

Weathercaster Views on Informal Climate Education: Similarities and Differences According to Climate Change Attitudes

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ABSTRACT

Surveys have found that weathercaster views on climate change are diverse, with a large majority agreeing that climate change is happening but most remaining unconvinced that human activities are the principal cause. We hypothesized that these differences in climate change views could have implications for weathercasters acting as informal climate change educators, as well as for professional development training for weathercasters attempting to serve such roles. We asked weathercasters at a professional society meeting to provide brief statements on climate change and their roles to educate viewers about climate. We then pooled these statements for an online card-sort activity completed by 29 weathercasters and used network analysis to study the epistemologies of groups according to climate change attitudes. Despite different views on climate change, all weathercasters had a shared ethos for developing their climate change views through consulting observational data and multiple sources of information. Additionally, all weathercasters shared the concern that informal climate education focus on “the science and only the science.” Looking specifically at factual statements on climate change, all weathercasters classified the statement, “Climate is always changing,” as significant for informal climate education. However, there were differences in how weathercasters perceived the importance of changes in the atmospheric concentration of CO₂ and how it relates to human activities. The implications of these findings are twofold. First, without interventions to empower all weathercasters as science communicators, the community may split into communicators explaining the contributions of human activities to climate change versus those who question it. Second, professional societies can play important roles to confront this schism through forums that address conflict, the science–policy interface, and scientific discussions around climate. By appealing to values and codes of conduct shared by all weathercasters, professional development activities can help them build confidence in making public statements about climate change as well as to develop appropriate conceptual scaffolding for relationships between human activities, greenhouse gas emissions, global warming, and climate change. © 2014 National Association of Geoscience Teachers. [DOI: 10.5408/13-046.1]

Key words: climate change, group epistemology, informal science education, science communication, weathercasters

INTRODUCTION

Background

TV broadcast meteorologists, or weathercasters, are science communicators (Wilson, 2008). Additionally, due to their high accessibility to TV viewers (Silcock et al., 2007; Smith, 2007) and viewer-perceived high trustworthiness for providing information relevant to climate change (Leiserowitz et al., 2010), it has been recognized that weathercasters could potentially be enabled as informal science educators for their viewing audiences on the topic of climate change. Weathercaster perspectives on climate change, however, are diverse (Maibach et al., 2010; Maibach et al., 2011), with a majority unconvinced that climate change is primarily caused by human activities. In line with research on the moderating effects of political orientation on climate

change views among members of the general public (McCright, 2011), some researchers have concluded the same for weathercasters; that is, climate change views that are not consistent with the scientific consensus can primarily be explained by political beliefs (Wilson, 2012). Instead, this study provides a fresh perspective by examining the epistemologies of weathercasters according to conclusions they have drawn about climate change.

Previous research has shown that TV weathercasters can be effective climate educators (Zhao et al., 2013), yet members of this professional community hold widely diverging views about two of the most fundamental climate change facts: that it is occurring, and that its cause is largely the result of human activity (Maibach et al., 2010; Maibach et al., 2011). Approximately half (54%) of weathercasters nationwide hold views that are more or less consistent with those of the consensus view among climate scientists (specifically, climate change is occurring and it is mostly human caused [19%], or is caused more or less equally by human activity and natural factors [35%]), while the other half (46%) hold views that are at odds with that of climate science (specifically, climate change is occurring but it is due primarily to natural factors [29%], climate change is not occurring [9%], and undecided/don't know [8%]).

Overview

To investigate beliefs—and epistemologies—that influence the diverging views of these five groups of weathercasters, and that may also influence their willingness to serve

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in the role of climate educator, we conducted a multipart study. We employed a novel methodology, an epistemic network analysis, which captures the most frequently noted ideas in a group's epistemology and determines the strength of the connections among the statements made by members of the group (Peters-Burton and Baynard, 2013). Network analysis has been used successfully in the fields of cognitive psychology (Weller and Romney, 1988), science education (Peters-Burton and Baynard, 2013), and Web design (Kaufman, 2006) to visually map relevant ideas and their relative interconnections. First, we elicited key beliefs about views on climate change from weathercasters at a professional society meeting. Next, we asked weathercasters to sort those beliefs into piles of statements that they felt were related using an electronic format, WebSort. Following the segmentation previously mentioned, the weathercaster groups identified categories. We then used a network analysis program, UCInet, to identify the within-group relationships among these categories of ideas. We found several belief categories that were particularly central to the thinking of weathercasters across the groups, which spanned the topics of factual statements about contemporary climate change, the role of weathercasters in explaining climate change, and sources of reliable evidence. These findings shed light on why some groups of weathercasters hold views about climate change that are at odds with the consensus view of climate scientists, and they suggest opportunities for professional development programs to facilitate the development of a consensus view on how to discuss climate among TV weathercasters.

Research Questions

This study was inspired by a Climate Change Education Partnership (CCEP) with TV weathercasters, which is an example of an effort to develop resources for informal science education to engage society in the issue of climate change. Because of the aforementioned research on the diversity of climate change views among weathercasters, this study aims to investigate two broad categories of questions across the weathercaster segments to enable them to be effective science communicators:

- What are the differences and similarities (if any) in ways of thinking about factual concepts related to climate change?
- What are the differences and similarities in ways of thinking about professional responsibilities, or codes of conduct, to engage in informal science education or science communication, specifically on issues of weather and climate?

METHOD

Network Analysis of Views on Climate Change and Science Communication

This study used a network analysis technique to examine the interrelationships of statements made by weathercasters who self-identified in one of the following five segments developed through empirical means by Maibach *et al.* (2011): (1) climate change is happening and primarily due to human activity (19% of weathercasters); (2) climate change is happening and primarily due to natural causes (29% of weathercasters); (3) climate change is happening and is due to both human and natural causes (35% of

weathercasters); (4) climate change is not happening (9% of weathercasters); and (5) don't know if climate change is happening (8% of weathercasters). The strength of network analysis is that it shows the interconnectedness of the data items of interest—in this case, ideas about climate change and communicating the issue. Moreover, our application of the network analysis technique has the advantage of accurately documenting the beliefs of the weathercaster segments by collecting original, verbatim ideas of the weathercasters and measuring the interconnections between their ideas. As will be elaborated below, the data were collected in two parts: (1) an open-ended questionnaire and (2) an electronic sort (also sometimes called a "card sort") performed on the proprietary software, WebSort, where the statements given to the weathercasters were derived from open codes of writing samples obtained in Part 1, the open-ended questionnaire (Hanneman and Riddle, 2005). The sorting activity was also designed a particular way, in which weathercasters were instructed to group statements into "bins" that had meaning for them. The bins were created and named by the individual weathercasters in the WebSort program. Each statement was dragged and dropped into the named "bin." This particular technique is a method used to develop information about the groupings and interconnections of specific ideas for weathercasters in each of the five segments. The sorting of statements technique originates in cognitive psychology, and one of the most notable examples is used in the Wisconsin Card Sorting Task (WCST) introduced in 1946 to demonstrate human thinking during categorization. Card sorting techniques have been used with web design extensively for the past 10 years (Kaufman, 2006).

The intention of the two-part design of our network analysis is to display the way of thinking of a group. Epistemology can be defined at a group level because it is the collective members of the culture that identify meaningful interactions of ideas, rather than individuals (Knorr-Cetina, 1999; Norgaard, 2011). A network analysis is especially useful in defining the cultural epistemology of a chosen group, as it uses the strengths of the connections across the group to indicate the important collective perceptions. In the same way that a mean can describe central tendency, the frequency of connections between statements among a group of people can indicate the most important features of the group epistemology. It has been found that as few as 25 participants can yield similar results to several hundred, provided that the participants are familiar with the knowledge domain and are representative of the group being measured (Tullis and Wood, 2004).

For the first part of our data collection, an open-ended questionnaire was developed to generate statements that were later placed into the WebSort software for sorting by the weathercasters. The open-ended questionnaire was used to eliminate researchers' predefined positions in the same way interviews have been used to develop surveys grounded in participants' ideas (Aikenhead *et al.*, 1987; Ryan and Aikenhead, 1992). Instead of fitting knowledge into an already constructed framework, the intent of this study was to frame what is taking place with respect to knowledge directly from the weathercasters' perspectives (Hammer *et al.*, 2005; Redish, 2004). Weathercasters were instructed to make meaningful connections among the statements during the electronic sort, so word choice needed to be as authentic

as possible (Lising and Elby, 2005). Since it is difficult to fully describe how particular groups of people make sense of the world around them and construct their epistemology (Carey et al., 1989; Khishfe and Abd-El-Khalick, 2002; Linn and Songer, 1993), a network analysis could be promising in eliciting something other than standard views to a controversial topic. Questions on the open-ended questionnaire were designed by experts in the fields of science communication, conflict analysis, climate change research, educational research, and meteorology. The questions on the free-write were:

- (1) How would you describe the factors that are most important to understanding climate change for you and others who feel as you do?
- (2) How would you describe the factors that you think others, with whom you would disagree, would find most important to understanding climate change?
- (3) What ideas about climate change do you find to be the most misunderstood?
- (4) What ideas about climate change, if any, do you feel are universally agreed upon by all parties?
- (5) What do you see as your role as a weathercaster to educate your viewers about climate change?

Weathercasters were recruited at a professional meeting of the American Meteorological Society ($n = 48$), and were given 20–30 minutes to write their answers silently on the questionnaires after an in-depth interview on climate change and climate change news reporting. Several of the weathercasters dictated their answers to the researchers, which were later transcribed. After the free-write responses were answered in a written format, the weathercasters' sentences were open coded qualitatively (Straus and Corbin, 1998). Open coding is accomplished by reading the responses to the free-write questions and selecting statements that have meaning in the context of communicating climate change. In later steps of the methodology, each statement will be a node on the network analysis map. Two educational researchers and one doctoral candidate in educational research independently coded the statements and a 96% agreement among the statements was found to be representative of the groups' statements. The high agreement after one attempt at coding was not surprising because there is little interpretation into the statements, and they were merely compiled (Strauss and Corbin, 1998). Once statements were identified, they were placed into the WebSort program for Part 2 of data collection, and an online link was sent out to the five different groups 2 months after the free-response questionnaire. Weathercasters were given written instructions to make as many bins for the statements as they saw fit in the WebSort program, as long as it was two or greater. Table I illustrates the statements from responses to the questionnaire that were put into the WebSort program.

The results from the sort were translated into a unit matrix for each group of weathercasters by WebSort, which is explained manually here for the purposes of understanding analytical procedures. The binned statements were considered binary data, where a "1" was placed in the cell column number and row number of two statements placed in the same bin. For example, if statement 2 and statement 10 were in the same bin, the cell that was in row 2, column 10 was marked with a "1." Additionally, column 10 and row

2 would have a "1" in the cell, which generates a symmetric matrix that is helpful in checking the accuracy of the data entry. All cells in the matrix will have either a "0" or a "1" entered. Unit matrices are developed for individuals first and then compiled to arrive at a single unit matrix for a group. After each unit matrix was recorded for the individuals, all unit matrices for the group were added together using simple matrix addition, thus creating a record of the most frequent combinations of statements across the group. The pairs of statements that were placed together most frequently across the group had high numbers once all of the unit matrices were added.

The compiled group matrix was uploaded to the network analysis software, UCInet, for constructing a network map and performing an analysis of network nodes and strengths of connections of statements within the node clusters. There are three features that are used in interpretation of the maps: (1) centrality of nodes, (2) clusters of nodes, and (3) distance between nodes. Central nodes represent anchoring ideas that tend to be connected to a more diverse array of ideas than other pairs of ideas. Close clustering of nodes represents similarity in association, and these clusters can be categorized to interpret the thinking of the groups. Lastly, the distance between the nodes represents the closeness of connection between two ideas, where a shorter distance indicates a closer connection.

RESULTS

As previously mentioned, weathercasters self-identified in one of five segments. For the sake of space, the groups will hereafter be called (a) Yes–Human, (b) Yes–Natural, (c) Yes–Both, (d) Not Happening, and (e) Don't Know. There were 11 respondents for the Yes–Human segment, eight respondents for Yes–Natural, eight respondents for Yes–Both, two respondents for Not Happening, and zero respondents for Don't Know. Tullis and Wood (2004) refer to the need for 25 respondents; however, their work investigated organizational decisions made by the general public. Due to the specialized background of our respondents (weathercasters) striated by climate change attitudes, it was difficult to obtain responses from 25 members for each segment, yet the maps generated from the small number of respondents can be interpreted as a group epistemology (Peters-Burton and Baynard, 2013). Although the number of participants in each group is small, the methodology of network analysis still allows for meaning-making because the analysis is driven by frequency counts, rather than probabilistic models. There were different respondents for each of the five groups; that is, the segments were kept distinct. Additionally, from network maps that were generated for each weathercaster segment, we looked for three features to interpret the group epistemology around climate change and its communication: (1) centrality of nodes, where each node represents a particular idea; (2) clusters of nodes; and (3) distance between nodes. We discuss findings specific to each segment below.

The Yes–Human Segment

The eleven respondents in the Yes–Human segment created a total of 61 bins for the electronic sort. Figure 1 displays the resulting network analysis map for this segment. There is one central node for the statement, "A misunder-

TABLE I. Statements extracted from the free-write that were sorted.

Public speaking arenas provide the best venue for informing viewers about climate change.
The role of weathercasters is to present factual information and let people make their own decisions about climate change.
Weathercasters need to explain the science and only the science when educating viewers about climate change.
Weathercasters have a responsibility to educate viewers about climate change because research indicates television is where most of the general public receives such information.
Weathercasters should present ideas in short, easy to understand stories with examples relevant to viewers
Weathercasters should explain that climate is always changing.
In order to solve climate change, weathercasters need to convince people how it affects them on a personal, day-to-day level.
It is important to use graphics to explain climate change simply to viewers.
Weathercasters should explain what factors contribute to climate change.
A convincing fact in understanding climate change is that Arctic ice is melting at rate that is faster than predicted.
A convincing fact in understanding climate change is that stratospheric cooling is the “smoking gun” against the theory that it is mainly the sun.
Evidence such as temperature graphs, ice melt, and before and after pictures of glaciers provide overwhelming proof that the climate is changing.
It is universally understood that there has been an increase in temperature from observational data.
The idea that humans are responsible for increased carbon emissions over the last century is universally agreed upon.
The misunderstanding of the link between climate change and daily weather is undermining the work that needs to be done in convincing the public and other scientists that we have a serious situation on our hands.
The facts about carbon emissions and their impact on the greenhouse effect are misunderstood.
It is misunderstood that there is a “debate” over climate change, when in reality 95% of the experts agree.
There is enough evidence that action should be taken to dramatically reduce our emission output.
An understanding of the CO ₂ record would convince viewers that climate change is human-influenced.
It is important that climate change be given a historical context so people can understand past climate events to evaluate climate change going forward.
A misunderstood idea in climate change is how a tiny amount of CO ₂ can have so much of an effect.
The role of human activity in climate change is misunderstood.
A misunderstood idea in climate change is how solar changes have so little effect.
People who don’t understand climate change look only at short term evidence.
The variability involved with the warming and how it includes both cool and warm years is misunderstood.
Concrete evidence about the human influence on climate is important in understanding climate change.
It is important to sort out extremist opinions on either side of the discussion.
It is important to research multiple sources in understanding climate change.
Understanding climate change requires attention to consistent observational data.
Understanding science and the scientific method is an important factor in understanding climate change.
It is important to know that climate change is not global warming.
Viewers are not convinced of a connection between an increase in CO ₂ emissions and global warming.
The link between climate change and daily weather is misunderstood by the public.
There are no ideas about climate change that are universally accepted.
There are no ideas about climate change that are universally agreed upon by all parties.
People who don’t agree that climate change is human-related just need to open their minds.
People who disagree that climate change is happening seem to find political and policy ideas more important than science.

stood idea in climate change is how a tiny amount of CO₂ can have so much of an effect.” The location of the node in the center of the map demonstrates that the entire group found this idea very significant and connected it to many other ideas that appear on the edge of the map.

Clusters of nodes can be interpreted by looking at the edge of the map. Here, we describe salient clusters by

following the map edge in a clockwise fashion beginning with the top of the map at “12:00.” At 11:30 to 1:00, there is a cluster of four nodes, two tightly grouped at just after 12:00, and two more distant nodes surrounding them. These can be interpreted as one cluster describing conceptual mistakes across space and time that are often made in relation to climate change. From left to right, the statements include the

ambiguity of the term “global warming” in common parlance versus climate change, the misunderstanding of the human role in contemporary climate change, and the mistake of detractors who focus primarily on short-term evidence. Interestingly, the two tightly grouped nodes at 12:00 include the role of weathercasters in explaining what factors contribute to climate change. The close proximity of this node to “The role of human activity in climate change is misunderstood” suggests that weathercasters in this segment strongly associate education about the human role of climate change with their professional duties.

The second cluster at 2:00 consists of nodes regarding informal science education needs and how weathercasters can address them. Additionally, some nodes are more about the responsible conduct of weathercasters with respect to climate change information, as they refer to consulting consistent observational data and researching multiple sources.

The third salient cluster consists of a path of seven tightly connected nodes that roughly form a line from 3:15 to 4:00. This cluster begins with the statement, “Understanding science and the scientific method is an important factor in understanding climate change,” and ends with the statement, “It is important that climate change be given a historical context so people can understand past climate events to evaluate climate change going forward.” This cluster refers to pedagogical views on what is important in order to understand climate change or what weathercasters should convey as science communicators. Topics include education on science and the scientific method, the fact that climate has changed throughout Earth’s history, appeals to concrete evidence that climate is changing, and providing a historical context for climate change.

The Yes–Natural Segment

The eight respondents in the Yes–Natural segment created 32 bins. Figure 2 displays the network analysis map for the Yes–Natural segment. There is no central node on this map, which demonstrates the lack of an agreed-upon anchor idea for this group. Additionally, it is noteworthy that this map is egg-shaped, as it indicates that the ideas on the far left on the map are less connected to the ideas on the far right of the map.

Following the same procedure for interpreting clusters as the Yes–Human segment, we begin with the cluster at the top of the map from 12:00 to 2:00. This cluster includes the statements, “There are no ideas about climate change that are universally agreed upon by all parties” and “There are no ideas about climate change that are universally accepted.” Additionally, within this cluster is the anchor idea for the Yes–Human segment, “A misunderstood idea in climate change is how a tiny amount of CO₂ can have so much of an effect.” The concentration of nodes in this portion of the cluster appears to generally be about widespread misunderstandings regarding climate change from the perspective of this segment, although a statement that this segment was likely to agree with, “It is universally understood that there has been an increase in temperature from observational data” is also located here. Potentially, this cluster represents general statements about climate change that the Yes–Natural segment agrees with but also important assumptions of the Yes–Human segment with which they do not.

Another salient cluster is diffuse and spans the arc over 7:00 to 11:00. This cluster begins with the statement, “It is important to research multiple sources in understanding climate change” and ends with, “It is important that climate change be given a historical context.” As noted previously, the egg shape of this map indicates that ideas on the left are more distantly related to ideas on the right. This helps in the interpretation of the left side of the map, as all of the nodes on the left have something to do with weathercaster responsibilities around climate change communication. Although this cluster is very large, there are distinct subclusters within. An important subcluster is around 7:00 and includes an inner subcluster also found within the Yes–Human segment, that it is important to consult multiple sources and observational data to understand climate change. For this segment, the ideas that “Weathercasters should explain what factors contribute to climate change” and “The role of human activity in climate change is misunderstood” are also closely related. This particular subcluster suggests that, through the same information processes valued by the weathercasters in the Yes–Human segment, this segment of weathercasters has arrived at the alternate conclusion that climate change is primarily due to natural causes. Another important subcluster consists of the four nodes at 11:00, which are more in line with the climate change perspectives of this segment. They pertain to explaining only the science of climate to viewers, the fact that Earth’s climate is always changing, the historical context of climate change, and the concrete evidence about the human influence on climate, where the latter has been concluded by this segment to be quite small in comparison to other natural drivers.

The Yes–Both Segment

The eight participants who built the Yes–Both map yielded 43 categories. The map constructed by the Yes–Both segment can be found in Fig. 3. This map is not radial like the Yes–Human and the Yes–Natural map because of the tight connections among the nodes in the 7:00 to 10:00 region; however, there is a core idea that is connected to all other ideas as in the Yes–Human map. The core statement can be found in the bottom right corner and states, “Weathercasters need to explain the science and only the science when educating viewers about climate change.” This statement is connected to all other statements but is not located at the center because it is more closely connected to the ideas in the 6:00 to 8:00 region of the map and distantly connected to the ideas in the 10:00 region of the map. This map also has more linear connections among the nodes than the other maps, especially in the 7:00 to 9:00 region, an indication that the number of connections between the linear cluster and adjacent clusters was comparable. Two salient clusters can be identified by beginning at the bottom of the map to the left of the core statement and proceeding clockwise.

The first cluster to the left of the core statement consists of three nodes. All three of these nodes discuss weathercaster responsibility in presenting ideas to viewers to educate them about climate change. It is notable that among these is the statement, “Weathercasters should explain that climate is always changing.” The next three nodes are more spread apart than the others and can be considered to stand alone,

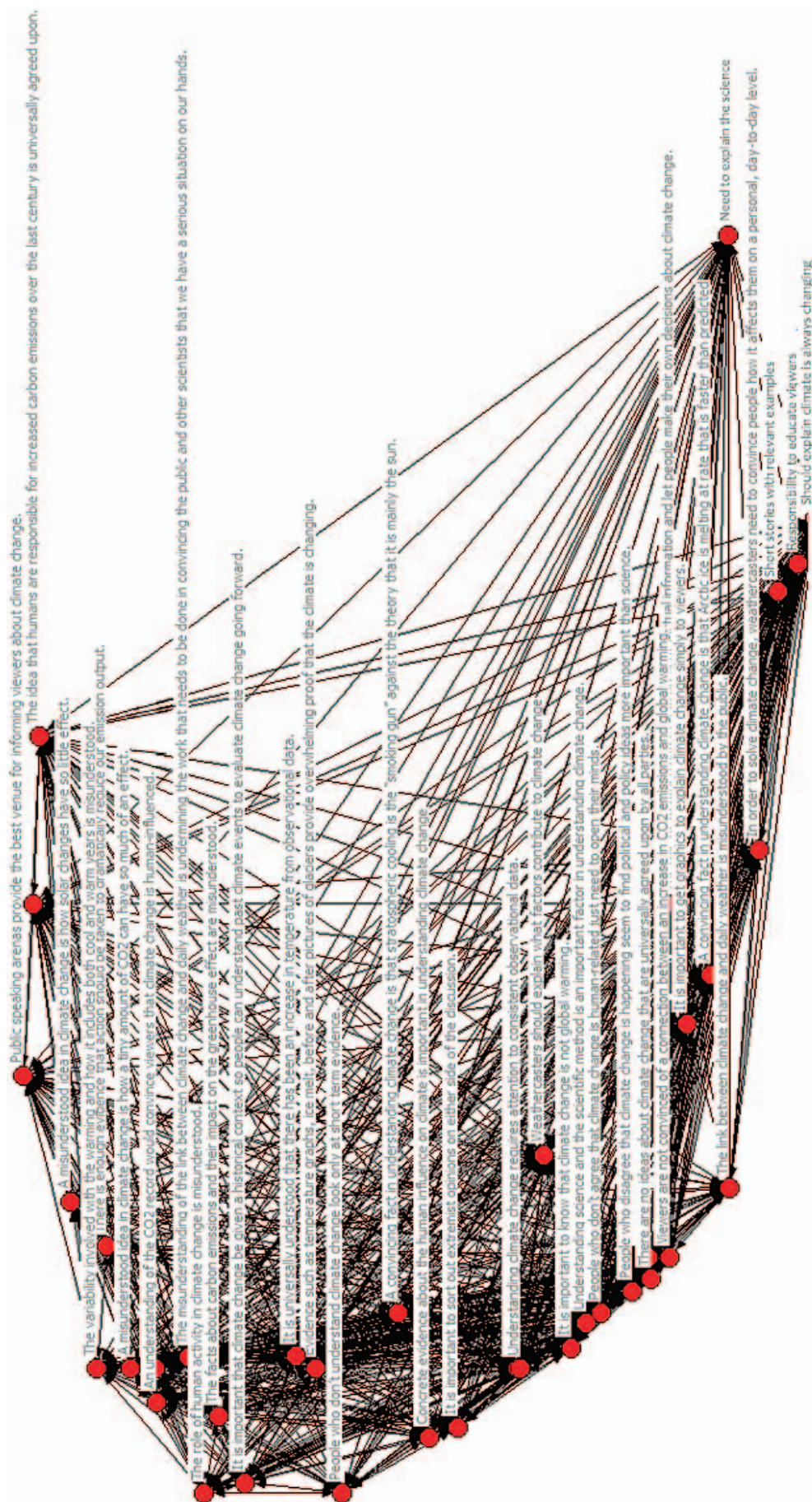


FIGURE 3. Network map illustrating beliefs about communicating climate change of the group of weathercasters who hold views that climate change is happening and is due to both human and natural causes.

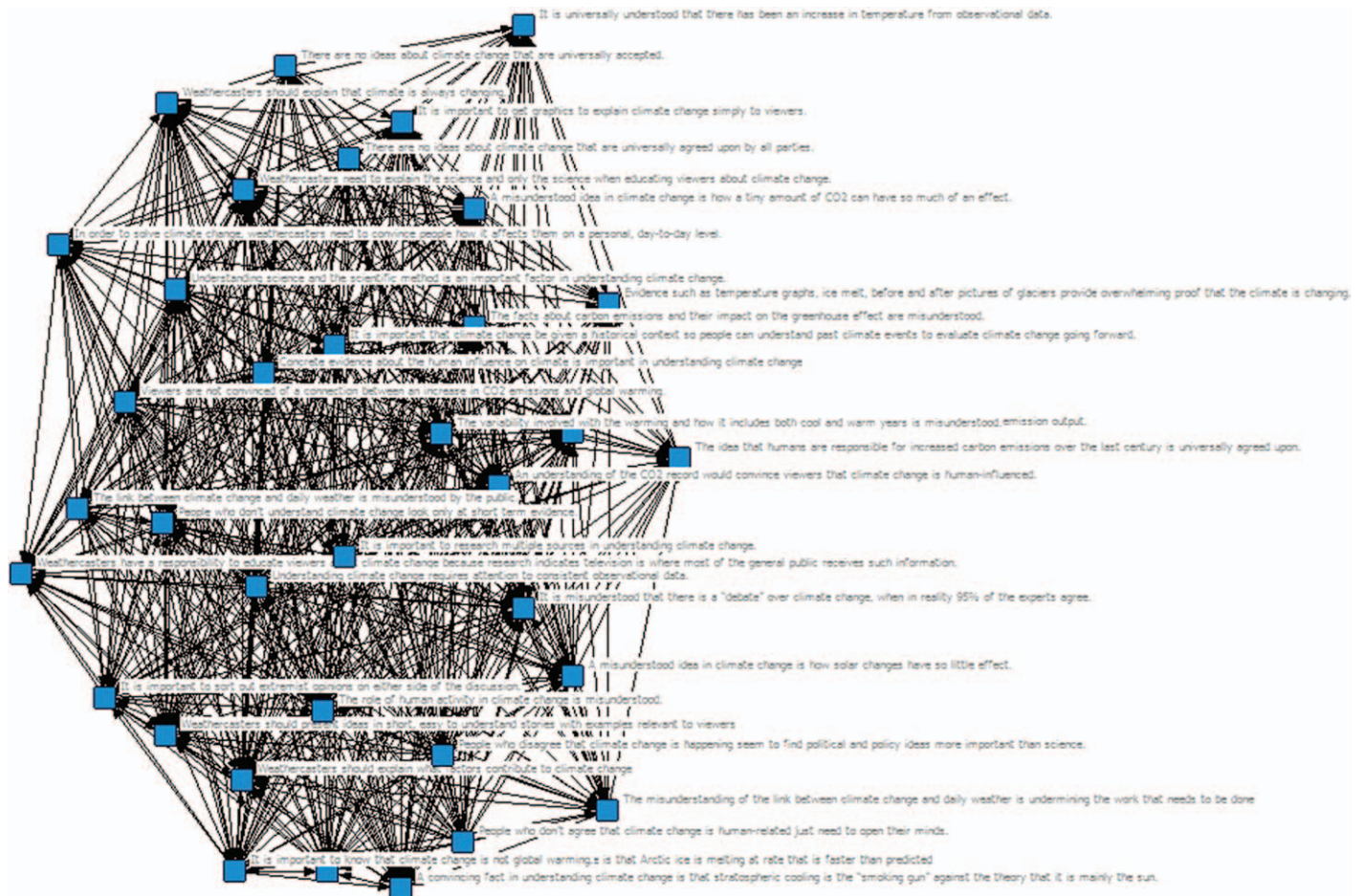


FIGURE 4. Network map illustrating beliefs about communicating climate change of the group of weathercasters who hold views that climate change is not happening.

not connecting well enough in a pattern to be interpreted as a cluster.

The second cluster consists of 10 nodes, where nine of the nodes form a line at the edge of the map and one node at a “subcentral” location pulls all of these ideas together. The subcentral node states, “Weathercasters should explain what factors contribute to climate change,” and the ideas that it anchors describe the information people need to know in order to understand climate change, as concluded by this segment. Across these nodes, references are made to topics such as the increase in CO₂ emissions and its connection to global warming, an understanding of science and the scientific method, linguistic ambiguities between global warming and climate change, and attention to consistent observational data. As alluded to previously, this linear cluster had about the same number of connections to nodes in the first cluster (bottom of map) and the next cluster (the 9:00 region).

The Not Happening Segment

Only two weathercasters responded for the sorting activity in the Not Happening segment. The two participants created eight different bins as categories. The map created by this segment can be seen in Fig. 4. Note that this map has nodes that are scattered across the map and it is difficult to identify any anchoring ideas (central nodes or clusters) or

even clusters. This could be due to the lack of representation in this group as compared to other groups, as the statements on the map were constructed by weathercasters of all segments and sent to all of the participants to sort. The Not Happening segment may not have agreed with many of the statements and thus, had difficulty reporting shared connections among the statements because they were not agreed upon. One notable occurrence in this map is located in the top right corner (approximately 1:00) with the node labeled “It is universally understood that there has been an increase in temperature from observational data.” This node is the most distant from the other nodes, indicating that it is least connected to the other ideas. Similarly, the node located midway down the map and to the right (at 3:00) is a distant node. It corresponds to, “The idea that humans are responsible for increased carbon emissions over the last century is universally agreed upon.” Other distant nodes include one at 4:30, “The misunderstanding of the link between climate change and daily weather is undermining the work that needs to be done in convincing the public and other scientists that we have a serious situation on our hands.” A final distant node is at 10:00, “In order to solve climate change, weathercasters need to convince people how it affects them on a personal, day-to-day level.” The distant placement of these nodes indicates that the persons in this group would disagree with the statements.

The Don't Know Segment

There were no responses to the sorting activity for weathercasters who self-identified in the “Don't Know” group, although a small number of weathercasters representing this segment ($n = 4$) did complete the initial questionnaire. With such a small number of participants contributing to the first part of the study, it is possible that we simply lost their participation for the card sort due to attrition.

DISCUSSION

From the anchoring ideas and main clusters in the maps of the group epistemologies of weathercasters by segment, we were better able to pinpoint important differences and similarities for how weathercasters think about climate change and their professional responsibilities to engage in informal science education or science communication about the topic. In the subsections below, we discuss these differences and similarities with respect to the organization of key ideas in the network maps.

Conceptual Structures Regarding Factual Statements About Climate Change

In this section, we discuss our findings with respect to research question 1 by focusing on the placement and organization of the following key ideas in the network maps for each segment:

- “A misunderstood idea in climate change is how a tiny amount of CO₂ can have so much of an effect.”
- “Weathercasters should explain that climate is always changing.”
- “Weathercasters should explain what factors contribute to climate change.”

So Much of an Effect From a Tiny Amount of CO₂

As discussed previously, this is the anchoring idea of the Yes–Human segment, while it is clustered with “erroneous” ideas about climate change by the Yes–Natural segment. The Yes–Both segment also has a developed understanding of the carbon cycle and its role in the greenhouse effect. In fact, this idea has a fairly central position in the cluster of ideas in the upper left of the Yes–Both segment map (Fig. 3), which pertains to the carbon cycle and greenhouse effect. In contrast, this idea is fairly disconnected from the other nodes from the Not Happening segment, which indicates that the idea stands fairly independently and is not connected to other ideas. Although it is not one of the most distant nodes for the Not Happening segment, it does lie toward the outer ring of ideas (see Fig. 4 in the area of 1:00; this idea is part of the next “ring” inside the distant node, “It is universally understood that there has been an increase in temperature from observational data.”)

These differences in idea placement reveal that the Not Happening segment has little conceptual scaffolding for how changes in the atmospheric concentration of CO₂ relates to substantial enhancement of the greenhouse effect. This could be due to the influence of the distant node regarding whether observational data support that there has been an increase in global average temperature. Potentially, by being unconvinced that there has been such a temperature increase, this segment may see no point in learning more

about explanatory scientific theories regarding contemporary global warming.

The Yes–Natural segment appears to have difficulty with this concept as well, although the problem for them may be how to situate small increases in the global carbon cycle from human activities with respect to (1) overall global carbon flows and (2) other natural drivers of climate change such as Earth's orbital position, which have explained previous changes in climate over geologic time.

Despite what appears to be a similar association of concepts and therefore, understanding, between the Yes–Human and Yes–Both segments for this key idea, it is noteworthy that this is not the anchoring idea for the Yes–Both segment. What this reflects is that while the Yes–Human segment sees this idea as fundamental to understanding climate change, common misunderstandings around climate change, and professional responsibilities for informal science education, the Yes–Both segment sees this idea as just one part of a larger set of issues.

Climate is Always Changing

A common counter-claim to concerns over contemporary climate change is that the climate is always changing. Thus, we examined where this particular statement fell in the network maps of each weathercaster segment. For the Yes–Human, this idea was recognized among the 34 nodes regarding pedagogical issues in informal climate science education. For the Yes–Natural, this statement also appeared among the diffuse arc of weathercaster responsibilities. For this segment, it is notable that this idea appeared in the subcluster closest to the cluster regarding understandings and common misunderstandings around climate change (the cluster at approximately 12:00 in Fig. 2). For the Yes–Both segment, this idea was closely related to the anchor idea for that segment, which is, “Weathercasters need to explain the science and only the science when educating viewers about climate change.” For the Not Happening segment, this idea was also fairly disconnected but loosely connected to, “There are no ideas about climate change that are universally accepted” and also, “Weathercasters need to explain the science and only the science when educating viewers about climate change.”

What is interesting about the placement of this idea across all segments is that weathercasters, regardless of segment, recognize that it would be useful to educate viewers about Earth's history on this point. In other words, it would be an example of a universally accepted idea relating to climate change. However, weathercasters in the Not Happening and Yes–Natural segments do not perceive this idea as universally accepted. Instead, these segments associate the fact that Earth's climate has always changed with both common “misunderstandings” about climate change and the responsibilities of unconvinced weathercasters to set the record straight. In other words, the latter segments present this factual statement as an antithesis to concerns about climate change, even though other weathercaster segments know that it is not.

Factors Contributing to Climate Change

This idea was presented in a very general fashion, so investigating where weathercasters placed this idea *with respect to other ideas* potentially provides clues for what each segment would say are the important factors to explain to

viewing audiences. Indeed, we uncovered some notable structural differences.

As would be expected for the Yes–Human segment, this statement was extremely closely related to the idea, “The role of human activity in climate change is misunderstood” (see Fig. 1, approximately 12:00). These same ideas were also most closely related for the Yes–Natural as well as Not Happening segments, but the coupling was not as tight (see Fig. 2 at 7:30 and Fig. 4 at approximately 7:00). As discussed previously, for the Yes–Both segment, this idea plays a “central” role for 10 other ideas regarding what people need to know in order to understand climate change (Fig. 3, lower left edge). However, it should be noted that for the Yes–Both segment, the statement, “The role of human activity in climate change is misunderstood” is *not* a closely related idea to factors contributing to climate change.

An explanation for the similarity across the Yes–Human, Yes–Natural, and Not Happening segments is that all three place a heavy focus on the role of human activity in contemporary climate change. The Yes–Human segment finds it important to explain why there is justified concern about anthropogenic global warming, while the Yes–Natural and Not Happening segments would disagree. It is also notable that the Yes–Natural and Not Happening segments selected “the role of human activity” as a closely related factor for discussing climate change and not something else, such as “climate is always changing” or the sun. This suggests that the Yes–Natural and Not Happening segments would approach informal science education on climate change primarily from the perspective of questioning the significance of human activity.

It is also worth commenting on what the different conceptual structure of the Yes–Both structure suggests. First, they clearly disagree that “the role of human activity” should be a central factor. This does not necessarily reflect that they disagree that it is a central factor but could mean instead that they are more sensitive to how polarizing this particular idea can be (Schweizer et al., 2014). Instead, the Yes–Both segment associated other ideas with factors contributing to climate change, some of them quite specific (CO₂ emissions) and others quite general (science and the scientific method). Potentially, this could mean that among the different segments, the Yes–Both segment may have the most sophisticated sense of how to deliver informal science education on the controversial topic of climate change without resorting to discussions about the role of human activity. Alternatively, it could mean something entirely different, such as that their group epistemology is still evolving and that the diversity of ideas associated with factors contributing to climate change reflects an epistemology still in flux.

Conceptual Structures Regarding Informal Science Education, Science Communication, and Weathercaster Codes of Conduct

In this section, we discuss our findings with respect to research question 2 by focusing on the placement and organization of the following key clusters and ideas in the network maps for each segment:

- General orientation of clusters related to weathercaster duties with respect to other clusters on the map.

- The ideas, “Understanding climate change requires attention to consistent observational data” and “It is important to research multiple sources in understanding climate change.”
- “Weathercasters need to explain the science and only the science when educating viewers about climate change.”

Weathercaster Duties With Respect to Other Ideas

For all segments, there was some cross-fertilization of ideas between weathercaster duties and factual statements related to climate change. However, it is most difficult to discern a pattern for the Not Happening segment. For the Yes–Human, Yes–Natural, and Yes–Both segments, ideas about weathercaster duties tended to be grouped together into their own cluster (see Fig. 1, 3:00 to 4:30; Fig. 2, 7:00 to 11:00; Fig. 3, bottom of map). For these segments, ideas about professional responsibilities to deliver informal science education or science communication on climate change were quite separate from ideas about climate change as a physical phenomenon.

Ideas About Attention to Consistent Observational Data and Multiple Sources

For all segments, ideas about attention to consistent observational data and researching multiple sources were closely related (Fig. 1, inner nodes at 1:30 to 2:00; Fig. 2, inner subcluster at 7:30; Fig. 4, see most central node at 6:00 and next most closely related node at 8:00). In fact, despite the lack of a clear anchoring idea for the Not Happening segment, the idea that it is important to research multiple sources could be a candidate. The close association between attention to consistent observational data and researching multiple sources cannot be said with as much confidence for the Yes–Both segment, since the statement, “It is important to research multiple sources in understanding climate change” cannot be seen on the network map; however, there is another unlabeled node directly behind the consistent observational data node in Fig. 3 (see approx. 8:30). With the software program, we verified that this statement is one of the nodes of the network map but, due to software limitations, the location of this particular node cannot be determined. Potentially, the unlabeled node directly behind the consistent observational data node could be regarding researching multiple sources for the Yes–Both segment. Across the weathercaster segments, this common close association is notable, as it reflects a code of conduct that all weathercasters share regardless of their particular climate change views.

Explaining the Science and Only the Science

This is an anchoring idea for the Yes–Both segment, and it appears among the cluster of weathercaster duties for the Yes–Natural segment (Fig. 2, subcluster at 10:30 to 11:00). Its placement in the Not Happening segment map is also interesting, as it is surrounded by the following ideas as most closely related: “There are no ideas about climate change that are universally agreed upon by all parties,” “Understanding science and the scientific method is an important factor in understanding climate change,” “Weathercasters should explain that climate is always changing” (see Fig. 4, nodes toward top of map around 11:30). For the Yes–Human network map, this idea cannot be seen, which we attribute to

the software limitation discussed in the previous paragraph. Nevertheless, the importance of this idea and its placement in the networks of other segments suggests that there is great concern that science communication around climate change can easily slip into nonscientific territory, such as policy advocacy. For segments unconvinced that climate is changing or that human activities play a significant role, there are genuine concerns that climate science is becoming politicized (see Schweizer *et al.*, 2014).

LIMITATIONS

This is an interpretive study of the way four segments of weathercasters (Yes–Human, Yes–Natural, Yes–Both, and Not Happening) organized statements relating to climate change as well as informal science education or science communication on the topic. The statements that weathercasters were asked to sort were pooled from five segments of weathercasters (the four previously mentioned and Don't Know). We collected enough statements from each segment to be confident that we had adequate coverage of their climate change views because all segments participated in the free-write, which was openly coded without weighting on the number of open-ended questionnaires completed per segment. We have already acknowledged that the participation of weathercasters from the Not Happening and Don't Know segments was lower than desired. In addition, it should be noted that the statements weathercasters were asked to sort underrepresented the views of the Not Happening segment. These limitations may provide partial explanations for why it was most difficult to uncover the group epistemology of the Not Happening segment. Other successful epistemic network maps have been created with as few as ten participants (Peters-Burton and Baynard, 2013); however, participation of 15 or more is considered to be more robust. There is also potential bias caused by taking a sample at a professional meeting of the American Meteorological Society (AMS) for two reasons. First, participating weathercasters may be most interested in weather as opposed to other aspects of their job such as communications. Maibach *et al.* (2011) found that most weathercasters have degrees in meteorology or Earth science (56%); the rest have degrees in journalism, communication, or other disciplines (43%). Second, not all weathercasters are members of the AMS. Maibach *et al.* (2011) found that 66% of weathercasters hold seals of approval from the AMS, but 33% do not. For these reasons, there may be some bias in our results due to the context in which we recruited participants for our study. It should be noted, however, that these subsets (*i.e.*, those with meteorological or scientific backgrounds, as well as AMS membership) still reflect a majority of the population of weathercasters.

Additionally, to assist in our interpretation of these data, we used the software package UCInet. It should be noted in the figures that only 35–40 nodes are labeled in each map, even though weathercasters sorted more than these statements. Where less than one-quarter of the group agreed on the connections, the statements did not appear on the map. In effect, this means that the bottom quartile of the frequency of connections is not displayed on the map. Thus, the use of this mathematical model can result in the loss of epistemological nuances among individual group members. Despite these limitations, many important pat-

terns in the group epistemologies could still be identified as previously discussed. Nevertheless, future work could be improved by collecting statements from weathercasters at a variety of professional meetings (rather being limited to only one meeting, as our study was) and by changing the constraints on the software to include and notate the lowest quartile of connections so that all statements will be retained.

IMPLICATIONS FOR WEATHERCASTERS AS INFORMAL SCIENCE EDUCATORS ON CLIMATE

Potentially, weathercasters could be very influential informal science educators on climate. They are highly visible in their local communities, both through their daily weather reporting and regular public speaking engagements, such as with schools. In surveys, weathercasters have stated that they receive questions from the general public on climate change (*e.g.*, Maibach *et al.*, 2010). Additionally, in local newsrooms, weathercasters are often the only staff with scientific training. For this reason, the American Meteorological Society has an initiative to bill weathercasters as “station scientists” (AMS, 2011). Given this working environment and the diversity of weathercaster views on climate change, we think it is important to understand two things: (1) the informal science education on climate that would likely be delivered by weathercasters if no programmatic effort is taken to help the professional community build its own consensus, and (2) the opportunities for professional development programs to help the professional weathercaster community arrive at its own consensus view.

Our study of the group epistemologies of weathercasters was conducted at a professional meeting of the AMS. As discussed in the Limitations section, this could mean that weathercasters who participated in our study represent a particular subset—those who have (or are in the process of completing) scientific training in meteorology. Even within this subset, we found salient differences through our study of the group epistemologies of weathercasters segmented by climate change views. This suggests that there may be potential differences in the current approaches of weathercasters to informal science education or science communication on climate change. An obvious difference across the segments is that the Yes–Human and Yes–Both segments see human activities as playing a significant role in contemporary climate change, while the Yes–Natural and Not Happening segments do not. Of course, these differences would impact the type of informal science education around climate change that each segment would deliver. The former two segments would aim to explain the significant contribution of human activities, while the latter segments would aim to question it.

Professional development opportunities for weathercasters could play an important role in enabling the weathercaster community to develop a consensus view on how to discuss weather, climate, and climate change in order to be effective informal science educators. There are two broad categories of opportunity, the first being to employ transformative interventions to address the latent conflict between segments of weathercasters who agree with the scientific consensus versus those who do not (Schweizer *et al.*, 2014). The second category of opportunity is to employ

informative continuing education to improve the factual knowledge of all weathercasters around the greenhouse effect and scientific theories for contemporary climate change.

With respect to the first opportunity of transformative interventions to address latent conflict, Schweizer et al. (2014) identified perceived occupational, interpersonal, and cultural barriers to actively discussing climate change with viewing audiences. These barriers could potentially be confronted through facilitated workshops (e.g., Schweizer et al., 2011), in which weathercasters share concerns, success stories with respect to informal science education on climate, and perhaps develop initiatives for ongoing professional community discussions around the contentious issue of climate change. In this regard, a relevant finding from the network analysis is that professional societies should confront the issue of the science–policy boundary on the topic of climate change, as this is a shared concern among the Yes–Both, Yes–Natural, and Not Happening segments of weathercasters. There is an insinuation from the Not Happening and Yes–Natural network maps that discussions of the human role in climate change stray from being scientific. The Yes–Both segment does not share this view, but it does have “explain the science and only the science when educating viewers about climate change” as an anchoring idea. This suggests there is a professional development need to help weathercasters navigate comments and questions that they might receive from their viewers or even peers, such as others in the newsroom, asking what they think about climate policy proposals or public statements by thought leaders on climate change. In our view, a weathercaster who has been provided the professional support to contemplate talking points on such topics that enable her or him to provide a scientific response while also acknowledging open questions that must be decided politically, will be more articulate and informative than a weathercaster who has not had this support.

For the second category of opportunity, which is to employ informative continuing education to improve the factual knowledge of weathercasters around the greenhouse effect and scientific theories for contemporary climate change, our recommendations begin with focusing on the similarities across weathercaster segments. All weathercasters have an interest in being knowledgeable by consulting observational data and multiple sources. This trait should be considered in continuing education programs on climate and climate change. Potentially, continuing education could highlight that the studies being summarized or resources being provided draw from the research of scientists working from many different institutions all over the world. Although this may appear to be a subtle difference, pointing out that the research on contemporary climate change comes from many studies from different sources may be an improvement from referring to only a few major sources, such as the Intergovernmental Panel on Climate Change, which could be mistaken for one monolithic organization.

Additionally, continuing education programs must assist weathercasters in developing their conceptual scaffolding for integrating new information that they encounter on climate change such as through the blogosphere. On this point, an important difference across weathercaster segments that demands attention is the breakdown in understanding of how increased atmospheric concentrations of CO₂ drives

climatic changes and has been an important natural feedback in the past. Moreover, there may be conceptual difficulties with how contemporary greenhouse gas emissions (in our study, CO₂ in particular) are related to human activities and whether the rate of these emissions is significant for contemporary climate change. These gaps in understanding appear to be especially significant for the group epistemology of the Yes–Natural segment (representing 29% of weathercasters, according to Maibach et al., 2011), which otherwise agrees that changes in climate are being observed.

Due to the visibility, salience, and trustworthiness of weathercasters, engaging them as informal science educators on climate change could be a powerful program for increasing the climate literacy of the general public. However, our network analysis of weathercaster views shows that much work remains to be done to enhance the climate literacy of the weathercaster community itself. Because of larger social controversies that surround climate change as a topic—such as its perceived potential by weathercasters to be a polarizing topic that alienates viewers, or the interpersonal discomfort that climate change conflicts with peers can cause, all of which are discussed by Schweizer et al. (2014)—professional development programs may need to offer more than informative continuing education to empower weathercasters to be effective climate change educators. In addition to continuing education, professional societies should also provide forums, such as facilitated workshops, that help weathercasters confront, grapple with, and transform other problematic associations that they may have with the topic of climate change. Such transformative interventions could help weathercasters build a community consensus on delivering informal climate change education that is appropriate for them while also being scientifically accurate.

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REFERENCES

- Aikenhead, G.S., Fleming, R.W., and Ryan, A.G. 1987. High-school graduates' beliefs about science-technology-society: Methods and issues in monitoring student views. *Science Education*, 71:145–161.
- American Meteorological Society (AMS). 2011. Station Scientist. Available at <http://www.ametsoc.org/stationscientist/index.html> (accessed 31 August 2012).
- Borgatti, S., Everett, M., and Freeman, L. 2002. UCINET 6 for Windows [computer software]. Harvard, MA: Analytic Technologies, Inc.
- Carey, S., Evans, R., Honda, M., Jay, E., and Unger, C. 1989. An experiment is when you try it and see if it works: A study of grade 7 students' understanding of the construction of scientific knowledge. *International Journal of Science Education*, 11:514–529.

- Hammer, D., Elby, A., Scherr, R.E., and Redish, E.F. 2005. Resources, framing, and transfer. In James Mestre, J., ed., *Transfer of learning from a modern multidisciplinary perspective*. Greenwich, CT: Information Age Publishing, p. 89–120.
- Hanneman, R.A., and Riddle, M. 2005. Introduction to social network methods (online textbook). Riverside, CA: University of California, Riverside. Available at <http://faculty.ucr.edu/~hanneman/> (accessed 15 May 2014).
- Kaufman, J. 2006. Card sorting: An inexpensive and practical usability technique. *Intercom*, 53:17–19.
- Khishfe, R., and Abd-El-Khalick, F. 2002. Influence of explicit and reflective versus implicit inquiry-oriented instruction on sixth graders' views of nature of science. *Journal of Research in Science Teaching*, 39:551–578.
- Knorr-Cetina, K. 1999. *Epistemic cultures: How the sciences make knowledge*. Cambridge, MA: Harvard University Press.
- Leiserowitz, A., Maibach, E., Roser-Renouf, C., and Smith, N. 2010. *Global Warming's Six Americas*, June 2010. Yale University and George Mason University, New Haven, CT: Yale Project on Climate Change. Available at <http://environment.yale.edu/climate/files/SixAmericasJune2010.pdf> (accessed 15 May 2014).
- Linn, M.C., and Songer, N.B. 1993. How do students make sense of science? *Merrill-Palmer Quarterly*, 39:47–73.
- Lising, L., and Elby, A. 2005. The impact of epistemology on learning: A case study from introductory physics. *American Journal of Physics*, 73:372–382.
- Maibach, E., Wilson, K., and Witte, J. 2010. A national survey of television meteorologists about climate change: Preliminary findings. Fairfax, VA: George Mason University, Center for Climate Change Communication. Available at [http://www.climatechangecommunication.org/images/files/TV_Meteorologists_Survey_Findings_\(March_2010\).pdf](http://www.climatechangecommunication.org/images/files/TV_Meteorologists_Survey_Findings_(March_2010).pdf) (accessed 15 May 2014).
- Maibach, E., Cobb, S., Leiserowitz, A., Peters, E., Schweizer, V., Mandryk, C., Witte, J., Seitter, K., Harned, S., Bierly, E., Todey, D., Hoerling, M., Straus, D., Cullen, H., Bonney, R., Sklarew, D., Clarke, L., and Thaker, J. 2011. A national survey of television meteorologists about climate change: Education. Fairfax, VA: George Mason University, Center for Climate Change Communication, Available at <http://www.climatechangecommunication.org/report/national-survey-television-meteorologists-about-climate-change-education-june-2011> (accessed 15 May 2014).
- McCright, A.M. 2011. Political orientation moderates Americans' beliefs and concern about climate change. *Climatic Change*, 104:243–253.
- Norgaard, K.M. 2011. *Living in denial: Climate change, emotions, and everyday life*. Cambridge, MA: MIT Press.
- Peters-Burton, E.E., and Baynard, E. 2013. Network analysis of domains of knowledge about the scientific enterprise: A comparison of scientists, middle school science teachers and 8th grade science students. *International Journal of Science Education*, 35:2801–2837.
- Redish, E. 2004. A theoretical framework for physics education research: Modeling student thinking. In Redish, E. and Vicentini, M., eds., *Proceedings of the Enrico Fermi Summer School, Course CLVI*. Bologna, Italy: Italian Physical Society.
- Ryan, A.G., and Aikenhead, G.S. 1992. Students' preconceptions about the epistemology of science. *Science Education*, 76:559–580.
- Schweizer, V., Cobb, S., Schroeder, W., Chau, G., Maibach, E., Henson, R., Mandryk, C., and Witte, J. 2011. Reframing the (discursive) environment in the climate change conflict for American weathercasters. Paper presented at the workshop, *Mediation in Environmental Conflicts Management: New Frontiers*, Politecnico di Milano, 28–29 November 2011, Milan, Italy.
- Schweizer, V., Cobb, S., Schroeder, W., Chau, G., and Maibach, E. 2014. TV weathercasters and climate education in the shadow of climate change conflict. In Crow, D.A. and Boykoff, M.T., eds., *Climate, culture and politics: How information shapes our common future*. New York, NY: Routledge Earthscan.
- Silcock, B.W., Heider, D., and Rogus, M.T. 2007. *Managing television news: A handbook for ethical and effective producing*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Smith, D. 2007. *Power producer: A practical guide to TV news producing*. Fredericksburg, VA: Radio Television and Digital News Association.
- Strauss, A., and Corbin, J. 1998. *Basics of qualitative research: Techniques and procedures for developing grounded theory*, 2nd ed. Thousand Oaks, CA: Sage.
- Tullis, T., and Wood, L. 2004. How many users are enough for a card-sorting study? *Proceedings of the Usability Professionals' Association 2004 Conference*, Minneapolis, MN. Available at <http://home.comcast.net/~tomtullis/publications/UPA2004CardSorting.pdf> (accessed 15 May 2014).
- Weller, S.C., and Romney, A.K. 1988. *Systematic data analysis*. Thousand Oaks, CA: Sage.
- Wilson, K. 2008. Television weathercasters as science communicators. *Public Understanding of Science*, 17:73–87.
- Wilson, K. 2012. Ideology trumps meteorology: Why many television weathercasters remain unconvinced of human-caused global warming. *Electronic News*, 6(4):208–228.
- Zhao, X., Maibach, E., Gandy, J., Witte, J., Cullen, H., Klinger, B., Rowan, K.E., Witte, J., and Pyle, A. 2013. Climate change education through TV weathercasts: Results of a field experiment. *Bulletin of the American Meteorological Society*, 95:117–130. Available at <http://dx.doi.org/10.1175/BAMS-D-12-00144.1> (accessed 15 May 2014).