation to take climate action, each of the studies described here is necessarily insufficient to fully describe the formation of climate change perceptions. These studies focused on the influences of scientific knowledge and information when, even for conservation professionals such as those described in chapter 2, the impact of physical science is often dependent on a wide range of other social relationships and dynamics (Edwards & Meagher, 2020; Meadow et al., 2015).

The results of these studies demonstrate that climate science and scientists influence individuals' perceptions of climate change beyond their socio-cultural contexts and will therefore continue to play important roles in engaging the public with the climate crisis. Each of these efforts are more effective when the information or communication tools used are tailored to an audience, context, and goal, and evaluations of those efforts can strengthen them further. Evaluation studies, such as those presented here, are opportunities for improving each of the specific organizations involved (i.e., the SE CASC, the Smithsonian NMNH) and ensuring effective tailoring, messaging, and implementation of future efforts. These studies add to the climate communication literature by demonstrating additional effects of climate change information use and perceptions based on participants' professional position and context (chapter 2); attention to and use of the information (chapter 3); and background characteristics including knowledge, political ideology, relationship to the environmental movement, and more (chapter 4). Communication of climate science by trusted public institutions, advancing positive and accurate portrayals of climate scientists, and increasing the use of climate science for decision-making and policy are all important opportunities to reduce harm from modern climate change. For these reasons, deliberate and appropriate climate change communication is a critical tool for both mitigation of and adaptation to climate change.

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Appendices

Appendix 2.1: Similar items used in previous literature

Organization
Author & Year: Lead author's last name, publication year
Question/Statement Location: e.g., appendix, question/statement number
Question/Statement: Unmodified, straight from publication
Question/Statement Context: e.g., online survey, in-person interview
Question/Statement Type: e.g., Likert scale, free response, etc.
Construct: Author-assigned construct code
Notes: Suggested team-assigned constructs; other important thoughts

Suggested Team-assigned Constructs

Use -	General	Stakeholder Engagement	Process
	Conceptual		
	Instrumental		
	Justification		

Literature

Kemp et al. 2015	10.5751/ES-07522-200217
Zviran et al. 2005	10.1080/08874417.2005.11645842
Doyle 2018	10.1080/07294360.2018.1504005
Evely et al. 2010	10.1017/S0376892910000792
Stokols et al. 2003	10.1080/14622200310001625555
Meagher et al. 2008	10.3152/095820208X331720
Morton 2015	10.1093/reseval/rvv016
Reed et al. 2014	10.1016/j.jenvman.2014.07.021
Kalafatis et al. 2019a	10.1007/s10584-019-02429-2
Kalafatis et al. 2019b	10.1175/WCAS-D-19-0002.1
Owen 2020	10.1016/j.gloenvcha.2020.102071

Other Sources
Western Water Assessment (WWA)
ACCCNRS Report 2015
SE CSC Review 2017

Author & Year	Question Location	Question/Statement	Question Context	Question Type	Construct
Kemp et al. 2015	App 1, pre #1	Do you use climate change science in the work you do? How?	Interview	Open-ended	Usefulness
Kemp et al. 2015	App 1, pre #2	Other than personal use, is your organization currently using science about climate change impacts? How?	Interview	Open-ended	Usefulness
Kemp et al. 2015	App 1, pre #3	Tell me what you think about the usefulness of climate change science in the work you do. What makes it useful or impedes its usefulness?	Interview	Open-ended	Usefulness
Kemp et al. 2015	App 1, #3a	*Are there organizational barriers that impede usefulness?	Interview	Open-ended	Usefulness
Kemp et al. 2015	App 1, pre #4	Are you aware of forest management actions that could reduce climate change impacts? (e.g., specific on-the-ground actions)	Interview	Open-ended	Usefulness
Kemp et al. 2015	App 1, pre #5	Are any of these actions being done now? Why or why not?	Interview	Open-ended	Usefulness
Kemp et al. 2015	App 1, pre #6	How confident do you feel in the ability of your organization/agency to take actions to reduce the potential impacts of climate change? Will they do it?	Interview	Open-ended	Usefulness
Kemp et al. 2015	App 1, pre #7	Do you have anything else you would like to add about what we have discussed today?	Interview	Open-ended	Usefulness
Zviran et al. 2005	Table 1, #1	Does the ERP system provide the precise information you need?	Questionnaire	Not specified, Numerical	Satisfaction
Zviran et al. 2005	Table 1, #2	Are you satisfied with the accuracy of the ERP system?	Questionnaire	Not specified, Numerical	Satisfaction
Zviran et al. 2005	Table 1, #3	Does the ERP system provide up-to-date information?	Questionnaire	Not specified, Numerical	Satisfaction
Zviran et al. 2005	Table 1, #4	Does the information content of the ERP system meet your needs?	Questionnaire	Not specified, Numerical	Satisfaction
Zviran et al. 2005	Table 1, #5	Is the ERP system user friendly?	Questionnaire	Not specified, Numerical	Satisfaction
Zviran et al. 2005	Table 1, #6	Does the ERP system provide sufficient information?	Questionnaire	Not specified, Numerical	Satisfaction
Zviran et al. 2005	Table 1, #7	Do you think the output is presented in a useful format?	Questionnaire	Not specified, Numerical	Satisfaction

Zviran et al. 2005	Table 1, #8	Does the ERP system provide reports that seem to be just about exactly what you need?	Questionnaire	Not specified, Numerical	Satisfaction
Zviran et al. 2005	Table 1, #9	Do you get the information you need in time?	Questionnaire	Not specified, Numerical	Satisfaction
Zviran et al. 2005	Table 1, #10	Is the information clear?	Questionnaire	Not specified, Numerical	Satisfaction
Zviran et al. 2005	Table 1, #11	Is the ERP system easy to use?	Questionnaire	Not specified, Numerical	Satisfaction
Zviran et al. 2005	Table 1, #12	Is the ERP system accurate?	Questionnaire	Not specified, Numerical	Satisfaction
Zviran et al. 2005	Table 5, #1	To what extent do you actually use the ERP system compared to your original expectations?	Questionnaire	Not specified, Numerical	Usefulness
Zviran et al. 2005	Table 5, #2	To what extent could you get along without the use of the ERP system?	Questionnaire	Not specified, Numerical	Usefulness
Zviran et al. 2005	Table 5, #3	To what extent does the ERP system assist you in performing your job better?	Questionnaire	Not specified, Numerical	Usefulness
Zviran et al. 2005	Table 5, #4	To what extent did you get along better on your job before the ERP system was implemented?	Questionnaire	Not specified, Numerical	Usefulness
Zviran et al. 2005	Table 5, #5	To what extent do you actually use the reports or output that are provided to you be the ERP system?	Questionnaire	Not specified, Numerical	Usefulness
Zviran et al. 2005	Table 5, #6	To what extent do data that you receive from the ERP system require correction?	Questionnaire	Not specified, Numerical	Usefulness
Zviran et al. 2005	Table 5, #7	To what extent does the ERP system overload you with more data than it seems you can possibly use?	Questionnaire	Not specified, Numerical	Usefulness
Zviran et al. 2005	Table 5, #8	To what extent does the ERP system provide reports to you that seem to be just about exactly what you need?	Questionnaire	Not specified, Numerical	Usefulness
Zviran et al. 2005	Table 5, #9	To what extent do you understand what the ERP system does in assisting you with your job?	Questionnaire	Not specified, Numerical	Usefulness
Zviran et al. 2005	Table 5, #10	To what extent is the ERP system troublesome for you, or difficult to operate, or to interact with, in order for you to get information to accomplish your job?	Questionnaire	Not specified, Numerical	Usefulness
Zviran et al. 2005	Table 5, #11	To what extent would you like the ERP system to be modified or redesigned all over again from the beginning?	Questionnaire	Not specified, Numerical	Usefulness

Zviran et al. 2005	Table 5, #12	To what extent is the ERP system actually used compared to the total number of people who potentially could be using it?	Questionnaire	Not specified, Numerical	Usefulness
Doyle 2018	Method (p. 1370)	What do you understand by the term research impact?	Interview	Open-ended	Research impact
Doyle 2018	Method (p. 1370)	How do you determine whether your research has had an impact?	Interview	Open-ended	Research impact
Evely et al. 2010	Identifying what the impacts… (p. 444)	What kind of impact do(es) your paper(s) have on colleagues and practitioners? (High, Moderate, Neither, Low, No)	Questionnaire	Likert	Impact
Stokols et al. 2003	App 1, #1.1	Recognizing that academic settings pose a variety of constraints or barriers to effective TDSC, what special circumstances or factors at your TTURC have enabled the group to get beyond and transcend these constraints?	Interview	Open-ended	Process
Stokols et al. 2003	App 1, #1.2	Are there ‘‘catalytic’’ or moderating factors that neutralize/offset interpersonal and institutional constraints on TDSC?	Interview	Open-ended	Process
Stokols et al. 2003	App 1, #1.3	Examples of institutional constraints on transdisciplinary collaboration in academic settings include: (a) tenure and merit review criteria that give priority to individual rather than collaborative achievements; (b) departmental chauvinism, or tendencies of university departments to favor one discipline over others; (c) bureaucratic structures within universities that make cross-departmental and inter-school collaboration more difficult; (d) highly evaluative and critical climates within academic settings that prompt clashes between competing theoretical and disciplinary perspectives, rather than inclusionist/ integrative thinking; and (e) increasing reliance on telework and solitary computer work as a substitute for more frequent face-to-face meetings among research team members.	Interview	Open-ended	Process
Stokols et al. 2003	App 1, #1.4	How have these obstacles to success been overcome within the context of your TTURC?	Interview	Open-ended	Process

Stokols et al. 2003	App 1, #1.5	What other kinds of barriers to effective TDSC have been encountered at each TTURC?	Interview	Open-ended	Process
Stokols et al. 2003	App 1, #2.1	What important collaborative successes and/or ‘‘missed opportunities’’ have occurred at your TTURC?	Interview	Open-ended	Process
Stokols et al. 2003	App 1, #2.2	Considering the successful outcomes that have occurred to date, to what extent do these scientific outcomes of TDS collaboration add value to the field of tobacco research that would not have been added through unidisciplinary approaches (or in the absence of the NIH TTURC initiative)?	Interview	Open-ended	Process
Stokols et al. 2003	App 1, #3.1	Describe the developmental sequence or milestones that have characterized the evolution of TDSC at each TTURC.	Interview	Open-ended	Process
Stokols et al. 2003	App 1, #3.2	What pivotal events and experiences were critical in paving the way for effective TDSC?	Interview	Open-ended	Process
Stokols et al. 2003	App 1, #4.1	‘‘Readiness to collaborate’’—to what extent did each TTURC team begin year-1 with high or low levels of readiness for collaboration?	Interview	Open-ended	Process
Stokols et al. 2003	App 1, #4.2	Had team members worked together on prior (pre-TTURC) projects?	Interview	Open-ended	Process
Stokols et al. 2003	App 1, #4.3	What number and diversity of disciplines are represented in each TTURC and how do those (or other) factors influence ‘‘readiness to collaborate,’’ and a smooth progression from ‘‘forming’’ to ‘‘performing’’ phases of collaboration?	Interview	Open-ended	Process
Stokols et al. 2003	App 1, #5.1	To what extent do the collaborative experiences within each TTURC during years 1–4 illustrate and support the working models and conceptual themes (outlined in Section II above)?	Interview	Open-ended	Process
Stokols et al. 2003	App 1, #5.2	For instance, have ‘‘middle-range’’ or ‘‘grand’’ conceptual integrations been achieved across two or more disciplines within each TTURC?	Interview	Open-ended	Process
Stokols et al. 2003	App 1, #5.3	How have social and intellectual integration processes influenced each other within the various TTURCs?	Interview	Open-ended	Process
WWA	p. 1	Over the past five years, how have you interacted with Western Water Assessment? (Select all that apply.)	Questionnaire	Select all that apply	Individual Experiences

WWA	p. 2	Please select the WWA-organized meetings and workshops that you attended. (Select all that apply.)	Questionnaire	Select all that apply	Individual Experiences
WWA	p. 3.1	Please select the WWA onlin webinar(s) you participated in. (Select all that apply.)	Questionnaire	Select all that apply	Individual Experiences
WWA	p. 3.2	In an average year, how many times do you interact with WWA?	Questionnaire	Likert	Individual Experiences
WWA	p. 4.1	Which of the following WWA-produced resources have you used or recommended to others? (Multiple Choice for each specific resource: I have recommended this; I have used this; or I am not sure.)	Questionnaire	Multiple Choice	Individual Experiences
WWA	p. 4.2	Have you initiated contact with WWA for your work?	Questionnaire	Yes/No	Perception of
WWA	p. 5.1	Please briefly describe the reason for contacting WWA and your experience.	Questionnaire	Open-ended	Perception of
WWA	p. 5.2	Has WWA provided information that helped you to become better informed about an issue or changes your opinion about the issue? If yes, please describe an example.	Questionnaire	Yes/No	Perception of
WWA	p. 6.1	Have you used WWA-provided information to help make a decision in your work? To the extent that you are comfortable sharing, please briefly give an example of information you used and what decision was made.	Questionnaire	Yes/No	Perception of
WWA	p. 6.2	Have you referred other people to WWA team members and/or resources? Who have you referred to WWA?	Questionnaire	Yes/No	Perception of
WWA	p. 7.1	What other organizations do you go to for climate information?	Questionnaire	Open-ended	Perception of
WWA	p. 7.2	Using the organizations you listed in the previous question, how often do you contact each of these organizations? (Multiple Choice for each specific organization: daily; weekly; monthly; or yearly)	Questionnaire	Multiple Choice	Perception of
WWA	p. 7.3	Please describe one instance in which WWA services, resources, or information have supported your work.	Questionnaire	Open-ended	Perception of
WWA	p. 8.1	Do you feel that your organization/agency/community is more resilient to climate variability and change than it was five years ago? If yes, please describe the ways in which WWA has contributed to this.	Questionnaire	Yes/No	Institutional Experiences and Impacts

WWA	p. 8.2	In your organization, are there more team members working on climate topics today than there were five years ago? Please describe.	Questionnaire	Yes/No	Institutional Experiences and Impacts
WWA	p. 8.3	In your organization, are you incorporating more climate science and climate information now than five years ago? Please describe.	Questionnaire	Yes/No	Institutional Experiences and Impacts
WWA	p. 9.1	In your field/organization/community, has the use of climate information changed over the last five years? Please describe.	Questionnaire	Yes/No	Institutional Experiences and Impacts
WWA	p. 9.2	Have you used information from WWA for your work with any of the following sectors? (Select all that apply.)	Questionnaire	Select all that apply	Regional Impacts
WWA	p. 10.1	How much do the following characteristics describe WWA services? (accessible, valuable, trusted, non-partisan, non-advocacy) (to a high degree; to a moderate degree; to a slight degree; or not at all)	Questionnaire	Multiple Choice	Regional Impacts
WWA	p. 10.2	Has WWA influenced your or your organization's ability to build resilience in the region? If yes, please describe.	Questionnaire	Yes/No/Unsure	Regional Impacts
WWA	p. 10.3	Are there any other ways in which WWA has supported or shaped your work over the last five years that you haven't mentioned above? If yes, please describe.	Questionnaire	Yes/No	NA
WWA	p. 11.1	What role(s) would you like to see WWA play in your work or your region in the future? (Select all that apply.)	Questionnaire	Select all that apply	NA
WWA	p. 11.2	Which of the following topics would be of most interest of your institution or your region for WWA to pursue in the future? (Select all that apply.)	Questionnaire	Select all that apply	NA
Meagher et al. 2008	Table 2, I.A.	Which of the researchers have seen their research lead to impacts?	Interview/ Questionnaire	Open-ended	Primary knowledge producers
Meagher et al. 2008	Table 2, I.C.	What user engagement, dissemination, knowledge transfer, objectives did they have/address?	Interview/ Questionnaire	Open-ended	Primary knowledge producers
Meagher et al. 2008	Table 2, I.E.	In what networks or communities involving potential users (where impacts might be felt) do researchers feel involved?	Interview/ Questionnaire	Open-ended	Primary knowledge producers
Meagher et al. 2008	Table 2, II.A.	In terms of policymakers, who – specifically and by 'type' – has been involved as users? In what way?	Interview/ Questionnaire	Open-ended	Knowledge users

Meagher et al. 2008	Table 2, II.B.	In terms of practitioners, who – specifically and by 'type' – has been involved as users? In what way?	Interview/ Questionnaire	Open-ended	Knowledge users
Meagher et al. 2008	Table 2, III.D.	As outcomes, how has the research directly or indirectly influenced policy formation and development?	Interview/ Questionnaire	Open-ended	Impacts
Meagher et al. 2008	Table 2, III.E.	As outcomes, how has the research directly or indirectly influenced changes in professional practice within the public and the private sector?	Interview/ Questionnaire	Open-ended	Impacts
Meagher et al. 2008	Table 2, IV.A.	What activities appear to have brought about research impacts, in policy or practice? (e.g.briefing papers/targeted publications, work-shops, series of seminars/meetings, reciprocal visits, CPD)	Interview/ Questionnaire	Open-ended	Process
Meagher et al. 2008	Table 2, IV.B.1	What factors and/or facilitating contexts shape the effectiveness of research processes leading to impacts?	Interview/ Questionnaire	Open-ended	Process
Meagher et al. 2008	Table 2, IV.B.2	What are the relative roles of the individual (researcher, policymaker, practitioner) and the organisation within which he or she operates?	Interview/ Questionnaire	Open-ended	Process
Meagher et al. 2008	Table 2, IV.D.	What factors shape stages in the dynamics of research processes leading to impacts, as they take place over time?	Interview/ Questionnaire	Open-ended	Process
Meagher et al. 2008	Table 2, IV.E.	Are there identifiable desirable mechanisms or ways in which research has been and can be utilised and applied by policymakers?	Interview/ Questionnaire	Open-ended	Process
Meagher et al. 2008	Table 2, IV.F.	Are there identifiable desirable mechanisms or ways in which research has been and can be utilised and applied by practitioners?	Interview/ Questionnaire	Open-ended	Process
Meagher et al. 2008	Table 2, V.B.	What lessons have been learned regarding enhancement of the effectiveness of linkages and flows of knowledge leading to research impacts?	Interview/ Questionnaire	Open-ended	Lessons learned
Morton 2015	Table 1, Final outcomes	Where might research have been used?	Interview/ Questionnaire	Open-ended	Impacts
Morton 2015	Table 1, Final outcomes	What change has it contributed to?	Interview/ Questionnaire	Open-ended	Impacts

Morton 2015	Table 1, Behaviors …	What were the practices and behaviors of individuals and groups? How did research influence these?	Interview/ Questionnaire	Open-ended	Impacts
Morton 2015	Table 1, Capacity…	What were the policy/practice applications of the research?	Interview/ Questionnaire	Open-ended	Impacts
Morton 2015	Table 1, Capacity…	What capacity do the target audiences have for using research?	Interview/ Questionnaire	Open-ended	Impacts
Morton 2015	Table 1, Awareness …	What was the aim in terms of the user's awareness of the issues addressed? How did they react to the work?	Interview/ Questionnaire	Open-ended	Impacts
Morton 2015	Table 1, Engageme nt…	Were there problems or gaps in the participation, engagement, or involvement of research users who are key to the area of interest?	Interview/ Questionnaire	Open-ended	Impacts
Morton 2015	Table 1, Activities…	What activities were carried out, and how do these address the issues identified in the research?	Interview/ Questionnaire	Open-ended	Impacts
Morton 2015	Table 1, Inputs	What level of financial, human, and technical resources was available? What was achievable within these?	Interview/ Questionnaire	Open-ended	Impacts
Reed et al. 2014	Supp Mat, #1.a	When did the project start/end?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Reed et al. 2014	Supp Mat, #1.b	Who/which groups were you engagine with?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Reed et al. 2014	Supp Mat, #1.c	How did you choose these groups/individuals?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Reed et al. 2014	Supp Mat, #1.d	What were the goals of the knowledge exchange process from both your perspective and the perspectives of those you were engaging with?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Reed et al. 2014	Supp Mat, #1.e	Could you give a brief history of your project discussing the approach taken to knowledge exchange, why the project was designed this way, and if you differed your approach over time?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Reed et al. 2014	Supp Mat, #1.f	Has there been a long-term legacy to the knowledge exchange process in your project? If so, what has it been?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Reed et al. 2014	Supp Mat, #2.a	What do you think were the primary motivations of stakeholders for getting involved (and remaining) in knowledge exchange linked to this project?	Interview/ Questionnaire	Open-ended	Knowledge exchange

Reed et al. 2014	Supp Mat, #2.b	To what extent did motivations differ between groups?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Reed et al. 2014	Supp Mat, #2.c	Were there any groups you wanted to engage with and didn't or couldn't?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Reed et al. 2014	Supp Mat, #2.d	What did you do to try to proactively address this?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Reed et al. 2014	Supp Mat, #2.e	Are there any generic incentives that other projects may be able to apply?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Reed et al. 2014	Supp Mat, #3.a	What were the main outcomes of your knowledge exchange process?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Reed et al. 2014	Supp Mat, #3.b	How effective do you consider your knowledge exchange activities to have been given the goals of the knowledge exchange process outlined in answer to my earlier question?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Reed et al. 2014	Supp Mat, #3.c	If there were one lesson you would like other projects to learn from your experience, what would it be?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Reed et al. 2014	Supp Mat, #3.d	What other generalizable lessons do you think it is important for others to learn from your experience?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Reed et al. 2014	Supp Mat, #4.a	What factors do you think were key to influencing how successful knowledge exchange in your project was?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Reed et al. 2014	Supp Mat, #4.b	Could you rank these factors in order of importance?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Reed et al. 2014	Supp Mat, #4.c	How do you think you could have made the process more effective?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Reed et al. 2014	Supp Mat, #5.a	What barriers have you witnessed in your project that prevented those running the project from communicating effectively with stakeholders and vice-versa, and that prevented new knowledge being generated together?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Reed et al. 2014	Supp Mat, #5.b	Could you rank these barriers in order of importance?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Reed et al. 2014	Supp Mat, #5.c	How did you attempt to overcome these barriers?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Reed et al. 2014	Supp Mat, #5.d	What worked best? What didn't work?	Interview/ Questionnaire	Open-ended	Knowledge exchange

Reed et al. 2014	Supp Mat, #6	Can you provide any examples as to how different stakeholders used knowledge from the project?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Reed et al. 2014	Supp Mat, #7	At the end of this project, we would like to produce guidance that can help others learn from your experiences and the experiences of others to design more effective knowledge exchange processes in the future. How do you think we can most effectively communicate these findings to specific target groups such as academics, practitioners, and policymakers?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Reed et al. 2014	Supp Mat, #8.a	Are there any other important questions/information you think we may have missed?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Reed et al. 2014	Supp Mat, #8.b	Can you think of anyone else that we should discuss this project with?	Interview/ Questionnaire	Open-ended	Knowledge exchange
Kalafatis et al. 2019a	Table 1	These collaborations can enhance trust between our Tribe/CSO and CSOs/Tribes.	Survey	Likert	Benefits and harms
Kalafatis et al. 2019a	Table 1	These collaborations can help sustain or enhance Tribal sovereignty.	Survey	Likert	Benefits and harms
Kalafatis et al. 2019a	Table 1	These collaborations can be an effective use of our Tribe's/CSO's time.	Survey	Likert	Benefits and harms
Kalafatis et al. 2019a	Table 1	These collaborations can help our Tribe/CSO recognize or address our needs.	Survey	Likert	Benefits and harms
Kalafatis et al. 2019a	Table 1	These collaborations can enhance our Tribe's/CSO's accountability in our work.	Survey	Likert	Benefits and harms
Kalafatis et al. 2019a	Table 1	These collaborations can provide access to resources that can help our Tribe/CSO.	Survey	Likert	Benefits and harms
Kalafatis et al. 2019a	Table 1	These collaborations can result in new knowledge created through Tribes and CSOs working together.	Survey	Likert	Benefits and harms
Kalafatis et al. 2019a	Table 1	These collaborations can help CSOs/Tribes understand important distinctions between our Tribe/CSO and others.	Survey	Likert	Benefits and harms
Kalafatis et al. 2019a	Table 1	These collaborations can enhance our capacity to make connections across different systems for developing knowledge.	Survey	Likert	Benefits and harms
Kalafatis et al. 2019a	Table 1	These collaborations can reduce trust between our Tribe/CSO and CSOs/Tribes.	Survey	Likert	Benefits and harms

Kalafatis et al. 2019a	Table 1	These collaborations can undermine Tribal sovereignty.	Survey	Likert	Benefits and harms
Kalafatis et al. 2019a	Table 1	These collaborations might not be an effective use of our Tribe's/CSO's time.	Survey	Likert	Benefits and harms
Kalafatis et al. 2019a	Table 1	These collaborations might not recognize or address our Tribe's/CSO's needs.	Survey	Likert	Benefits and harms
Kalafatis et al. 2019a	Table 1	These collaborations can conflict with our Tribe's/CSO's considerations about accountability in our work.	Survey	Likert	Benefits and harms
Kalafatis et al. 2019a	Table 1	These collaborations might result in our Tribe/CSO sharing resources in ways that could hurt us.	Survey	Likert	Benefits and harms
Kalafatis et al. 2019a	Table 1	These collaborations can result in knowledge that our Tribe/CSO helped create that we will not own.	Survey	Likert	Benefits and harms
Kalafatis et al. 2019a	Table 1	These collaborations can show that our collaborators do not recognize important distictions between our Tribe/CSO and others.	Survey	Likert	Benefits and harms
Kalafatis et al. 2019a	Table 1	These collaborations can conflict with our Tribe's/CSO's way of developing knowledge.	Survey	Likert	Benefits and harms
Kalafatis et al. 2019b	The interviews covered… p. 684	Based on your definition of success, what needs to happen for these collaborations to be successful?	Interview	Open-ended	Collaboration
Kalafatis et al. 2019b	The interviews covered… p. 685	Based on your definition of success, what needs to be avoided for these collaborations to be successful?	Interview	Open-ended	Collaboration
Kalafatis et al. 2019b	The interviews covered… p. 686	How have you prepared for these collaborations?	Interview	Open-ended	Collaboration
Kalafatis et al. 2019b	The interviews covered… p. 687	How would you assess your preparation for and performance during these collaborations?	Interview	Open-ended	Collaboration
Kalafatis et al. 2019b	The interviews	What advice would you give others in a similar position about taking part in these collaborations?	Interview	Open-ended	Collaboration

	covered… p. 688				
ACCCNRS	App VIII	Are stakeholders and decision makers substantively involved in project definition, design, and execution?	NA	NA	Actionable Science - Processes
ACCCNRS	App VIII	To what degree are the data, information, and science products easily accessible online?	NA	NA	Actionable Science - Accessibility
ACCCNRS	App VIII	To what degree are science products developed in ways that meet the specific communication needs of target audiences?	NA	NA	Actionable Science - Accessibility
ACCCNRS	App VIII	To what degree are stakeholders and decision makers applying CSC scientific products and services?	NA	NA	Actionable Science - Impact and Efficacy
ACCCNRS	App VIII	To what degree have CSC products and services been incorporated into specific decisions or decision-processes?	NA	NA	Actionable Science - Impact and Efficacy
ACCCNRS	App VIII	To what degree is the CSC building capacity among decision makers and other stakeholders in the co-production and appropriate use of climate science products and services?	NA	NA	Capacity Building - Partner/ Stakeholder
ACCCNRS	App VIII	Has the center developed any innovative approaches to capacity building among partners and stakeholders?	NA	NA	Capacity Building - Partner/ Stakeholder
ACCCNRS	App VIII	Is capacity building resulting in people and organizations using the knowledge to change practices or otherwise make a difference in planning or management outcomes?	NA	NA	Capacity Building - Impact and Efficacy
ACCCNRS	App VIII	To what extent does the CSC engage partners across its geographic region and across different institution types (e.g., local, state, federal, tribal, nongovernmental organization, industry)?	NA	NA	Partnerships - Breadth and Scope

ACCCNRS	App VIII	Are partnerships yielding desired outcomes?	NA	NA	Partnerships - Outcomes
SE CSC	p. 6	To what extent are science users and producers involved with the CSC?	NA	NA	Partnership involvement
SE CSC	p. 6	What are the predictors of this involvement? What limits involvement?	NA	NA	Partnership involvement
SE CSC	p. 6	To what extent do partners believe the CSC is producing actionable science?	NA	NA	Partnership involvement
SE CSC	p. 6	To what extent are CSC-affiliated science users and producers involved in coproduction? What are the predictors of this involvement?	NA	NA	Partnership involvement
SE CSC	p. 6	To what extent does the CSC play a role as a boundary organization, facilitating the coproduction of actionable science? What characterizes that role?	NA	NA	Partnership involvement
SE CSC	App C	Why did you become involved with the Climate Science Center (CSC)?	Interview	Open-ended	Partnership Effectiveness - Producers
SE CSC	App C	What are the benefits of your involvement with the CSC? As individuals, to scientific knowledge, to people who are in need of scientific information, to professional development of others.	Interview	Open-ended	Partnership Effectiveness - Producers
SE CSC	App C	What are the challenges you face in your involvement with the CSC?	Interview	Open-ended	Partnership Effectiveness - Producers
SE CSC	App C	To what degree have you worked with the intended users of your climate science, produced with or for the CSC?	Interview	Open-ended	Partnership Effectiveness - Producers
SE CSC	App C	Tell us more about your efforts to work with these potential climate science users. Why and how have you worked with them?	Interview	Open-ended	Partnership Effectiveness - Producers
SE CSC	App C	What challenges have you faced in working with or reaching out to science users?	Interview	Open-ended	Partnership Effectiveness - Producers

SE CSC	App C	How have you overcome (or tried to overcome) barriers to working with or reaching out to climate science users (or to ensuring that the science you produce is used)? How has the CSC staff played a role in overcoming the barrier?	Interview	Open-ended	Partnership Effectiveness - Producers
SE CSC	App C	Generally speaking, what could generate more benefits from your involvement with the CSC— whether to you individually, to scientific knowledge, to people who use currently or could use climate scientific information, and so forth?	Interview	Open-ended	Partnership Effectiveness - Producers
SE CSC	App C	Why did you become involved with the CSC?	Interview	Open-ended	Partnership Effectiveness - Users
SE CSC	App C	What are the benefits of your involvement with the CSC? As individuals, to scientific knowledge, to people who are in need of scientific information, to professional development.	Interview	Open-ended	Partnership Effectiveness - Users
SE CSC	App C	What are the challenges you face in your involvement with the CSC?	Interview	Open-ended	Partnership Effectiveness - Users
SE CSC	App C	To what degree have you worked with climate scientists or used the science produced in association with the CSC?	Interview	Open-ended	Partnership Effectiveness - Users
SE CSC	App C	Tell us more about your impressions of this climate science. Has it been useful? How have you used it?	Interview	Open-ended	Partnership Effectiveness - Users
SE CSC	App C	What challenges have you faced in using the science as part of the CSC? Are there challenges in working with scientists in using science?	Interview	Open-ended	Partnership Effectiveness - Users
SE CSC	App C	How have you overcome (or tried to overcome) barriers to using climate science? How has the CSC staff played a role in overcoming barriers?	Interview	Open-ended	Partnership Effectiveness - Users
SE CSC	App C	Generally speaking, what could generate more benefits from your involvement with the CSC— whether to you individually, to scientific knowledge, to people who use currently or could use climate scientific information, and so forth.	Interview	Open-ended	Partnership Effectiveness - Users

Owen 2020	Table 2	Did the project reduce risk and vulnerability? (as indicated by biophysical and social vulnerability to potential climate hazards)	NA	NA	Effectiveness
Owen 2020	Table 2	Did the project enhance social wellbeing? (as indicated by relationships, community building, collaboration, improved access to resources and information)	NA	NA	Effectiveness
Owen 2020	Table 2	Did the project improve the environment? (as indicated by ecosystem health, environmental quality, natural resources)	NA	NA	Effectiveness
Owen 2020	Table 2	Did the project increase economic resources? (as indicated by income levels, access to economic resources)	NA	NA	Effectiveness
Owen 2020	Table 2	Did the project strengthen institutions? (as indicated by institutional policies, governance structures and practices, partnerships, conflict resoluation)	NA	NA	Effectiveness

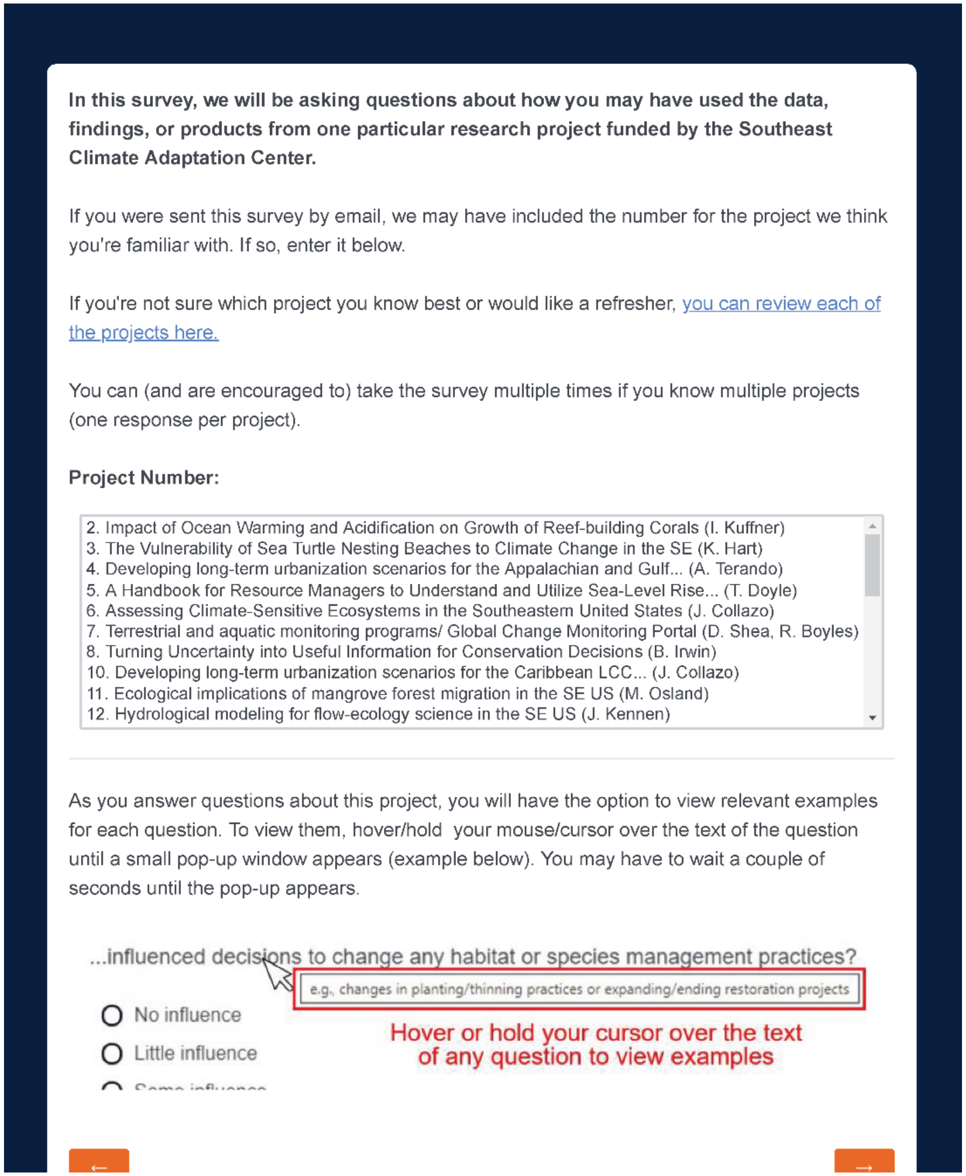
Appendix 2.2: Examples presented with survey questions

Table B.1: Hover-text examples presented for each survey item

Item:	Examples:
C1	helped you interpret sea level rise models better, use a GIS data set more effectively, or conduct safer prescribed burns
C2	informed you about vulnerable species or adaptation management techniques, or exposed gaps in your knowledge about a site
C3	made you aware of an organization researching similar topics, introduced colleagues to collaborate with, or strengthened existing relationships
C4	introduced a new website or decision support tool or exposed a gap in regional data
C5	informed planning documents for the next 10-50 years, Wildlife Action Plans, or Species Status Assessments
C6	assigned a new species of greatest conservation need or shift in land acquisition priorities

C7	informed an agency's mission/vision
CI1	changed outreach topics/audience or inspired a new education program
CI2	internal prescribed burn tranings or pollinator-friendly planting outreach to developers
CI3	prompted additional monitoring of a species or influenced a research project or proposal
I1	changes in planting/thinning practices or expanding/ending restoration projects
I2	new park infrastructure or additional reinforcement of coastal roadways
I3	increased education staffing or decreased time spent removing invasive species
I4	changes in grant distribution/proposals or changes in budgets between program areas
I5	change in departmental forms or project requirements
I6	change in fishing catch limits or use in legal proceedings
J1	confirmed what you knew about future temperature changes or bolstered your confidence around existing departmental priorities
J2	to convince other resource managers to assist in a prescribed burn or get a coworker to support an infrastructure upgrade
J3	used in outreach to justify increased restoration efforts at a local park or to convince locals that climate change needs to be included in site planning
J4	to convince a supervisor that current management practices have been successful or back-up a change in education programs
J5	to gain approval for a new project or justify increased budgets
J6	cited in a research grant or to justify an increased budget for park operations

Appendix 2.3: Survey instructions and visual presentation



In this survey, we will be asking questions about how you may have used the data, findings, or products from one particular research project funded by the Southeast Climate Adaptation Center.

If you were sent this survey by email, we may have included the number for the project we think you're familiar with. If so, enter it below.

If you're not sure which project you know best or would like a refresher, you can review each of the projects here.

You can (and are encouraged to) take the survey multiple times if you know multiple projects (one response per project).

Project Number:

2. Impact of Ocean Warming and Acidification on Growth of Reef-building Corals (I. Kuffner)
3. The Vulnerability of Sea Turtle Nesting Beaches to Climate Change in the SE (K. Hart)
4. Developing long-term urbanization scenarios for the Appalachian and Gulf... (A. Terando)
5. A Handbook for Resource Managers to Understand and Utilize Sea-Level Rise... (T. Doyle)
6. Assessing Climate-Sensitive Ecosystems in the Southeastern United States (J. Collazo)
7. Terrestrial and aquatic monitoring programs/ Global Change Monitoring Portal (D. Shea, R. Boyles)
8. Turning Uncertainty into Useful Information for Conservation Decisions (B. Irwin)
10. Developing long-term urbanization scenarios for the Caribbean LCC... (J. Collazo)
11. Ecological implications of mangrove forest migration in the SE US (M. Osland)
12. Hydrological modeling for flow-ecology science in the SE US (J. Kennen)

As you answer questions about this project, you will have the option to view relevant examples for each question. To view them, hover/hold your mouse/cursor over the text of the question until a small pop-up window appears (example below). You may have to wait a couple of seconds until the pop-up appears.

...influenced decisions to change any habitat or species management practices?

e.g., changes in planting/thinning practices or expanding/ending restoration projects

No influence

Little influence

Hover or hold your cursor over the text of any question to view examples

← →

AUBURN UNIVERSITY

Please answer each question **about the research project you selected** and how you or the organization/agency you work for may have used information from it.

Hover your mouse/cursor over any of the questions to view a small pop-up with examples of each possible use.

To what degree has this project...

...impacted any of your professional skills?

- No impact
- Little impact
- Some impact
- Quite a bit of impact
- A great deal of impact

...impacted your knowledge relevant to your job?

- No impact
- Little impact
- Some impact
- Quite a bit of impact
- A great deal of impact

..influenced your professional network?

- No influence

Appendix 4.1: Survey

Start of Block: Climate Inventory - Libarkin et al.

1
Please select the correct answers, to the best of your ability, for the questions below.

Which is the best definition of a positive feedback loop in the climate system?

- ○ A change in the climate system leads to a response that benefits climate change.
- ○ A change in the climate system leads to a response that slows down climate change.
- ○ A change in the climate system leads to a response that speeds up climate change.
- ○ A change in the climate system leads to a response that harms climate change.
- ○ I do not know.

---

2 Which of the following will occur if the amount of ice floating in the ocean decreases?

- ○ More sunlight will be reflected back into space and Earth's temperature will decrease.
- ○ Less sunlight will be reflected back into space and Earth's temperature will increase.
- ○ More sunlight will be reflected back into space and Earth's temperature will increase.
- ○ Less sunlight will be reflected back into space and Earth's temperature will decrease.
- ○ I do not know.

---

3 Which of the following contributes to the transfer of thermal energy from place to place around the Earth?

- ○ The movement of ocean water but not the movement of air.
- ○ The movement of air but not the movement of ocean water.
- ○ Both the movement of ocean water and the movement of air.
- ○ Neither the movement of ocean water nor the movement of air.
- ○ I do not know.

4 How does sunlight affect temperature on Earth?

- ○ Sunlight warms the air directly, but the air does not warm the land.
- ○ Sunlight warms the land directly, but the land does not warm the air.
- ○ Sunlight warms the air directly, and the air warms the land.
- ○ Sunlight warms the land directly, and the land warms the air.
- ○ I do not know.

5 Which of the following is the best definition of a greenhouse gas?

- ○ An atmospheric gas that is produced as plants grow.
- ○ An atmospheric gas that absorbs infrared radiation.
- ○ An atmospheric gas that produces acid rain.
- ○ An atmospheric gas that absorbs ultraviolet radiation.
- ○ I do not know.

6 How has the amount of carbon dioxide in the atmosphere changed since the start of the Industrial Revolution 150 years ago?

- ○ The amount of carbon dioxide has remained the same.
- ○ The amount of carbon dioxide has decreased.
- ○ The amount of carbon dioxide has increased.
- ○ I do not know.

7 Which of the following best describes how plants take in carbon dioxide?

- ◯ Plants take in carbon dioxide from rain.
- ◯ Plants take in carbon dioxide from sunlight.
- ◯ Plants take in carbon dioxide from air.
- ◯ Plants take in carbon dioxide from soil.
- ◯ I do not know.

---

8 Which of the following would most likely occur if the oceans stopped absorbing carbon dioxide?

- ◯ Carbon dioxide in the atmosphere would remain the same.
- ◯ Carbon dioxide in the atmosphere would increase.
- ◯ Carbon dioxide in the atmosphere would decrease.
- ◯ I do not know.

---

9 Which is the best description of the differences between climate and weather?

- ◯ Climate does not change over time, and weather does change over time.
- ◯ Climate changes over time, and weather does not change over time.
- ◯ Climate changes over long periods of time, and weather changes over short periods of time.
- ◯ Climate changes over short periods of time, and weather changes over long periods of time.
- ◯ I do not know.

---

10 Which of the following statements about global warming over the past 50 years is most accurate?

○ Global warming over the past 50 years is slightly due to natural processes and mostly due to human activities.

○ Global warming over the past 50 years is mostly due to natural processes and slightly due to human activities.

○ Global warming over the past 50 years is about equally due to natural processes and human activities.

○ Global warming over the past 50 years has not occurred whether due to natural processes or human activities.

○ I do not know.

11 Which of the following statements about air temperature change over the past million years is most accurate?

○ Air temperature change over the past million years is slightly due to natural processes and mostly due to human activities.

○ Air temperature change over the past million years is mostly due to natural processes and slightly due to human activities.

○ Air temperature change over the past million years is about equally due to natural processes and human activities.

○ Air temperature change over the past million years has not occurred whether due to natural processes or human activities.

○ I do not know.

12 Which is the most common form of radiation given off by the Sun?

○ The Sun mostly gives off visible radiation.

○ The Sun mostly gives off infrared radiation.

○ The Sun mostly gives off ultraviolet radiation.

○ The Sun does not give off radiation.

○ I do not know.

13 How much incoming sunlight do greenhouse gases absorb?

- ○ Greenhouses gases absorb almost no incoming sunlight.
- ○ Greenhouses gases absorb about half of the incoming sunlight.
- ○ Greenhouses gases absorb most incoming sunlight.
- ○ I do not know.

---

14 Which is the most common form of radiation given off by Earth's surface?

- ○ The Earth's surface mostly gives off visible radiation.
- ○ The Earth's surface mostly gives off infrared radiation.
- ○ The Earth's surface mostly gives off ultraviolet radiation.
- ○ Earth's surface does not give off radiation.
- ○ I do not know.

---

15 What do greenhouse gases do?

- ○ Greenhouse gases absorb energy emitted by Earth.
- ○ Greenhouse gases reflect energy emitted by Earth.
- ○ Greenhouse gases reflect energy reflected by Earth.
- ○ Greenhouse gases absorb energy reflected by Earth.
- ○ I do not know.

---

16 Where will a photon emitted by a greenhouse gas molecule most likely go?

- ○ In an upward direction relative to Earth's surface.
- ○ In a downward direction relative to Earth's surface.
- ○ In a random direction relative to Earth's surface.
- ○ I do not know.

17 Averaged over long time periods, how does the amount of energy arriving from space compare to the amount of energy leaving Earth?

- ○ The amount of energy arriving from space is greater than the amount of energy leaving Earth.
- ○ The amount of energy arriving from space is less than the amount of energy leaving Earth.
- ○ The amount of energy arriving from space is roughly equal to the amount of energy leaving Earth.
- ○ I do not know.

18 Which of the following could cause the Earth's surface temperature to change?
CHOOSE ALL THAT APPLY.

- ☐ Changes in the tilt of the Earth's axis.
- ☐ Changes in the reflectivity of the Earth's surface.
- ☐ Changes in methane concentrations in the atmosphere.
- ☐ Changes in carbon dioxide concentrations in the atmosphere.
- ☐ I do not know.

19 Which of the following can be caused by climate change?
CHOOSE ALL THAT APPLY.

- [ ] Climate change can cause food shortages.
- [ ] Climate change can cause changes in temperature.
- [ ] Climate change can cause water shortages.
- [ ] Climate change can cause changes in weather.
- [ ] I do not know.

---

20 What information do ice cores from glaciers contain about Earth?
CHOOSE ALL THAT APPLY.

- [ ] Ice cores contain information about Earth's air temperature.
- [ ] Ice cores contain information about Earth's seasonal precipitation.
- [ ] Ice cores contain information about Earth's carbon dioxide concentration.
- [ ] Ice cores contain information about Earth's daily weather events.
- [ ] I do not know.

Page Break

21 Which statements about non-greenhouse gases are accurate?
CHOOSE ALL THAT APPLY.

- ◯ Non-greenhouse gases do not absorb a lot of energy given off by the Sun.
- ◯ Non-greenhouse gases do not absorb a lot of energy given off by the Earth.
- ◯ Non-greenhouse gases absorb a lot of energy given off by the Earth.
- ◯ Non-greenhouse gases absorb a lot of energy given off by the Sun.
- ◯ I do not know.

---

22 How confident are you in your responses to the previous questions?

- ◯ Very confident
- ◯ Fairly confident
- ◯ Not very confident
- ◯ Not at all confident

---

23 Personally, how well informed do you feel you are about how the Earth's climate system works?

- ◯ Very well informed
- ◯ Fairly well informed
- ◯ Not very well informed
- ◯ Not at all informed

---

24 Which comes closest to your own view?

- Most scientists think climate change is happening
- Most scientists think climate change is not happening
- Scientists generally disagree about whether or not climate change is happening
- I do not know.

---

25 How sure are you that climate change is happening?

- Extremely sure
- Very sure
- Somewhat sure
- Not at all sure

---

26 We use this question to discard the survey of people who are not reading the statements. Please select DISAGREE to preserve your answers.

- Strongly Disagree
- Disagree
- Agree
- Strongly Agree

---

27 On a scale of 1 (no risk) to 10 (extreme risk) what is your assessment of the risk for:

	1	2	3	4	5	6	7	8	9	10
Climate Change										
Nuclear Power										

End of Block: Climate Inventory - Libarkin et al.

Start of Block: McCroskey & Teven 1999: Ethos/Credibility Instrument

Q52
Please indicate your impression of climate scientists by circling the appropriate number between the pairs of adjectives below. The closer the number is to an adjective, the more certain you are of your evaluation.
In general, I believe climate scientists are...

	1	2	3	4	5	6	7	
	1	2	3	4	5	6	7	
Intelligent								Unintelligent
Untrained								Trained
Inexpert								Expert
Informed								Uninformed
Incompetent								Competent
Bright								Stupid
Cares about me								Doesn't care about me
Has my interests at heart								Doesn't have my interests at heart
Self-centered								Not self-centered
Concerned with me								Unconcerned with me
Insensitive								Sensitive
Not understanding								Understanding
Honest								Dishonest
Untrustworthy								Trustworthy
Honorable								Dishonorable
Moral								Immoral
Unethical								Ethical
Phoney								Genuine

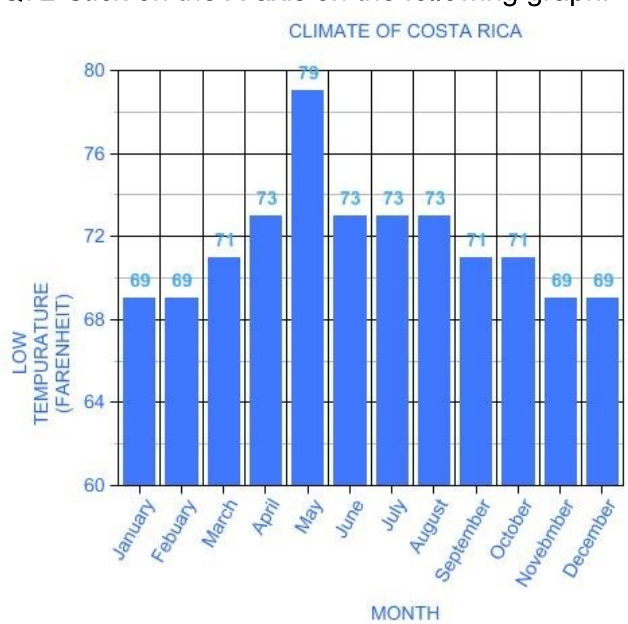
End of Block: McCroskey & Teven 1999: Ethos/Credibility Instrument

Start of Block: Rachel's Graph questions

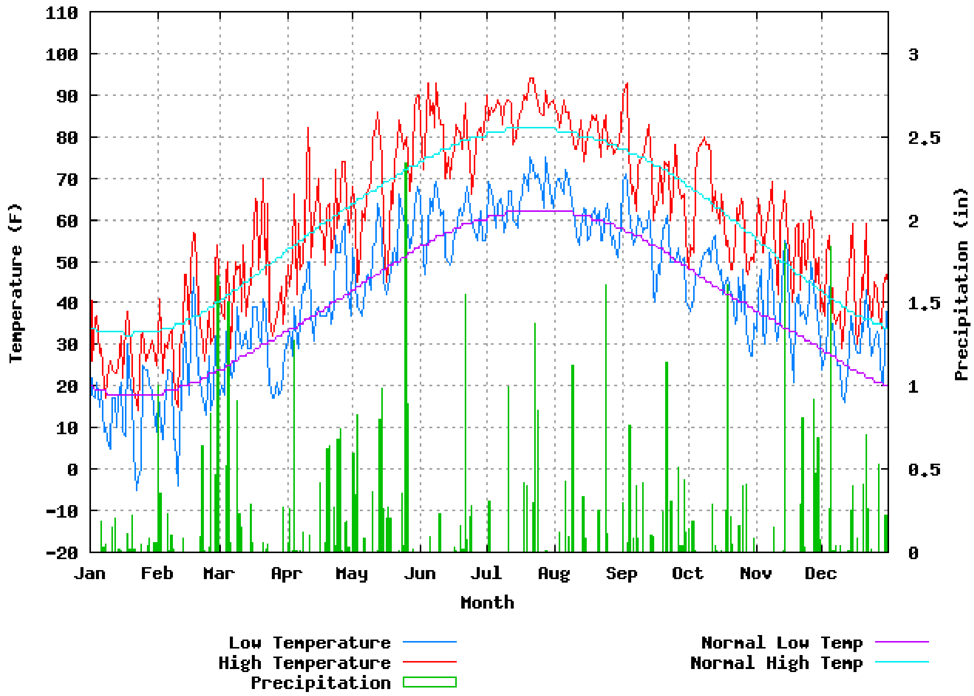
Q60 How often do you...

	Never	Once a year or less	Several times a year	Once a month	2-3 times a month	Once a week	2-3 times a week	Daily
...construct graphs using paper and pencil?	○	○	○	○	○	○	○	○
...interpret existing graphs?	○	○	○	○	○	○	○	○
...use computers for data analysis?	○	○	○	○	○	○	○	○
...use Microsoft Excel for data analysis?	○	○	○	○	○	○	○	○
...use Microsoft Excel for graphing data?	○	○	○	○	○	○	○	○

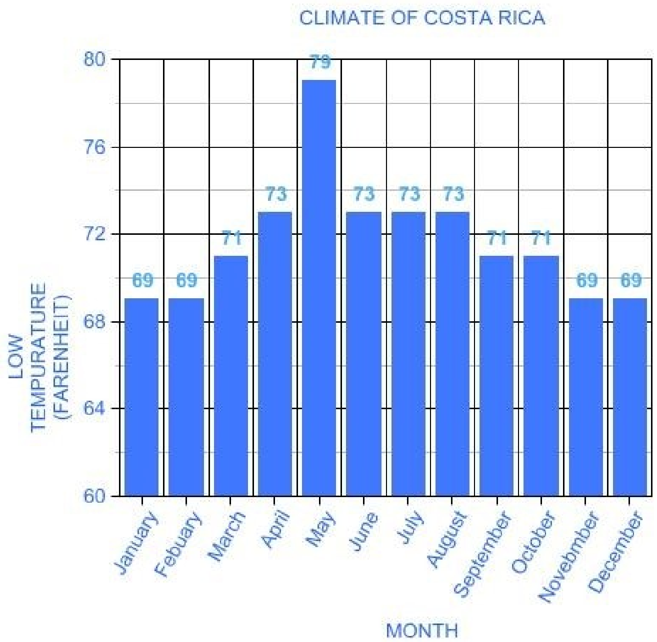
Q72 Click on the X-axis on the following graph:



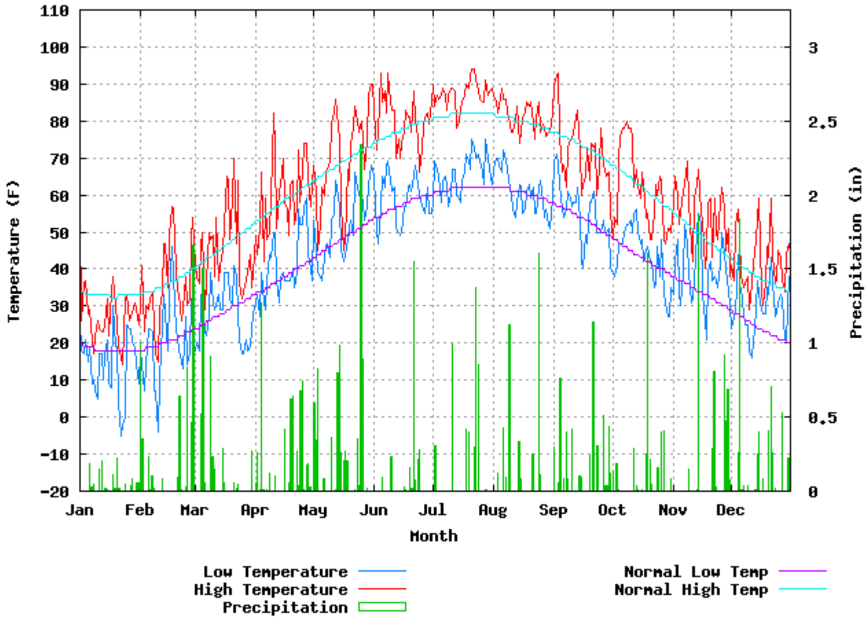
Q75 Click on the independent variable (or one of the independent variables) in the following graph:



Q73 Click on the dependent variable on the following graph:



Q76 Click on the Y-axis or one of the Y-axes in the following graph:



End of Block: Rachel's Graph questions

Start of Block: Borrowed Leiserowitz et al. risk perception

Q64
Please click on the slider bar below to indicate your answer. You can slide the indicator to the position that best describes your opinion.

	0 10 20 30 40 50 60 70 80 90 100
To the best of your knowledge, what percentage of climate scientists think that human-caused global warming is happening?	

Q70 When do you think global warming will start to harm people in the United States?

- ○ They are being harmed right now
- ○ In 10 years
- ○ In 25 years
- ○ In 50 years
- ○ In 100 years
- ○ Never

Q69 How worried are you about global warming?

- Very worried
- Somewhat worried
- Not very worried
- Not at all worried

Q66 How much do you think global warming will harm you personally?

- A great deal
- A moderate amount
- Only a little
- Not at all
- Don't know

Q71 How much do you think global warming will harm people in your community?

- A great deal
- A moderate amount
- Only a little
- Not at all
- Don't know

Q67 How much do you think global warming will harm people in the United States?

- A great deal
- A moderate amount
- Only a little
- Not at all
- Don't know

Q68 How much do you think global warming will harm people in developing countries?

- A great deal
- A moderate amount
- Only a little
- Not at all
- Don't know

End of Block: Borrowed Leiserowitz et al. risk perception

Start of Block: Libarkin et al. demographics

Q41 Please provide additional information about yourself by answering the questions below.

Your AGE:

____

Q42 Your Home U.S. 5-digit ZIP CODE:

____

Q43 Your GENDER:

____

Q44 Do you self-identify as LGBTQIA?

▼ No, Yes, Prefer not to answer

Q45 Your Ethnicity:
CHOOSE ALL THAT APPLY

- ☐ American Indian/Native American/Alaskan Native
- ☐ Asian/Asian American
- ☐ Black/African/African American
- ☐ Latino(a)/Hispanic
- ☐ Native Hawaiian/Pacific Islander
- ☐ White/Caucasian
- ☐ Other: ____

Q46 How often do you attend religious worship services?

- ○ Weekly or more often
- ○ Monthly to yearly
- ○ Seldom
- ○ Never
- ○ I do not know

Q47 What is your relationship to the environmental movement?

- ◯ I am an active participant in the environmental movement.
- ◯ I am sympathetic towards, but not active in, the environmental movement.
- ◯ I am neutral towards the environmental movement.
- ◯ I am unsympathetic towards the environmental movement.

Q48 How would you describe your political orientation?

- ◯ Very conservative
- ◯ Conservative
- ◯ Middle of the road
- ◯ Liberal
- ◯ Very liberal

End of Block: Libarkin et al. demographics

Start of Block: Extras

Q50 When is the last time you took a STEM (Science, Technology, Engineering, Mathematics) class? (college or high school)

- ◯ Currently enrolled in at least 1 STEM course
- ◯ Last Semester
- ◯ Within the last year
- ◯ In the last 2-3 years
- ◯ 4 or more years ago

Q51 How many college-level STEM classes have you taken?

- ◯ None
- ◯ 1-2
- ◯ 3-4
- ◯ 5 or more

Q56 What is your major or planned major?

____

Q59 What is your GPA? (approximate if needed)

____

Q57 What is your year?

- ◯ Freshman
- ◯ Sophomore
- ◯ Junior
- ◯ Senior
- ◯ Graduate Student