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Great Lakes Climate Change Science and Education Systemic Network (GLCCSESN)

Education White Paper

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SECTION 1: Introduction

In September 2010, the Great Lakes Climate Change Science and Education Systemic Network (GLCCSESN) convened for a two-year planning effort funded by the National Science Foundation to better understand the current state of climate change education, from the perspective of climate scientists, learning scientists, formal and informal educators and journalists. GLCCSESN takes a regional focus on the unique characteristics of climate change impacts on the Great Lakes region and the intersection of regionally based climate research with regionally-based climate education in order to enhance opportunities for research-education partnerships and build a consensus framework to guide collaboration.

The current partners include University of Wisconsin - Madison, NOAAs Great Lakes Environmental Research Lab, University of Michigan, Michigan State University, Knight Center for Environmental Journalism, Ashland University, Ann Arbor Hands-On Museum, and the College of Exploration.

As part of the planning process, GLCCSESN undertook several research initiatives to assess what climate change educators in the Great Lakes understand about climate change, how they use climate change in their practice, and what barriers and gaps they face in climate change education. This white paper is a report on the GLCCSESN team's research as well as previous, related research done by others. In this paper we explore:

1) The general **background** on climate change education in informal and formal setting (Section 2)
2) The **current state** of climate change education in the Great Lakes, from the perspective of formal educators, educators, and journalists (Sections 3-5)
3) **Barriers and gaps** to climate change education, particularly in the Great Lakes region (Section 6)
4) Overall **implications** of this research (Section 7)

In doing this, we draw from published research and position papers in the field as well as from primary data collected by the authors and the GLCCSESN team.

SECTION 2: Climate Change Education in Formal and Informal Settings

Climate Change in Formal Education

Earth science education has been on the minds of many organizations over the last decade or so. In 2001, a conference was held in Snowmass, Colorado to form an action plan to change Earth and space science education across the nation (Barstow and Geary 2001). This call for change has been followed by numerous other documents, such as the Essential Literary Principles of the Ocean, Great Lakes, and Climate and the Earth Science Literacy: The Big Ideas and supporting concepts of Earth science (National Geographic Society 2004; Ohio Sea Grant 2010; U.S. Global Change Research Program 2009; Earth Science Literacy Initiative 2010). Also since, 2001, the American Geological Institute, AGI has been regularly reporting on the status of the geoscience workforce and education (AGI 2009) thereby keeping the focus on improving Earth and space science education with data that can be used by different organizations. The report *Revolutionizing Earth System Science Education for the 21st Century* came out in 2007 and authors Hoffman and Barstow have shown in this report that although there have been significant improvements occurring in several states since 2001 more still needs to occur.

Recently, the new Common Core State Standards for math and English language have been formally adopted by all but 9 states/insular areas, Alaska, American Samoa Islands, Guam and the Northern Mariana Islands, Minnesota, Nebraska, Puerto Rico, Texas, and Virginia (Common Core 2011). The intent is that these standards will provide consistent appropriate benchmarks for all students, regardless of where they live. In July 2011, the new *Framework for K-12 Science Education* was released which is the being used by Achieve, Inc. to produce new standards for K-12 science education (Next Generation 2011). These new science standards are expected to be included in the Common Core State Standards.

The Earth Science Literacy principles and the new science framework both suggest that climate change is making headway in formal education standards and curriculum. In the new K-12 Framework (Chapter 7; Earth and Space Science) (Next Generation 2011) climate is discussed throughout with references to the recent history of climate, greenhouse effect, climate models, climate as affected by Earth's systems, and human impacts. There is even a core idea specific to climate change (ESS3.D: Global Climate Change). The Framework committee indicated that their "efforts have been strongly influenced by several recent efforts in the ESS community that have codified the essential sets of information in several fields", including the recently developed principles *Climate Literacy: Essential Principles of Climate Science* (U.S. Global Change Research Program 2009).

The inclusion of climate change in the curriculum is new to many teachers in both middle school and high school. In previous (1996) National Science Education Standards (NRC, 1996), only global climate is mentioned. Climate change is also a new piece in many recently revised state standards documents. For example, the Michigan Merit Curriculum High School has a content expectation specific to climate change (E5.4) (MDE, 2006).

Over the last 10 years, education journals have researched the teaching of climate change, bringing to light many student misconceptions. Knowing the types of misconceptions that students can have help an educator address and correct them (Table 1).

Table 1: Indicates a few of the student misconceptions that have been determined from the literature.

Student Misconception	**Journal article**
• Inappropriate mental models of shortwave and longwave radiation. • Think increased global temperatures caused by increase in solar input through the ozone hole. • Misunderstand the Earth and greenhouse gases as radiating bodies. • Unaware of natural greenhouse effect	Catherine Gautier, Katie Duetsch, Stacy Rebich, 2006, Misconceptions About the Greenhouse Effect, Journal of Geoscience Education, 54 (3) 386-395.

produced by atmospheric gases or that natural greenhouse effect maintains habitable temperatures on Earth and that global warming was related to enhanced greenhouse effect • Misconceptions regarding greenhouse gases themselves and their role in preventing longwave radiation from leaving the lower atmosphere.	
• Use anecdotal evidence of climate change, sometimes where examples did not apply to climate change. • Not understand the time scale needed to measure climate data. • Believe climate change is part of a natural cycle. • Belief there is disagreement among scientists about what was causing climate change.	Theissen, K. M., 2008, The Earth's Record of Climate: a focused-topic introductory course, Journal of Geoscience Education, 56, 342-353. and Theissen, K. M., 2011, What Do U.S. Students Know About Climate Change. EOS, Transactions American Geophysical Union, 92(51), 477, 2011 doi:10.1029/2011EO510001
• Think ozone depletion causes global warming and climate change • Think air pollution causes global warming and climate change • Think climate change is caused by an increase in solar radiation • Unaware of the greenhouse effect, or do not link the greenhouse effect to global warming • Unaware of impact of global warming on society • Unaware that climate change impacts may vary by region • Believe global warming and climate change cannot be stopped	Daniel P. Shepardson, Dev Niyogi, Soyoung Choi, Umarporn Charusombat, 2011, Students' conceptions about the greenhouse effect, global warming, and climate change, Climatic Change 104:481–507, DOI 10.1007/s10584-009-9786-9.
• Believe that the seasons are caused by differences in the Earth-sun distance in various times of the year • Misinterpretation of block diagrams, aerial and satellite photos, and topographic maps • Misunderstanding of geologic time, kinematic and molecular theory, scale models and astronomical distance, size of scientific objects	Alice A. (Jill) Black, 2005, Spatial Ability and Earth Science Conceptual Understanding Journal of Geoscience Education, 53 (4) 402-414.

• Believed the ozone hole to be the main cause of global warming. • Awareness of the decisive role played by the concentration of CO_2 in the atmosphere does not reach the level of understanding required to grasp how significant rising CO_2 levels in the atmosphere are to the process of global warming	Sibylle Reinfried, Urs Aeschbacher & Benno Rottermann (2012): Improving students' conceptual understanding of the greenhouse effect using theory-based learning materials that promote deep learning, International Research in Geographical and Environmental Education, 21:2, 155-178 To link to this article: http://dx.doi.org/10.1080/10382046.2012.672685

Informal Venues for Climate Change Education

Our project considers the roles of both formal and informal approaches to climate change education. We define informal educators broadly to include those working directly in free-choice learning institutions (e.g. museums, nature centers, zoos, aquaria) as well as those working in community and government agencies that include education of public audiences in their scope and mission (e.g. extension agents, Sea Grant, non-profit advocacy groups).

Previous research on climate change education in informal settings shows this to be an effective route to building knowledge, retention, and action. For example, an assessment of radio documentaries about climate change found that participants could recall both "big ideas" and specific examples from the program and that they increased their knowledge of the climate change research process (Russell, 2010). In a summative evaluation of a climate change exhibit, most participants could identify the exhibition's core subject matter, cite evidence of climate change, talk about individual solutions, and identify something new they learned about climate change (RK&A, 2010).

Currently, science centers and other informal venues are highly engaged in climate change as a topic area. The Association of Science-Technology Centers' International Action on Global Warming highlights exhibits, programs and events centered on climate change at science museums. To illustrate the breadth of science center involvement, we include a brief listing of these activities taken from the ASTC website (http://astc.org/iglo/at-science-centers/, on February 29, 2012).

- Interactive forum for teachers to meet with climate change researchers (The Marian Koshland Science Museum, Washington, DC (http://www.koshland-science-museum.org/))
- Themed semester on climate change with lectures, science cafes, family programs, workshops (University of Michigan – Museum of Natural History (http://www.lsa.umich.edu/ummnh/))
- Global Awareness Day to educate visitors on contributing to a healthy environment (Arizona Science Center (https://www.azscience.org/))
- Polar-Palooza, to bring polar researchers to cities across the nation (multiple institutions)

- Events including film screening, talks, exploring a research vessel used by polar scientists (MTN Sciencentre, Cape Town, South Africa (http://www.mtnsciencentre.org.za/))
- Science-themed farmers' market (New York Hall of Science (http://www.nysci.org/))
- Large-format film and sensory experience of climate change impacts (Swedish Museum of Natural History (http://linnaeus.nrm.se/welcome.html.en))

Science centers are often viewed as unbiased sources of science information, including climate change. The Association of Science-Technology Centers' Communicating Climate Change (C3) Project included a comprehensive study of climate change in informal settings, which found that people identified science centers as sources of unbiased information (McCracken, 2009). Teens were more likely to trust climate change information coming from a science museum than from sources such as Wikipedia, a blog, or discussions on television. Indeed, some visitors were motivated to visit the science center precisely because they wanted to learn more about climate change. McCracken concludes, "Across focus groups, participants overwhelmingly agreed that science centers should play a role in educating the public about climate change." This conclusion is mirrored by Cameron and Deslandes (2011) who demonstrate that visitors perceive science centers as effective venues for deliberative democracy on climate change.

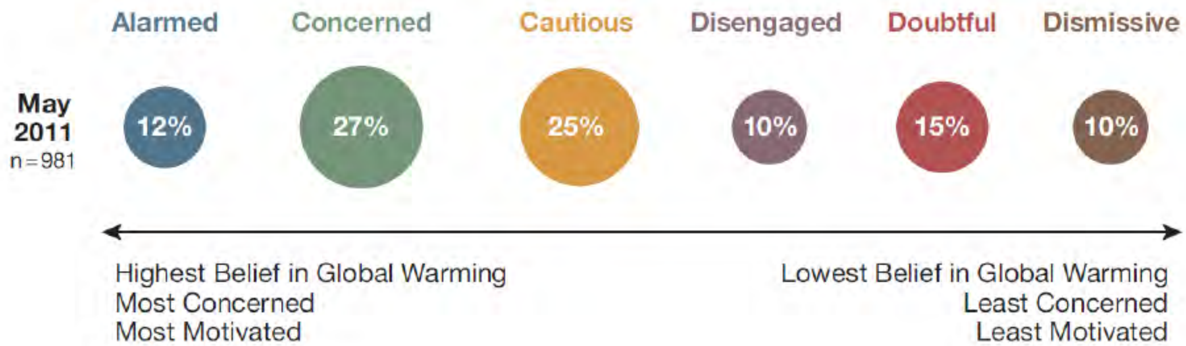
Audience Perceptions of Climate Change

Significant work has been done by the Yale Project on Climate Change and George Mason University Center for Climate Change Communication to better understand public perceptions of climate change. This work informs our discussion of climate change education in formal and informal settings. The Yale Project on Climate Change and George Mason University Center for Climate Change Communication conducted a national survey in 2008 that identified 6 different positions on global warming and the proportion of Americans who fell into each: alarmed, concerned, cautious, disengaged, doubtful and dismissive. They repeated the survey in 2010 and 2011. Below is a brief description of each position (Maibach, et al., 2009).

1. **Alarmed**: convinced global warming is a real and serious issue; already take action to address it.
2. **Concerned**: convinced global warming is happening and a serious problem; haven't engaged the issue personally.
3. **Cautious**: believe global warming is a problem but less certain it is happening; don't view as personal threat; don't feel sense of urgency about it.
4. **Disengaged**: haven't thought much about it and don't know much about it; could easily change their minds about global warming.
5. **Doubtful**: evenly split between people who think global warming is happening, think it isn't happening, and don't know; many believe it is caused by natural changes in the environment, won't harm people for several decades, and America is already doing enough in response.
6. **Dismissive**: very sure global warming is not happening and is not a threat; actively involved as opponents of national effort to reduce greenhouse gas emissions

Figure 1 shows the national distribution of these 6 positions. Note that there has been some shift over the years of the study (in particular, between 2008 and 2010 the Alarmed category went from 18% to 10% and dismissive went from 7% to 16%. The 2008 survey was done before climategate and before the economic downturn – authors attribute both to the changing attitudes on global warming).

FIGURE 1 | Proportion of the U.S. Population in the Six Americas, May 2011



Proportion represented by area

Source: Yale/George Mason University

The National Science Teachers Association highlighted common misconceptions about climate among people generally, in a half-day symposium at their national conference in 2011. These misconceptions included:

- Recent global warming is caused by the Sun.
- There is no scientific consensus on the existence or causes of global climate change.
- Global warming is caused by the ozone hole because the hole lets in more radiation. (Ozone hole created by chemicals like hair spray.)
- Climate is simply long-term weather and therefore can't be predicted.
- The atmosphere is large and small amounts of carbon dioxide or a few degrees of temperature change can't make much difference.
- Weather anomalies can be used as evidence for or against climate change. The huge snowstorms in the past 2 winters show that global warming isn't happening.
- Carbon is destroyed when fossil fuels are burned and CO_2 is released in to the atmosphere. Carbon released from combustion doesn't have an impact on the climate system.
- The only greenhouse gas emitted by human activities is carbon dioxide from burning fossil fuels.
- The Earth gets closer to the Sun in summer and is farther away in winter.
- Plants gain their mass from water and nutrients through roots.
- Fossil fuels have been around since the origins of the Earth.
- The carbon cycle and water cycle are linked. Water carries carbon about the cycle.

SECTION 3: Methodology

GLCCSESN used several methods for gathering information about the state of climate change education in the Great Lakes. We were primarily interested in understanding the following:

1) How well grounded are formal and informal educators in climate science?
2) Where do educators get climate information from?
3) How do educators use climate change in their professional practice?
4) What are the barriers, gaps, and needs relative to improving climate change education?

We focused on these questions in the context of the Great Lakes region. This section on methodology describes 5 different approaches we used between August 2010 and December 2011 to collect primary data to answer these questions: an Online Stakeholder Survey, In Person Focus Group, Online Workshop and Focus group, and 6 Americas Survey (Leiserowitz et al., 2011).

APPROACH 1: Online Stakeholder Survey

In spring 2011 we conducted an online survey of K-12 teachers, science education professors, university faculty (climate professors), climate scientists, community and agency educators (informal), and museum educators (informal), and journalists. We used a snowball sampling method, with project partners producing lists of possible people/institutions to recruit for the survey, and then inviting those people/institutions to pass the survey on to others.
We had the following number of responses for each subgroup in the survey:

Subgroup	**Respondents**
K-12 teachers	52
Science education professors	50
University faculty (climate professors)	107
Climate scientists	23
Community and agency educators (informal)	30
Museum educators (informal)	24
Journalists	117
TOTAL	**403**

The survey was divided into three parts: 1) Questions to assess understanding of climate science and climate change, 2) Demographic questions, and 3) Questions about professional concerns or perspectives of the various stakeholders. Each stakeholder group was given a slightly different version of the survey. Parts 1 and 2 were consistent across surveys; Part 3 was tailored to be relevant to their professional practice.

APPROACH 2: In Person Focus Group

From the spring 2011 surveys, we identified broad categories of “intermediaries” who mediate climate change information between scientists and the public. Categories included organizing groups for formal education (e.g. Intermediate School Districts, teacher associations), non-profit organizations, extension agents, managers of web repositories, journalists, and formal/informal educators themselves. We recruited 12 key representatives for these categorical groups to participate in an in person focus group in November 2011. The focus group was a diverse group in terms of organizations represented, but shared strong ties to climate change as a content area. Participants were also all very involved in both trying to access information about climate change (from scientists) and in trying to translate that information, either for other educators or directly to the public (formal and informal audiences).

The first half of the focus group focused on a concept mapping activity, where participants placed themselves on a concept map of Great Lakes climate change education and identified connections between one another. Participants then identified the sources (people/organizations) and resources (print, web or other media) that they use in their climate change 'literacy programming' (types of programming vary dramatically among participants, e.g., writing an article, preparing a lesson, developing a website, conducting a workshop, etc.). Due to the huge volume of resources generated in a very short time (<15 minutes) we did not map the individual connections of specific resources to participants. The second half of the focus group was spent in in-depth discussion of the challenges and barriers intermediaries face in their professional practice. Participants provided feedback about challenges on both sides: in accessing information from scientists and in communicating that information to public audiences.

APPROACH 3: Online Workshop and Focus Group

GLCCSESN offered a 3-week online workshop and focus group for formal and informal educators in November 2011. This workshop was implemented and facilitated online by the College of Exploration with support from members of the GLCCSESN team. The workshop had multiple purposes:

1. Professional Development: Connect education community directly with the scientific research community for information about climate change research findings and issues in the Great Lakes
2. Focus Group Feedback: Solicit feedback from educators through an online focus group format about their use of and need for climate change curriculum and resources
3. Observing the Community in Action: Record and analyze participant behavior (how they participated and who they participated with) to better understand where educators get climate information from.

Participants were recruited through a process similar to the spring 2011 survey sample. A total of 216 people registered and 130 of those actually entered and engaged with the online activities (either simply reading of material and/or engagement in dialogue). Registrants came from 22 different states, including every state in the Great Lakes region. The states most represented were Michigan, Illinois, New York, Ohio, and Wisconsin. Registrants identified their job titles, the most mentioned being "educator" (listed both generally and specifically). The largest group of educators listed was high school followed by post-secondary. In addition to the educators, the registrants included research scientists, learning scientists, and other professions (e.g. environmental quality analyst, instructor of adult basic education, reference librarian, etc.).

All workshop activities and discussions took place online. Participants could visit several different online "rooms" to listen to presentations, share resources, and engage in discussions. Activities included live webinars and archived presentations, with asynchronous question and answer sessions afterward. Additionally, in the Focus Group Room, a series of questions was posted to participants each week (sources of their information about climate change, the current state of climate change resources, barriers to climate change education). Educators broke out into groups based on educator category and grade level taught, to engage in asynchronous dialog around these questions.

After the Online Workshop and Focus Group, our social network analysis team (Dr. Ken Frank and student Tingqiao Chen) studied the dissemination of climate change knowledge among educators and climate science researchers within this online context. The original data were conversations posted by participants online with time stamps. We then coded the conversations into two-mode (person to event) network data indicating whether a person had participated in a given event.

Numbers 1 to 220 were assigned to represent 220 different individuals. Numbers 251 to 271 were assigned to represent 21 different online sessions (i.e. events). 'Count' was used to represent the number of times each person posted in a particular session. An example of coded data is presented below in which person 12 participated 3 times in event 257.

People Index	Event	Count
12	257	3

In order to understand the communication patterns of these educators, we identified clusters of educators who posted comments in common online sessions. To do so we employed Field and colleagues' (2006) clustering algorithm for two-mode network data. The algorithm adapted Frank's (1995) clustering technique for one mode network data to two-mode data. We created four network pictures for different time points in the online workshop (pictures for week 1, 2, 3 and the picture including keynote speaker sessions) so that we could see the emergence of clusters as people communicated more and more throughout the online workshops. Results of this analysis are included in Section 4 (below) under Question 2: Where Do Educators Get their Climate Information From?

APPROACH 4: Six Americas Survey

From the online and in person focus groups with informal and formal educators, GLCCSESN learned that a significant area of concern for educators in climate change education is the attitude and assumptions of their audiences towards the topic. These attitudes and assumption shape how educators select and present material from their climate science sources. Because understanding the audience is fundamental to educators, GLCCSESN sought to identify how the Great Lakes audience views climate change. We chose to focus our initial work on the museum audience. To do this, we replicated a study done by the Science Museum of Minnesota (SMM), based on the 6 Americas national study described in the introduction of this paper that identifies six distinct audiences in terms of climate change (Leiserowitz, et al., 2011). The Center of Science and Industry (COSI) in Ohio was just finishing a similar replication. We conducted our study at the Ann Arbor Hands-On Museum (AAHOM). Thus, the three science centers form an interesting triangulation of data to understand attitudes towards climate change of the museum audience in the Great Lakes area.

All three science centers used a short form of the Six Americas survey instrument – 16 questions instead of 146 – which was developed for KQED and is available on the Yale Project for Climate

Change Communication website (http://environment.yale.edu/climate/) (Leiserowitz, et al., 2011). The short form is 80% accurate overall compared to the full survey (Phipps, 2011). AAHOM administered this survey to 213 adults visiting the museum in December 2011. Out of the 213 adults surveyed, 193 completed enough questions to be included in the analysis. We also collected information about zip code, museum membership, and frequency visiting the museum. We analyzed the data using segmentation analysis provided by the Yale Project on Climate Change and the George Mason University Center for Climate Change Communication. Their segmentation was first identified in 2008 using Latent Class Analysis based around four constructs: global warming beliefs, issue involvement, policy preferences, and behaviors. Later surveys used discriminant functions, derived from latent class analysis, for the analysis.

APPROACH 5: CCEP Concept Systems for Strategic Planning

Throughout the project, the College of Exploration collected open-ended data from various stakeholder groups (informal and formal educators, faculty, scientists etc.) in response to the question: "What is your understanding of the definition of climate change?" This question was designed to ascertain knowledge and misconceptions about this topic of climate change. There were 900 statements in response to this question from 900 respondents. The responses were extremely varied so in an attempt to cluster the response ideas we employed the Concept Systems process and software. The goal of this was to help give a picture about which content areas were important.

The Concept Systems process and software was designed and created by Professor William Trochim from Cornell University. Over the years Dr. Trochim has refined this process and developed software to support it. The software is now offered by a company called Concept Systems and is described in the book by Trochim and Kane (2007). The process is accomplished by receiving input from relevant stakeholders on a specific issue and then organizing and portraying ideas in easily understood maps and pictures.

SECTION 4: Results – Climate Change Education in the Great Lakes Region

Question 1: How well grounded are educators in climate science?

The Online Stakeholder Survey asked ten questions to assess climate change knowledge. Dr. Julie Libarkin provided most of the questions from her Geoscience Concept Inventory (https://www.msu.edu/~libarkin/research_gci.html). Dr. David Poulsen and his student Kanni Haung designed the remaining questions.

Our results showed that K-12 teachers, science education professors, and journalists had the lowest scores on the test (between 72% and 75%). Museum educators scored 84% and community/agency educators scored 80%. Climate scientists and university faculty had the highest scores on the test (90% and 89%, respectively). While we did not survey the general public, previous research shows that formal climate change educators are typically better educated than the public on climate change (Johnson, 2011).

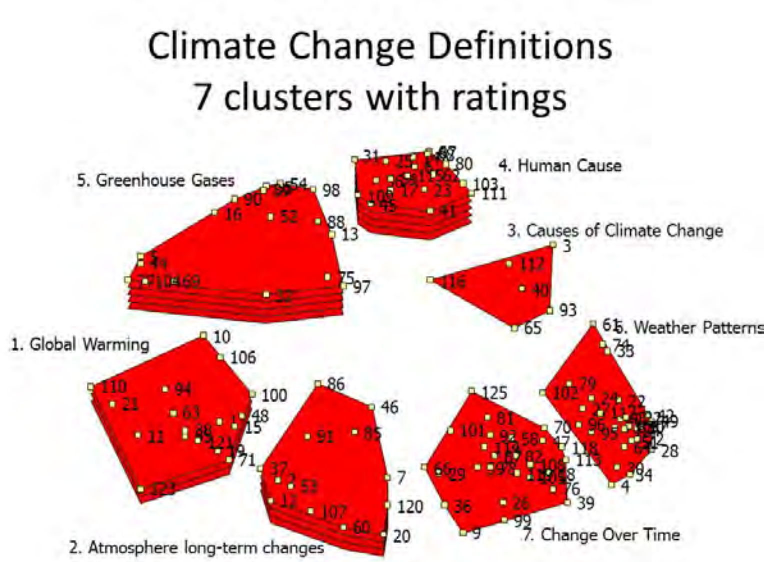
Concept Systems for Strategic Planning: Climate Change Definition There were 900 statements in response to the question "What is your understanding of the definition of climate change?" from 900 respondents. A subset of our virtual community members (which includes the GLCCSESN team, advisory board, and participants from the November 2011 Online Workshop and Focus Group) were asked to sort the survey responses about the definition of climate change and to rate them in importance for our project's learning activities. This process yielded clusters or topics and their importance. We started by taking these 900 statements and paring them down to 125 that most represented that 900. We then invited 51 participants to sort those statements into piles or clusters and to group the like responses and then name the group.

Nineteen respondents sorted the statements into piles and named the piles. They also went through the 125 statements and rated them from importance to our project's educational activities on a scale of 1 to 5 with 5 being very important. Tina Bishop and Peter Tuddenham of the College of Exploration then analyzed the piles, which were put into clusters by the software. We worked with the software to come up with a representative grouping of the statements in clusters.

The Concept Systems software took the sorting and rating completed by the 19 participants and performed a number of analyses in conjunction with the analysis of Tina Bishop and Peter Tuddenham. First a point map, (a way of relating the statements to other) was created (Figure 4). Then through a process of analysis of multidimensional scaling we were able to produce a map of the various statements and where they occurred and to look at how closely they were related to each other in the in the sorting.

We then went through a hierarchical cluster analysis, which gave us a way of bringing the number of clusters down to a size that could be manageable. By looking at the various groupings and how strongly they were related, we decided on a cluster a map with seven clusters, shown above. The layers on the clusters related to the relative importance of those statements in these clusters.

Figure 4: Climate Change Definitions



It is noteworthy that " greenhouse gases" and" human cause" piles are slightly more highly weighted in importance than "causes of climate change" or "weather patterns" or "change over time." These are determined to be the important definitions with which to work. The results showed seven statements or clusters with definitions associated, ranging from global warming, atmosphere long term changes, causes of climate change, human caused, greenhouse gases, weather patterns, change over time with the greenhouse gases and human causes along with global warming and atmospheric changes being the most important.

Figure 5 shows the top 10 climate change definitions. To highlight the particular statements receiving the highest ratings in this process the two that came out on top were "increased variability of the Earth's climate system related to increase in the average global temperature" and the other one was the "response of biological, geochemical and atmospheric processes and cycles to the increasing concentrations of greenhouse gases such as carbon dioxide and methane in the atmosphere". These came up on top and then the next three tied "increasing temperatures over land air and water and decreasing ice in ice regions", "changes in global climate weather patterns as a result from rising temperatures on the earth surfaces, ocean and atmosphere" and "long-term and gradual changes in patterns of regional climate due to factors related to the interconnected earth systems". These 10 statements came out at the top in terms of importance.

Figure 5:

Great Lakes CCEP Climate Change Definition

Top10 most important topics in the Great Lakes

How important the subject of the statement is for Great Lakes regional education programs.

Climate Change Definition

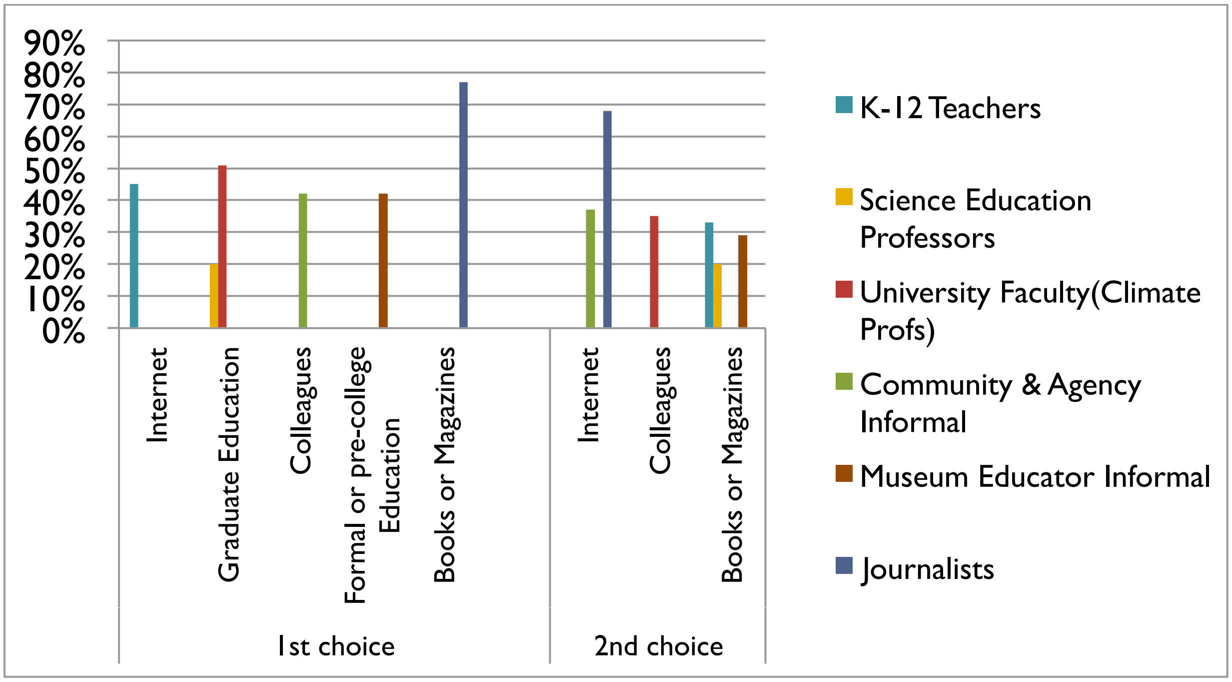
Statements By Ratings - Descending

3/4/2012

#	Statement	Rating
1	The increased variability of the earth's climate system related to increases in the average global temperature.	4.12
44	The response of biological, geochemical, and atmospheric processes and cycles to the increasing concentrations of greenhouse gases such as carbon dioxide and methane in the atmosphere.	4.12
19	Increasing temperature over land, air, and water and decreasing of ice in ice regions.	4.06
46	Changes in global climate and weather patterns that result from rising temperatures of the earth's surface, oceans and atmosphere.	4.06
79	Long-term and gradual change in weather patterns and regional climate due to changes in the factors affecting the interconnected earth systems.	4.06
2	Changing temperatures and atmospheric conditions on the planet.	4.00
5	The warming of the earth's surface due to increasing greenhouse gases.	4.00
6	The effects that the human population has on the climate of the earth.	4.00
17	The condition where due to human activities earth's atmosphere is absorbing more heat causing the climate to shift.	4.00
25	Change in the earth's long-term climate and is caused by human activities, primarily releasing CO2 by burning fossil fuels.	4.00

Question 2: Where do educators get climate information from?
The Online Stakeholder Survey asked respondents to identify which sources they used to get information about climate change. For all stakeholder groups (not just educators), the main choices were books and magazines, Internet, colleague, formal pre-college education and graduate education. Other less cited options included newspapers, television, radio, family and friends, undergraduate education, museums, zoos and aquariums, and movies (Figure 3).

Figure 3: The breakdown by stakeholder group of first and second choices where respondents checked "a lot" for their answer.



We used the Online Workshop and Focus Group and In Person Focus Group to investigate the specific climate change resources that educators use most. In the Online Workshop and Focus Group, participants identified resources such as:

- Centers For Ocean Sciences Education Excellence (COSEE) http://www.cosee.net/
- Antarctic Geological Drilling (ANDRILL) http://www.andrill.org/
- Wisconsin Department of Natural Resources http://dnr.wi.gov/
- The Ohio State University - Changing Climate http://changingclimate.osu.edu/
- Climate Literacy and Energy Awareness Network (CLEAN) www.cleanet.org
- National Oceanic Atmospheric Administration (NOAA) http://www.education.noaa.gov/
- United States Environmental Protection Agency (EPA) http://www.epa.gov/
- National Aeronautics and Space Administration (NASA) http://www.nasa.gov/
- American Meterological Society (AMS) http://www.ametsoc.org/
- Sea Grant Network http://www.seagrant.noaa.gov/
- Investigating Climate Change and Remote Sensing (ICCARS) http://www.resa.net/climatechange/
- PBS NOVA http://www.pbs.org/wgbh/nova/

- Intergovernmental Panel on Climate Change (IPCC) http://www.ipcc.ch/
- Great Lakes Information Network (GLIN) http://www.great-lakes.net/
- National Center for Case Study Teaching in Science http://sciencecases.lib.buffalo.edu/cs/collection/
- Climate Ready Great Lakes (NOAA) http://www.regions.noaa.gov/great_lakes/climate_ready.html

They also referenced the Climate Literacy Principles http://www.climate.noaa.gov/education/ as important to use as a framework and discussed the Michigan High School Content Expectations http://www.michigan.gov/science.

In the In Person Focus Group, participants were asked to write down the sources (people/organizations) and resources (print, web or other media) they use in their climate change 'literacy programming' (types of programming vary dramatically among participants, e.g., writing an article, preparing a lesson, developing a website, conducting a workshop, etc.). In under 15 minutes, participants generated a huge volume of resources: 16 individuals, 24 government agencies, 18 university sources, 11 professional societies, 13 journals/papers, 14 projects/programs, 5 media, and 33 other (e.g. non profits). The types and variety of resources was similar to those references in the Online Workshop and Focus Group. It became clear from this exercise, and from participants' comments, that in general, they have an abundance of climate change resources at their disposal.

When the In Person Focus Group was asked to identify a top few sources from the extensive list, participants said that would be a next to impossible task. Their top resources depended on their purpose (e.g. trying to access the raw information or trying to find pre-made educational materials). As they looked for information, they deliberately diversified their resources, to get valid and balanced perspectives.

"I feel saturated. I feel I have access to everything I need"
(Focus Group Participant)

" It's all a matter of what the output is that you're producing."

"Never go to just one source. I go to a variety of sources. Need to balance it."

(Focus Group Participants)

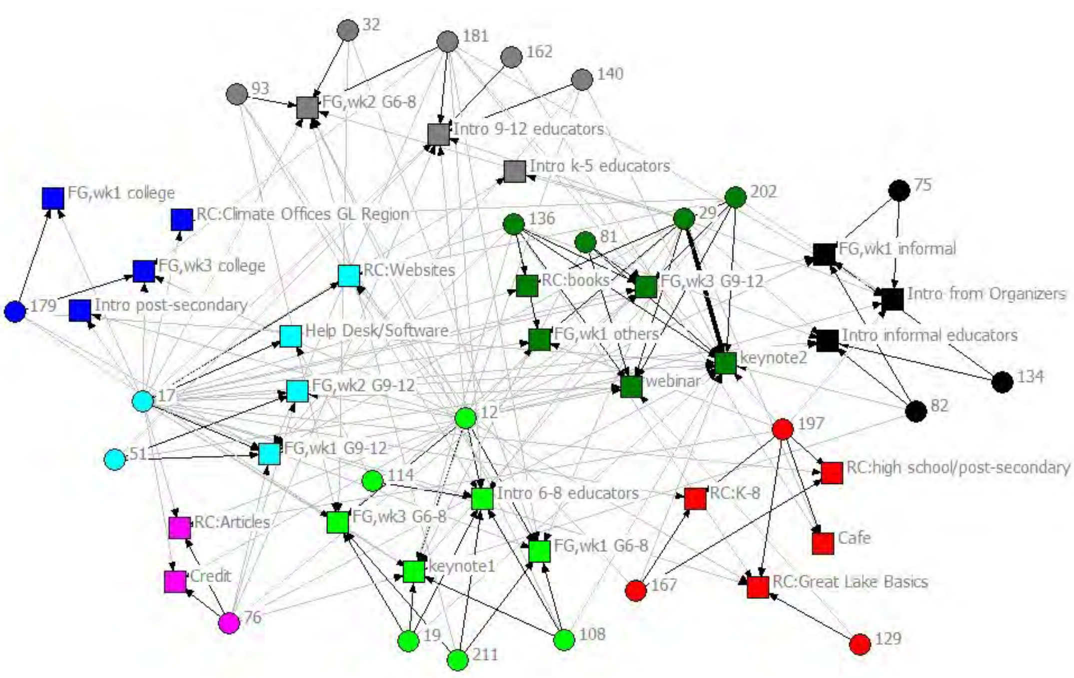
We also note evidence from the In Person Focus Group that informal educators themselves are a closely connected network of practitioners, at least within the specific topic of climate change. Participants identified either direct or indirect connections to each other (for example, belonging to the same organization or knowing that their organizations had worked together previously). Connectivity among participants was high (38% - 10 direct connections and 11 indirect connections among the 8 Michigan-based participants and 2 facilitators). When asked to put a verbal description to this network, one participant's comment, which seemed to reflect the group feeling, was "We have one degree of separation. We're pretty well connected with one another."

Social Network Analysis of Online Workshops and Focus Groups

Overall activity in the Online Workshops and Focus Groups can be summarized as follows. The presentation on climate change in the Great Lakes by Dr. Don Scavia was the most visited area of the workshop, viewed by 95 people and receiving 30 discussion postings. There was also a lively discussion related to a webinar on education resources (46 viewers). Participation in focus groups was distinctly lower: 18 educators participated in the focus group and interacted with a dozen or so of the CCEP team members in contributing responses to the questions. Although this number is relatively small, comments were thoughtful and in depth. As this was a voluntary process of participation, this was not an unexpected outcome and resulted in a satisfactory amount of participant feedback overall.

Our social network analysis team conducted in-depth analysis of individual-level connections based on participation in online discussions around the various workshop/focus group events. This analysis gives us concrete data about how educators connect to, access, and share information about climate change in a real-world scenario. Below is the picture representing the state of individual connections at the end of week 3 including the keynote speaker sessions (Figure 2).

Figure 2: Clusters in a Two-Mode Network of Educators and Online Sessions They Participated in Week 3 including Keynote Speakers Session.



We then used Figure 2 to understand the formation of different groups and identify their foci. We note most of the clusters were focused around specific grade level activities, such as the light green cluster at the bottom of the figure focused around activities for teachers in grades 6-8 or the light blue cluster focused around activities intended for teachers in grades 9-12. But the clusters did not fully conform to grade level. More than one cluster contained activities for grades 9-12. For example, the dark green cluster on the right center and the gray cluster near the top center each included an activity for grade 9-12 teachers. Furthermore, many of the clusters were focused around activities that were not designated for a particular set of grade levels, such as the black cluster on the right that is designated for informal educators. Thus the clusters represent an emergent pattern of interaction beyond what can be explained by a priori formal designations such as grade level.

In general, there is value when members of a social system establish themselves within subgroups in which they can develop a common language for articulating their problems and knowledge about how to address those problems (Nonaka, 1994; Yasumoto et al., 1998). Yet if all interaction is contained within the clusters then the ability to generalize knowledge and problems, and to coordinate action is limited (Durkheim, 1964; Simon, 1965). One way to integrate across clusters is to establish activities intended to attract participants across clusters. Keynote 1 (Scientific Research about Climate Change in the Great Lakes) in the light green cluster and Keynote 2 (Resources on Climate Change in the Great Lakes and discussion) in the dark green cluster were intended to be just such events that attracted participants across clusters. Keynote 1 attracted 33 responses and Keynote 2 attracted 47 responses.

An alternate way to integrate across clusters occurs as particular people serve as “bridgers” by participating in events across clusters. Such people can play a critical role from the systemic perspective (Frank et al., forthcoming). In Figure 2 we identify actors 12 (in the light green cluster), 17 (in the light blue cluster) and 29 (in the dark green cluster) as “bridgers of interest”. Each attended events within his/her own cluster, but also participated in multiple events focal to other clusters. By responding to comments, “bridgers” might help to bring communications among other educators. For example, in event 258 (week-2 focus group for grade 6-8 teachers), actor 12 responded to an educator: “….I see now that the curriculum is old and hard to locate on the web. Maybe someone else knows where to find it.” Then, another educator responded that he/she also found it difficult to find climate change resources specific local areas.

All three “bridgers” we identified were employed by the College of Exploration, demonstrating the critical role that members of the College of Exploration served in integrating across the system. And yet the actors were designated with different a priori roles, as social scientists 12 and 17 entered the process with the intent of bridging, while the role of natural scientist 29 emerged throughout the process. In particular, actor 29 presented the second keynote address, and became a “bridger” partly by responding (17 times) to comments from other participants. Thus actor 29’s bridging role emerged out of his participation in a bridging event, but this need not be the case. For example, the speaker for keynote 1 only responded twice to others. Furthermore, actor 76 was not a workshop organizer, but was a bridger.

Ultimately we intend to explore more the emergence of clusters and roles through the duality of the two mode networks defined by people and on-line forums (Breiger 1974, 1991). For purpose of future research, we may investigate how and why actor 76 emerged as a “bridger”. Why is he so active in participating the online workshop about climate change in the Great Lakes region? Will he communicate with other teachers who did not participate the workshop about the climate change knowledge in the Great Lakes region?

As we move into future virtual experiences, we intend to establish focal activities that cultivate the emergence of clusters in which participants can develop a common language and engage in similar activities. But given the clusters, the bridging role is critical, and the College of Exploration intends to fill that role. A particular goal would be to have natural scientists such as 29, but also those not employed by the College of Exploration, take on new roles to engage a broad audience. These roles are especially relevant in this context of informal education, where scientific knowledge, motivation and interest need not be structured by formal grade levels as much as we would expect with the core curricula in schools such as mathematics.

Question 3: How do educators use climate change information in their professional practice?

The Online Stakeholder Survey asked each group to report on a variety of possible activities they may engage in as part of their professional practice in climate change. Each stakeholder group was asked to respond to a slightly different list of activities, relevant to their work (Table 2).

Table 2: Reports main findings for each group.

Stakeholder Group	How do they use climate change information?
Science Education Professors	Students create lesson plans or activities about climate change (38%) Students do library or internet research about climate change (31%)
Journalists	Reporters primarily tend to report on climate change 1-3 times a year
Informal Educators (community and agency)	Primarily develop climate change online resources, workshops or activities, and lectures (40%) Mostly for adults 18 to 30 years of age (60%)
Informal Educators (museums)	Primarily develop climate change exhibits, workshops, demonstrations, and lectures (30%) Mostly for youth 6 to 12 years of age (60%)
Climate Scientists	45% typically partner with extension, education, or media professionals to meet their broader impacts, but 86% would be interested in partnering with these groups
K-12 Educators	Cover climate change in some way in their teaching (76%) Teach about climate change in the context of the Great Lakes (9.8%) Resources are needed in multiple areas to teach climate change (Glaciers/Artic, Math, Plant Biology)
Climate Professors	Lecture on climate change without a lab (79%) Lecture on climate change with a related lab (36%) Students do library or internet research about climate change (59%)

A Logic Model overview was prepared by NOAA and Sea Grant on climate literacy and can be found at (http://www.miseagrant.umich.edu/greatlakes/climate/images/2011ext_LogicModel04.pdf). It identified that "educators (formal, informal and media) are not currently engaged in any systemic way with improving climate literacy in the Great Lakes region" and "needs for improving regional climate literacy at the level of the general public and student populations are not well understood." They also mention that NOAA Climate Literacy Principles have not been adapted for the Great Lakes area and that climate literacy is not a major component of K-16 curricula. Note there are Great Lakes Literacy Principles (http://greatlakesliteracy.net/).

Informal educators in museums are actively developing and implementing climate change exhibitions and programs (see RK&A, 2010 for an example). From the Online Stakeholder Survey results, it is clear that museum educators are focused on a younger audience (6-12 years) than community/agency educators (18-30 years). In the In Person Focus Groups, we found that informal educators' work in regards to climate change education was varied. Some educators focused on teaching public audiences, others worked at the organizational level, and others were focused on professional development for teachers.

- *"A big part of my job is working with educators, formal and informal."*
- *"Goal to help all these different groups and organizations and different levels of climate change movement be able to access each other and network with each other and know what's going on in these different areas and realms."*
- *"We work directly with teachers and classrooms and areas of professional development. Providing access to lots of resources on climate change to teachers, trying to narrow down the overflow from online."*
- *"Helping our audiences understand a lot of aspects of climate change – physics (atmosphere and ocean acidification), the controversy of climate change, address solutions to climate change."*

SECTION 5: An in-depth Look at Journalists

How well are Great Lakes journalists grounded in climate science?

In the Online Stakeholder Survey journalists' knowledge was assessed in two ways. One used the original six questions shared by the Great Lakes CCEP team (used to gauge environmental knowledge across all formal and informal educators). None of the 95 reporters answered all six questions correctly. Nearly half (41.1 percent) failed to answer more than three correctly. Most journalists recognized states/provinces that border the Great Lakes. Quebec is the only state or province not recognized by most journalists surveyed. Slightly less than one third (32.3 percent) correctly identified Quebec as bordering the Great Lakes.

Although most (78.1 percent) journalists knew that an increase in the greenhouse effect may cause global warming, only a little more than half (56.8 percent) knew that the greenhouse effect referred to gases in the atmosphere that absorbed infrared energy. More than half (58.9 percent) also knew that if human civilization had never developed on earth that there still would be a greenhouse effect. Most journalists incorrectly answered two items: Very few knew that the sun mainly gave off infrared and visible energy and that warmer and drier climate patterns were predicted in the Great Lakes region. Table 3 presents the percentages of journalists who answered each item correctly.

Table 3: Percentages of correct-incorrect answers to climate change knowledge (*N*=95)

	Correct	Incorrect
1) If human civilization had never developed on Earth, would there be a greenhouse effect?	58.9	41.1
2) The "greenhouse effect" refers to gases in the atmosphere that absorb infrared energy.	56.8	43.2
3) What conditions of the climate patterns are predicted in the Great Lakes?	33.7	66.3
4) The sun mainly gives off which two forms of energy?	15.6	84.4
5) Which of the following best describes the relationship between the greenhouse effect and global warming?	78.1	21.9
6) Which of the following states/provinces are on the borders of the Great Lakes (Click all that apply)?		
Illinois	95.8	4.2
Michigan	97.9	2.1
New York	90.9	9.4
Pennsylvania	84.4	15.6
Vermont	97.9	2.1
Quebec (Canada)	32.3	67.7
Ontario (Canada)	96.9	3.1
Minnesota	83.3	16.7

We also gauged the journalists' knowledge of climate change with additional questions developed independently from those used by the entire Great Lakes CCEP partnership. This was done because the first six questions shared by the research team were limited to knowledge about greenhouse effects and to regional Climate Change.

Other dimensions of climate change knowledge, such as scientific prediction of climate change, human adaption and mitigation of climate change and the consequences of climate change were not tested in that assessment. Also, additional research indicated that the answer to one question was controversial and not a valid test of climate change knowledge.

To establish a more comprehensive knowledge index for climate change, a pretest was conducted in March 2011 among journalism students at Michigan State University. Sixteen questions testing climate change knowledge was answered by respondents. Based on their answers, the knowledge index was later refined into eleven questions after conducting the difficulty, discrimination, and reliability analysis of the knowledge index.

Three of the 95 reporters answered all of them correctly. Five reporters failed to answer more than three correctly. On average, respondents answered more than seven (more than half) correctly.

We graded respondents with a scale where 90 percent or better is an A, 80 percent is a B, 70 percent is a C, 60 percent is a D and less than 60 percent is a failing grade. That scale indicates only 10.4 percent of reporters got a grade of A (see table 4). Most journalists could answer between five to nine questions. A grade of C was earned by most journalists (16.6 percent). Most journalists (72.9 percent) received a C or worse.

Table 4:Percentages Questions Correctly Answered by Reporters (*N*=95)

11 questions	3.1%
10 questions (A)	10.4%
9 questions (B)	13.5%
8 questions (C)	16.7%
7 questions (D)	14.6%
6 questions	15.6%
5 questions	14.6%
4 questions	5.2%
3 questions	4.2%
2 questions	2.1%

Overall, few regional journalists knew much about scientific predictions of climate change. For example, only some (33.7 percent) respondents knew that most scientists did not predict an ice age in the 1970s. A similarly small number (36.8 percent) correctly indicated that scientists estimated that global sea levels rose 6-9 inches from 1900 to 2000. Only slightly more than half (56.8 percent) knew that the greenhouse effect refers to gases in the atmosphere that absorb infrared energy. A similar number (58.9 percent) knew that there would be a greenhouse effect if human civilization had never developed on earth. Less than half (48.4%) knew that the worldwide banning of aerosol spray cans would not reduce global climate change. The correct-incorrect percentages of the eleven questions are listed in table 5.

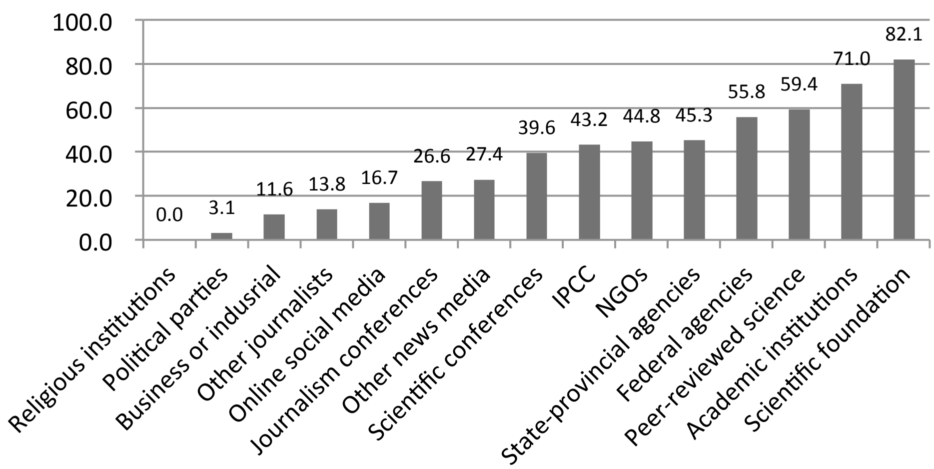
Table 5: Percentages of correct-incorrect answers to climate change knowledge (*N*=95)

	Correct	Incorrect
1) Causes of climate change		
2) If human civilization had never developed on Earth, would there be a greenhouse effect?	58.9	41.1
3) The “greenhouse effect” refers to gases in the atmosphere that absorb infrared energy.	56.8	43.2
4) Which one of the following gases in the atmosphere is NOT good at trapping heat from the Earth's surface?	66.3	33.7
5) Which one of the following conditions CANNOT affect the average global temperature of the Earth?	85.3	14.7
6) Scientific estimation of climate change		
7) In the 1970s, most scientists were predicting an ice age.	33.7	66.3
8) Scientists can’t predict the weather more than a few days in advance – they can’t possibly predict the climate of the future.	87.4	12.6
9) How much do scientists estimate that global sea levels rose from 1900 to 2000?	36.8	63.2
10) Human activities and climate change		

11) Which of the following countries emits the most carbon dioxide per person?	76.8	23.2
12) Which one of the following actions would NOT reduce global warming if they were done worldwide?	48.4	51.6
13) Regional climate change		
14) A watershed is the area where all of the water drains to a common waterway.	88.4	11.6
15) What conditions of the climate patterns are NOT predicted in the Great Lakes?	66.3	33.7

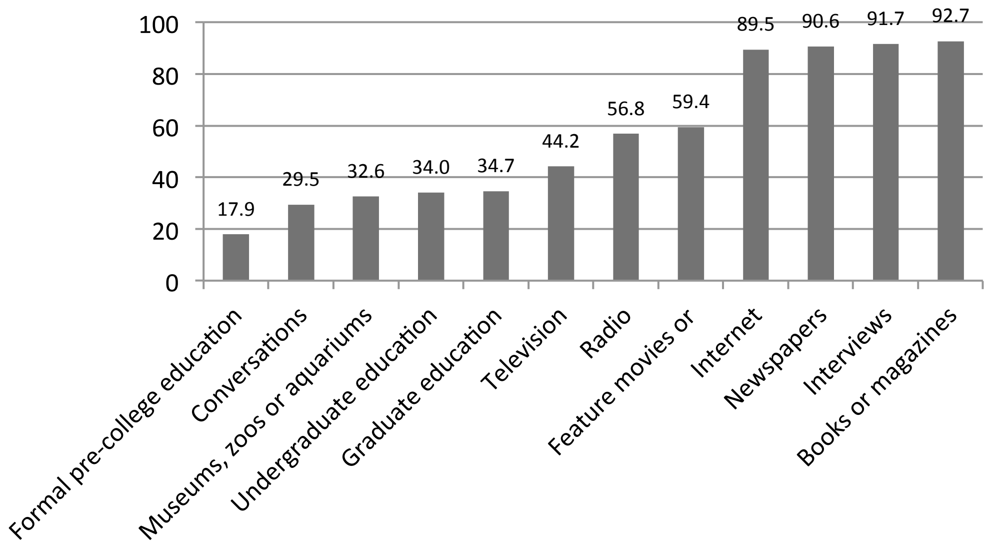
Where do journalists get climate information?
Most regional reporters surveyed said they frequently used scientific reports (82.1 percent), academic institutions (71 percent) and peer-reviewed science journal (59.4 percent) as information sources. None frequently used religious institutions as sources of information about climate change. Only a few had often or always used political parties (3.1 percent), business or industrial corporations (11.6 percent), other journalists (13.8 percent), and online social media (16.7 percent) as information sources for reporting on climate change (see figure 9).

Figure 9: Percentages of journalists who had frequently used each information source.



The survey provides evidence that books or magazines are the major channel that these reporters learned about climate change. Nearly 93 percent of respondents said they learned some or a lot about climate change from books or magazines. But nearly the same number (91.7 percent) used interviews and 90.6 percent used newspapers (90.6 percent) to learn some or a lot about climate change. Formal pre-college education was less likely to serve as a source of knowledge of climate change. Only 17.9 percent of respondents acquired some or a lot of their climate change knowledge in this manner. Conversations with family and friends (29.5%) and museums, zoos or aquariums (32.6%) were the other two channels that reporters were less likely to gain some or a lot of their knowledge of climate change (see figure 10).

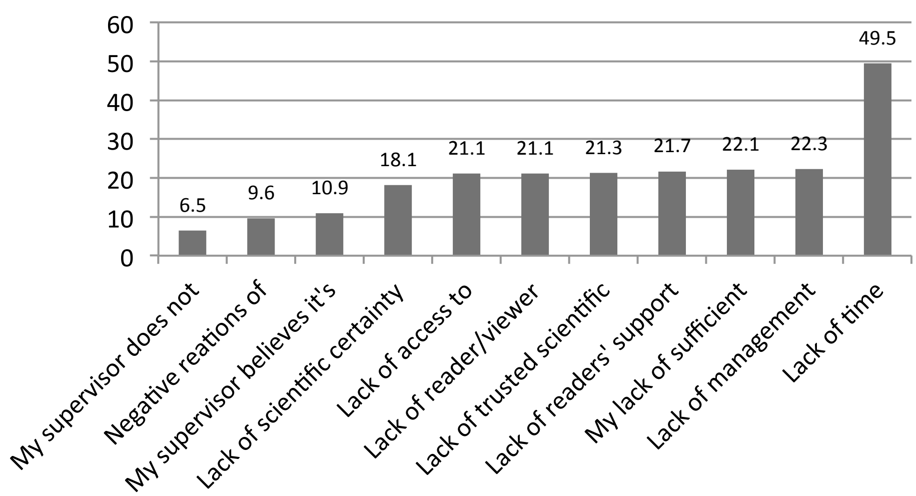
Figure 10: Percentages of journalists who had learned some or a lot about climate change from each medium.



What are the barriers to accessing and disseminating information on climate change science?
Environmental reporters were asked to indicate how important particular obstacles are for reporting on climate change. The lack of time was easily the most significant barrier. Nearly half (49.5 percent) indicated that it is an important or very important obstacle. Other obstacles that were indicated as important or very important are: lack of management support (22.3 percent), lack of sufficient knowledge (22.1 percent), lack of viewers'/readers' support (21.7 percent), lack of trusted scientific information (21.3%) and lack of readers'/viewers' interest (21.1 percent).

Only 6.5 percent of reporters perceived that their supervisor does not believe in climate change. Potentially negative reactions of readers was perceived as important or very important obstacles to their climate change coverage by only 9.6 percent (See figure 11).

Figure 11: Percentages of journalists who indicated obstacles in climate change reporting.



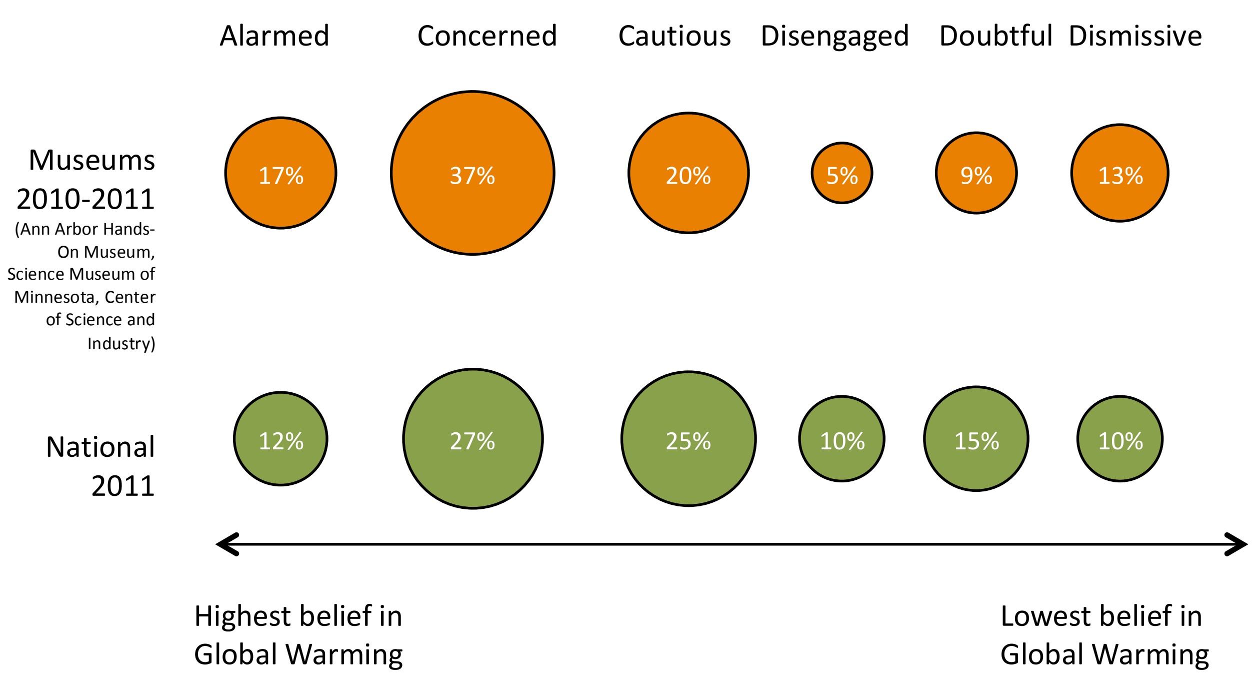
SECTION 6: Results – Barriers and Gaps

Based on the primary research GLCCSESN conducted as well as a review of relevant literature on climate change education for formal and informal audiences, we determined 3 major categories of barriers/gaps to climate change education in the Great Lakes. We present these here, broken down by subtopic. We indicate in parentheses whether informal or formal educators specifically identified the barrier, although we recognize that even barriers only mentioned by one group could be applicable to the other as well.

1. Audience Considerations

Diverse Audiences (Formal, Informal)
Audiences are very diverse, particularly for informal educators. An audience could be a classroom of high school students, a group of climate change activists, a family visiting a museum for a fun outing, or a policy-making group for a city. Each audience comes with diverse demographics, motivations, perceptions, and attitudes. Communication and education programs are most effective when targeted to specific audiences; therefore, treating "the public" as a homogenous group is a barrier in and of itself (In Person Focus Group).

Science center visitors generally reflect the diverse range of opinions in the general population in terms of climate change perceptions. From the 6 Americas Survey, combined with results from other museums that conducted the survey, we see museums serving a diverse audience in terms of attitudes, beliefs and perceptions towards climate change (although we note evidence that science centers see a slightly larger segment of Concerned and Alarmed visitors) (Figure 12).
Figure 12: shows the distribution of audience segments for museums and the national population.



Addressing skepticism and misconceptions (Formal)

Teachers identify one of the biggest barriers to teaching climate change as student (and parent) skepticism and misconceptions. Preliminary survey results show that 38% of teachers identify student misconceptions as a major barrier to teaching climate change (Johnson, 2011). 25% of teachers "report that students, parents, administrators, or other community members have argued with them either that climate change is not happening, or that it is not the result of human activities" and 38% of teachers feel influence to teach "both sides" of the issue (Johnson, 2011). From 2007 to 2011, the "controversy" around climate change has become a greater concern for teachers than lack of curriculum alignment and content knowledge (Wise 2010 and Hirabyashi 2011, cited in Buhr 2011).

"What I see with teachers is that there's tons of info there but a lot of us don't want to, or don't have the time, to get the information. There's a big gap between what our teachers know and what we're willing to do. It's tiring – the overwhelming amount of information and lots of ways to look at it."
(In Person Focus Group)

"There's a lot of agencies that are trying to consolidate these resources. These places need to get this information out to teachers because it's available." (In Person Focus Group)

"Be a hub for information on climate change in the Great Lakes" (Online Workshop and Focus Group)

Different experiences and information based on perceptions (Informal)

Effective framing of climate change and selection of content can be highly dependent on the user's individual position regarding climate change. Audiences who are skeptical or unsure of climate change want to see how science/scientists work. Those who are sure want to see action and efforts to reduce global warming (McCracken, 2009). People's idea of what it means to "take action" depends on their current lifestyle and actions (RK&A, 2011).

Perceptions of prior knowledge (Informal)

Visitors to climate change exhibits tend to think they are already well informed about the issue. This mindset becomes problematic when trying to reach educational objectives (RK&A, 2011).

"The biggest challenge that I had had when teaching climate change in the classroom is the automatic resistance to the idea."
(Online Workshop and Focus Group)

"It quickly became an awkward topic"
(Online Workshop and Focus Group)

"Once the issue becomes a political one, SCIENTIFIC evidence means very little in the students' mind"
(Online Workshop and Focus Group)

"Their parents tell them it's not real."
(In person Focus Group)

Different opinions about what's credible (Informal)
Previous focus group research shows discrepancies in what adults consider reliable information sources. For example, some distrust government and university agencies; others consider them quite reliable (McCracken, 2009)

2. Resources

Information overload (Informal, Formal)
Participants generally agreed that there is plenty of information available and in fact noted that they are dealing with 'information overload'. The plethora of politicized information that is based in rhetoric or opinion rather than fact was noted as impeding the capacity of intermediaries to access scientifically based information (In Person Focus Group). For teachers, information overload results in a feeling that the resources are 'out there' but cannot be located, either because of lack of time or motivation or because teachers don't know where to go (In Person Focus Group). Buhr (2011) describes it as a "bewildering landscape" of information that leaves teachers "feeling their knowledge is fragmented, and are unsure what is credible."

Lack of local and Great Lakes-specific materials (Informal, Formal)
While educators feel the burden of information overload for climate change materials generally, they identified a significant lack of resources specific to the Great Lakes or to local environments and contexts. Focus group participants felt that the best way to communicate to the public audience was to make climate change relevant at the local, issue-specific level. This is substantiated by previous research indicating that showing local impacts of climate change helps engage audiences (Russell, 2010). Most resources that educators know about or have access to are national and global in scope. (In Person Focus Group) Teachers said they simply cannot find resources relevant to the Great Lakes and requested that data specific to the Great Lakes be made available (Online Workshop and Focus Group).

"We need to talk about why it matters – to a farmer with water quality, if it's a business, how it effects business. Need to get it down to the place and it also needs to be broken down into the groups within that place."
(In Person Focus Group)

"There aren't many local, geographic relevant resources. That's what good – to make something relevant it needs to be place-based."
(In Person Focus Group)

"It hasn't been put through the lens of a local geography or local issue."
(In Person Focus Group)

Separate science from politics (Informal, Formal)
As educators discussed vetting the plethora of climate change information available to them, they talked about the need to separate the science from the politics. This is important to them to personally know what resources are accurate, and to build credibility with their audiences.

"I need to be able to present in a community climate of skeptics with accurate data."
(Online Workshop and Focus Group)

"Establish an impartial reputation. Try to stay out of the political 'spin cycle.' "
(Online Workshop and Focus Group)

"In the classroom it needs to be put into [framed as] what is the science."
(In Person Focus Group)

"The idea is to get kids to start questioning things. Make him look at that newspaper article, journal, and question where are they getting their information."
(In Person Focus Group)

Lack of activities and packaged materials (Formal)
Teachers identified a need to move beyond just climate change information to packaged materials, activities and lessons plans ready for them to use in their classrooms. Teachers noted that climate change isn't in the textbooks (Online Workshop and Focus Group). It is also more difficult to find good classroom activities than simply education resources (Johnson, 2011).

"Anything I want to be locally relevant I have to make it myself."
(In Person Focus Group)

"I think there's a translation gap. There's a lot of information and there's a limited about of our time and resources to translate that to our offices." (In Person Focus Group)

"There's a translation problem. There are a lot of resources out here. It needs to be categorized into useful tools. We need help, time and resources to translate the information."
(In Person Focus Group)

"It's pedagogy to some extent. How do I frame this with different audiences?"
(In Person Focus Group)

Unconnected to science community (Formal)
Teachers feel less connected to the science community, but see great value from establishing this link. Teachers identified a need for liaisons between climate scientists and educators and expressed interest in more materials such as the webinar featuring a climate scientist (Online

Workshop and Focus Group). Teachers place a high value on face time with scientists (Buhr, 2011).

3. Time

"Climate change is not the main part of our facility (museum). We just have 3-4 minutes to convince them that this is a topic to explore later. Steer them to seek out more info post-visit." (In Person Focus Group)

"Most of the audience I work with is the adult practitioner. If I go into the group and try to tell them we're going to talk about climate change, they say no we're not. We're working with a group now and they came out and said climate change is not an issue and we're not going to talk about it." (In Person Focus Group)

Lack of time to craft a tailored message to audience (Informal, Formal)

Because of the lack of locally relevant materials, practitioners feel there is a large burden on them to make the connection between the "big picture" of climate change to local issues their audience cares about. This barrier was a major theme of the in person focus groups. Teachers, in particular, have only a very limited amount of time available to access resources, craft a lesson (or presentation, product or message) and deliver the message. Siloing (e.g., separation of climate science into separate subjects in education or separate plans in decision-making) further limits available time and complicates communication.

"[The problem] mostly has to do with standards, time, curriculum." (In Person Focus Group)

"Maybe trying to do too much. It's becoming a subject in and of itself. To bring it into a classroom and say we'll have a lecture on climate science – you won't do it all in one class." (In Person Focus Group)

Not reflected in standards and curriculum (Formal)

Teachers face pressure to teach to the test. Without climate change being integrated into the existing standards, teachers "have to be creative to work it into the curriculum" (Online Workshop and Focus Group, In Person Focus Group). For the most part, climate change is not integrated into the curriculum (Johnson, 2011; Buhr, 2011).

Additionally, climate change encompasses many aspects of science and could almost be a subject itself. This makes it difficult to simply throw in to one day in the classroom. (In Person Focus Group)

Limited attention of audience (Informal)

While educators face a lack of time in preparing materials, they also face a lack of time in presenting materials. The available time of the audience is often short (one lesson, a 30 minute presentation, a sound bite) (In Person Focus Group). Of particular concern for informal educators is the challenge to capture the attention of their audience. In informal education, the audience has much more control over what topics they choose to listen to. If they are not interested in climate change, or don't consider it an issue, then they can easily opt out of any type of climate change education.

SECTION 7: Discussion

Based on the above barriers and gaps, we can characterize the challenge of climate change education for formal educators and informal educators.

Formal educators

One of the greatest challenges facing teachers is the need to diffuse the political aspects of climate change, addressing student and parent skepticism and misconceptions by focusing on the science behind climate change. Teachers need access to critical resources given their limited time. This includes educational materials packaged for classroom use, materials that are locally based and Great Lakes based, and access to the scientific community directly. An underlying tension for teachers is the fact that their time and attention is driven by curriculum and standards: if climate change is not aligned with curriculum and standards it becomes very difficult to integrate into the classroom in a meaningful way.

Informal educators (including community agencies, museum professionals, and journalists)

The first challenge facing informal educators is to first understand their audience. Beyond basic demographics and motivations, it is critical to understand audience perspectives and attitudes towards climate change. Informal educators must then frame climate change based on this understanding. A major component of this is to make climate change a relevant issue – bringing it to a local level for their audience. The underlying constraint for informal educators is that their audiences often have a great deal of control over what information they will attend to and for how long.

Areas of Opportunity

We see several areas of opportunity for helping educators' meet these challenges of climate change education.

1. Provide materials and content specific to Great Lakes and local contexts. Over and over again, educators told us there is a gaping hole in resources focused on Great Lakes and local contexts, from raw data on climate and environmental changes to fully formed lesson plans.
2. Connect educators with scientists. Both formal and informal educators feel the need to ground their educational materials in science. Problems of information overload make it difficult to accurately vet resources. However, establishing strong ties to scientists could provide educators with a personal network rich in accurate and credible climate change materials.
3. Build or identify teaching frameworks for climate change education, based on audience attitudes and motivations. Because varying audience attitudes influence what content and approach works best, there is need for clear frameworks for teaching climate change that take those audience variances into consideration. These frameworks could help educators more easily craft tailored messages for their audiences. Additionally, they could help ground messages in solid pedagogy for climate change education.
4. Build professional development around existing teacher channels. Although not discussed directly in the preceding sections, we heard from teachers that the most effective ways to communicate with and train teachers was through existing avenues of professional development: in-person professional development workshops, professional conferences

and associations, pre-service training. This is echoed in previous research on how to best reach formal educators with climate change information (Johnson, 2011). The best professional development, it is noted, is also sustained over a longer period of time rather than a one-time lesson or meeting (Buhr, 2011).

5. Leverage science center and museum audiences. While informal educators face the inherent challenge of selective attention from audiences in these “free-choice learning environments”, there is promise in venues such as science centers and museums to reach a diverse audience group who may not intentionally be seeking out climate change education. In general, visitors come to science museums as an appealing option for rich family learning experiences rather than as a specific route for learning about climate change (McCracken, 2009). This makes science museums a unique place to have the attention of people from a full range of climate change positions, at a time when they are receptive to learning. Additionally, people view science museums as unbiased sources of climate change information and feel they should be part of the landscape of climate change education (McCracken, 2009; Cameron & Deslandes, 2011).

References

American Geological Institute (2009) Status of the Geoscience Workforce: Report Summary. http://www.agiweb.org/workforce/reports/2009-StatusReportSummary.pdf. Accessed 30 September 2011

Barstow D, Geary E (2001) Blueprint for Change: Report from the National Conference on the revolution in Earth and Space Science Education. TERC 100 p

Boyes, E., Chuckran, D., and Stanisstreet, M., 1993, How do high school students perceive global climate change? What are its manifestations? What are its origins? What corrective action can be taken? J. Sci. Educ. Technol. 2, 541- 557

Buhr, Susan, M., 2011, Navigating Climate Science in the Classroom Teacher Preparation, Practices, Perceptions and Professional Development, CIRES Education and Outreach Group, 15 p., http://www7.nationalacademies.org/bose/1CCEW2_Susan_Buhr.pdf (21 May 2012)

Breiger, Ronald L., 1974. "The Duality of Persons and Groups." *Social Forces* 53(2): 181-90.

Breiger, Ronald L., 1991. *Explorations in Structural Analysis: Dual and Multiple Networks of Social Interaction*. New York, NY: Garland Press.

Cameron, F. and Deslandes, A., 2011, Museums and science centres as sites for deliberative democracy on climate change, Museum and Society, 9(2) 136-153 http://www2.le.ac.uk/departments/museumstudies/museumsociety/documents/volumes/camerondeslandes.pdf (8 May 2012)

Common Core (2011) Common Core State Standards Initiative: Preparing America's Students for College and Career. http://www.corestandards.org/. Accessed 22 October 2011

Durkheim, E. 1964. *The Division of Labor in Society*. New York, New York: Free Press.

Earth Science Literacy Initiative, 2010, Earth Science Literacy Principles: The Big Ideas and Supporting Concepts of Earth Science. Arlington, VA: National Science Foundation. Available: http://www.earthscienceliteracy.org/es_literacy_6may10_.pdf (21 May 2012)

Field, S., Frank, K. A., Schiller, K., Riegle-Crumb, C., and Muller, C. 2006. "Identifying Social Contexts in Affiliation Networks: Preserving the Duality of People and Events. *Social Networks* 28: 97-123.

Frank, K. 1996, "Mapping Interactions within and between Cohesive Subgroups." Social Networks 18: 93-119.

Frank, K.A., Chen, I-Chien., Lee, Youngmi; Kalafatis, Scott; Chen, Tingqiaol; Lo, Yun-jia; Lemos, Maria, *Accepted*, Network Location and Policy-Oriented Behavior: An Analysis of Two-

Mode Networks of Co-authored Documents Concerning Climate Change in the Great Lakes Region. Accepted to *Policy Studies Journal*

Hoffman M, Barstow D (2007) Revolutionizing Earth System Science Education for the 21st Century: Report and Recommendations from a 50-State Analysis of Earth Science Education Standards. TERC Center for Earth and Space Science Education. http://www.terc.edu/downloads/TERC_RevEarthSci.pdf. Accessed 15 August 2011

Johnson, R., 2011, Climate Change Education in K-12: Teacher Preparation, Understanding, Needs and Concerns, 17 p. http://www7.nationalacademies.org/bose/1CCEW2_Roberta_Johnson.pdf *(21 May 2012)*

Leiserowitz, A., Maibach, Roser-Renouf, C. and Smith, N., 2011, Global Warming's Six Americas, May 2011. Yale University and George Mason University, New Haven, CT: Yale Project on Climate Change Communication. http://environment.yale.edu/climate/files/SixAmericasMay2011.pdf (29 February 2012)

National Geographic Society, 2006, Ocean Literacy: The Essential Principles of Ocean Science K-12. Washington, DC: Author. Available: http://www.coexploration.org/oceanliteracy/documents/OceanLitChart.pdf (26 June 2012)

National Research Council, 1996, *National science education standards.* Washington, D.C.: National Academy Press

National Research Council, 2011, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Idea*. National Academies Press. 282p
Michigan Sea Grant, 2011, Climate Literacy Logic Model, http://www.miseagrant.umich.edu/greatlakes/climate/images/2011ext_LogicModel04.pdf (21 May 2012)

Next Generation Science Standards (2011) http://www.nextgenscience.org/. Accessed 22 October 2011

Nisbett, M.C., 2010, Civic Education About Climate Change:
Opinion-Leaders, Communication Infrastructure, and Participatory Culture, Draft White Paper, Climate Change Education Roundtable, National Academies Washington, DC, 19p.

NSTA, 2011, NSTA Climate Change Symposium. Presentation http://learningcenter.nsta.org/products/symposia_seminars/sanfrancisco11/climatechange/symposium_post.aspx. You can access the actual PPT presentation through the website, about halfway down the page is a section called "Presenters Presentations" and the link is the first one "Controversial issues in the classroom"

Maibach, E., Roser-Renouf, C., and Leiserowitz, A., 2009, *Global Warming's Six Americas 2009: An Audience Segmentation Analysis.* Yale Project for Climate Change and George Mason

University Center for Climate Change Communication. http://environment.yale.edu/climate/files/climatechange-6americas.pdf (21 May 2012)

McCracken, K., 2009, Communicating Climate Change 2009 Audience Research Results. Washing DC: Association of Science Technology Centers, DAVID HEIL & ASSOCIATES, INC. http://www.nysci.org/learn/research/CommunicatingClimateChange (see .pdf link in page) (16 May 2012)

Michigan Department of Education (MDE), 2006, Michigan Merit Curriculum: High School Content Expectations Earth Science, http://www.michigan.gov/mde/0,4615,7-140-38924_41644_42814---,00.html (16 May 2012)

Nonaka, I., 1994, A Dynamic Theory of Organizational Knowledge Creation, *Organization Science*, 5(1): 14-37.

Ohio Sea Grant (2010) Great Lakes Literacy: Essential Principles and Fundamental Concepts for Great Lakes Learning. http://greatlakesliteracy.net/ (22 October 2011)
Phipps, M., 2011, Global Warming's Six Americas: A Science Museum of Minnesota Audience Segmentation Analysis. Minneapolis, MN: Science Museum of Minnesota.

RK&A, 2010, Summative Evaluation: Altered State: Climate Change in California Exhibition, Museum Visitor Studies, Evaluation & Audience Research, Randi Korn & Associates, Inc., http://informalscience.org/reports/0000/0228/2009_CAS_Altered_State_Summ_final_distribution_copy.pdf, 25 pages (20 May 2012)

RK&A, 2011, Program Evaluation Climate Change and the Oceans: From Awareness to Action. Monterey Bay Aquarium. http://staging.informalscience.org/evaluation/show/385 (21 May 2012)

Russell, R. L., 2010, Summative Evaluation of Soundprint's Pole to Pole (NSF #0632194): An Exploratory Study of the Impact of Radio Documentaries on Listener Understanding of Science Research on Climate Change (This report was published in *The Informal Learning Review*, #103, July/August 2010, Learning Experience Design, Washington, DC

Simon, H.A. 1965, The Architecture of Complexity, In *General Systems: Yearbook of the Society for General Systems*. von Bertalanffy, L. and Rapaport, A. (eds.). Vol. 10, p.63-76.

Trochim, William and Mary Kane, 2007, *Concept Mapping for Planning and Evaluation*, Sage Publications, 216 p.

University Corporation for Atmospheric Research. (2008). Atmospheric Science Literacy: Essential Principles and Fundamental Concepts of Atmospheric Science. Boulder, CO http://eo.ucar.edu/asl/pdfs/ASLbrochureFINAL.pdf

U.S. Global Change Research Program/Climate Change Science Program, 2009, Climate Literacy: The Essential Principles of Climate Sciences. Washington, DC: http://downloads.climatescience.gov/Literacy/Climate%20Literacy%20Booklet%20Low-Res.pdf

(21 May 2012)

Yasumoto, J. Y., Uekawa, K., and C. Bidwell, C., 2001, The collegial focus and student achievement: Consequences of high school faculty social organization for students on achievement in mathematics and science, *Sociology of Education*, 74, 181–209.

Appendix: Finding Great Lakes Climate Change Educational Resources

An accompanying document to this white paper is a survey of the development of climate change educational resources in general and identification of specific resources for teaching climate change in the Great Lakes region. If not included in the white paper, the survey can be found at: http://www.coexploration.org/greatlakesclimatechange/GL_Presentation_v2.0_SC.pdf