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Development and validation of the anthropogenic climate change dissenter inventory

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ABSTRACT

Individuals are exposed to misleading or outright false anthropogenic climate change (ACC) information. The goals of this study are to identify ACC dissenter messages, and to develop an instrument that quantifies the extent to which individuals agree with these messages. The instrument was developed using a sequential mixed methods design. A qualitative analysis of YouTube videos produced a bank of dissenter messages. A Likert-type survey was derived from these statements and completed by adults who reside in the United States of America ($N = 133$) via Amazon's Mechanical Turk. Parametric and non-parametric tests were used to explore the data, determine relations, and test the instrument's validity and reliability. Dissenter statements factored into five unique categories. Confirmatory Factor Analysis ($N = 151$) was used to validate the instrument. Results suggest this instrument will be useful for understanding how different segments of the public, as measured by demographic variables, agree with misleading climate material.

1. Introduction

Understanding anthropogenic climate change (ACC) is a crucial part of an individual's overall scientific literacy, and will become increasingly more important as the world is subjected to environmental changes brought on by ACC. A population that understands the anthropogenic nature of climate change is far more likely to make positive personal and societal choices concerning energy use and carbon dioxide emissions (Vainio and Paloniemi 2013). In the United States, the need for a climate literate society has pushed science education standards to place ever greater emphases on teaching the science behind ACC (Earth Science Literacy Initiative 2010; NGSS 2013).

This project is distinct from other ACC literacy research because we aim to develop an instrument that assesses the degree to which individuals believe various messages produced by climate change denial organizations. These counter-claims are prevalent in the World media (Boykoff 2007), and often are not addressed in ACC literacy efforts likely because many educators are unfamiliar with them. Understanding ACC counter-claims and who believes them has the potential to be useful to informal and formal science educators as well as science communicators. The Anthropogenic Climate Change Dissenter Inventory (ACCDI) was developed and validated using authentic ACC dissenter messages found within what is referred to as the 'echo-chamber' (Dunlap and McCright 2011).

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1.1. Public perceptions of anthropogenic climate change

Extensive research in the field of public understanding of science, or public awareness of science, documents the public's knowledge, opinions, and personal decision-making surrounding a scientific topic. The U.S. public's knowledge of climate change has changed over the last 30 years as the effects of ACC and media coverage increase. For instance, the percentage of individuals who self-identify as understanding climate change 'very well' has increased from 11% in 1992, to 33% in 2014 (Saad 2014). Between 2001 and 2014, Gallup found that the number of U.S. citizens who believe global warming is caused by humans rather than nature has remained largely static (Saad 2014). In 2001, 61% of U.S. respondents believed in a human cause for global warming; in 2014, that number was 57% (Saad 2014). According to the Yale Project on Climate Change Communication 2014 report (Leiserowitz et al. 2014), approximately two thirds of the U.S. adult population thinks global warming is happening, whereas only half think global warming is caused by humans (Leiserowitz et al. 2014). The number of Americans who believe climate change is not anthropogenic is in stark contrast to climate scientists, ~97% of whom believe the recent climate change is anthropogenic (Cook et al. 2013). A similar percentage of meteorologists, 96%, hold the same consensus view as climate scientists (Maibach et al. 2016).

An international Gallup poll conducted in 2009 indicates public belief of the cause of global warming varies greatly by country (Pelham 2009). This poll shows that South Koreans and Japanese are the most likely to blame human actives for the rise of global temperatures, 92 and 91% respectively. English speaking countries' populations were more or less split on the cause of climate change (Canada 61%, Australia 54%, the United States 49%, & the United Kingdom 48%). The citizens of Tajikistan and Uzbekistan were least likely to believe humans are at fault, 18 and 15% respectively. These types of reports are important because public perceptions ultimately drive policy changes.

1.2. Organized climate denial

Teaching ACC, like evolution, is complicated because it is a socioscientific issue. What an individual believes about ACC or evolution can extend beyond simple content knowledge and include ideological conflicts. Evangelical Creationists complicate evolution education through the development of anti-evolution 'educational materials' and provide contrarian scientists a platform from which to speak. Similarly, the source of ACC misinformation and the promotion of contrarian scientists often comes from well-funded and organized climate denial groups (Dunlap and McCright 2011).

In response to policies that aim to reduce carbon dioxide emissions, numerous fossil fuel, manufacturing, and mining industries have provided funds to organizations that attempt to increase ACC skepticism (Dunlap and McCright 2011). The organizations that receive monetary donations are almost exclusively conservative think tanks whose own beliefs include promoting limited government (Boykoff and Boykoff 2004; Brulle 2013; Dunlap and McCright 2011). These organizations are often well-funded and are capable of spreading anti-ACC information through 'Congressional testimony, publication of documents on these [conservative think tank] organizations websites, the publication of conservative anti-climate change editorials, and books critical of the need to address climate change' (Brulle 2013, 133). Statements manufactured by these organizations are intended to foster doubt concerning climate change's existence or that climate change is anthropogenic (Boussalis and Coan 2016; McCright and Dunlap 2000). These statements are then repeated by major anti-ACC players in what researchers refer to as the 'echo-chamber,' which includes news media, politicians, and online sources (Dunlap and McCright 2011).

McCright and Dunlap (2000) document and examine the claims made by particular conservative think tanks between 1990 and 1997 on their webpages. Through thematic content analysis of 224 documents, McCright and Dunlap (2000) determined that counter ACC-arguments fell into three categories: statements that asserted the evidence for climate change is weak, statements that climate change would be beneficial, and statements that warned of the consequences of an attempt to mitigate climate change. Recently, Boussalis and Coan (2016) compiled one of the largest collections (*N* = 16,000) of

anti-ACC literature produced by conservative think tanks. This body of knowledge was used to determine what topics related to ACC messages dominate conservative think tank literature. Boussalis and Coan (2016) used a clustering algorithm to systemically analyze what topics were associated with ACC, and unlike the results of McCright and Dunlap (2000), Boussalis and Coan's (2016) results represent a broader picture of what topics are associated with ACC discussions. Boussalis and Coan's (2016) topics are divided between those that focus on policy, and those that focus on the science of ACC. Boussalis and Coan's (2016) policy topics included the economic impacts of climate policy, automotive fuel standards, and international trade among others. Boussalis and Coan's (2016) scientific topics included the notion that the scientific consensus on ACC is exaggerated, that scientists unethically modify data, and that non-carbon dioxide forces are driving climate change. Boussalis and Coan (2016) also found that conservative think tank literature on the topic of ACC has grown from the time of McCright and Dunlap's (2000) study.

The work conducted by McCright and Dunlap (2000) and Boussalis and Coan (2016) provide a wealth of information about anti-ACC source material. Documenting anti-ACC literature is important to better understand the scope of climate change dissension. However, from an educator's perspective it is equally important to know what information exists in the echo-chamber because this is where most students will likely be exposed to anti-ACC messages. Several other issues that educators and researchers may find important, but were beyond the scope of these studies include identifying: the types of messages that are the most appealing to the echo-chamber; what remnant messages from past anti-ACC efforts still prevail within the echo-chamber; and which, if any, anti-ACC messages arise through everyday conversation grounded in personal experiences rather than reiteration from a scholarly source. Currently, no work has systematically documented anti-ACC statements propagating within the echo-chamber. In order to comprehensively address the knowledge gaps and alternate conceptions that surround ACC, it is imperative that researchers and educators fully understand the nature and impact of the cumulative efforts of the interest groups and organizations that form the anti-ACC echo-chamber.

1.3. Anti-ACC messages in the classroom

The term echo-chamber may create its own misconception by implying that anti-ACC messages remain within the sphere of conservative political groups, and their ideologically like-minded audiences. However, anti-ACC messages have spread into areas of science education and scientific research. McCaffrey and Buhr (2008) report that 30% of the teachers surveyed in their study taught students that global warming is due to natural causes. The majority of the teachers in this study also failed to correctly identify what percentage of scientists are part of the consensus on ACC. ACC confusion among students and teachers may also be exacerbated by how textbooks frame the scientific consensus of ACC. Román and Busch (2015) found that many textbooks present human contributions as only a *possible* contributor to climate change.

Matkins and Bell (2007) illustrate the potential for researchers to fail to discern the difference between the science of climate change and the messages of the anti-ACC echo-chamber. Matkins and Bell (2007) investigated the impact of teaching the nature of science (NOS) alongside the socioscientific issue of climate change. However, Matkins and Bell (2007) appear to have failed to recognize that the majority of climate scientists agree climate change is occurring and is due to anthropogenic causes (Cook et al. 2013). The assigned readings in the authors' intervention included anti-climate change blogs, writings by well-established contrarian scientists, and non-contrarian peer-reviewed journals. The anti-ACC readings were provided in order to demonstrate to students that scientists are not in agreement on ACC. The authors failed to disclose whether they taught students about the scientific credibility, or lack thereof, of some of the provided sources. Matkins and Bell (2007) conclude their paper by asserting their intervention was a success and quote one student who said, '[Studying GCC/GW [global climate change/global warming] and the NOS] makes you realize that science isn't always exact, and so you have a responsibility to teach both sides and all angles of a scientific issue' (Matkins and Bell 2007, 158). In this instance Matkins and Bell (2007) duplicated a common error made by news outlets through

framing ACC as a debate with two valid sides (Boykoff and Boykoff 2004). Matkins and Bell's (2007) study demonstrates the effectiveness of the messages produced by anti-ACC organizations. In order to fully inoculate educators, students, and the public from anti-ACC rhetoric, anti-ACC messages must be documented and studied in depth. Otherwise, educators may inadvertently teach anti-ACC messages in their classrooms.

1.4. Present study

Educating students and informing the public of ACC science is made difficult by misinformation produced by anti-ACC organizations and misconceptions that arise from everyday experience. This difficulty is exacerbated by the news-media's poor coverage of ACC (Boykoff and Boykoff 2004; Fisher, Waggle, and Leifeld 2012; Gauchat 2012). To date, no research has examined dissenter messages hosted on YouTube. The purpose of this project is to establish what information exists in one popular source within the public realm, then to develop and validate an instrument that gauges the extent to which an individual agrees with specific messages in dissenter propaganda. Uncovering which dissenter statements a population agrees with, and to what degree, is vital to building informal and formal ACC curricula.

2. Methods

The instrument design used a sequential, two phase, mixed methods approach (Creswell and Plano Clark 2007). The first was a qualitative exploratory phase aimed at identifying the emerging themes that exist within an authentic source of dissenter messages. The study of this phenomenon resulted in the identification of two major themes each with multiple sub categories, or codes. These codes were each used to develop several Likert-type statements of ACC dissent in a broad survey instrument ($K = 73$). The second was a quantitative confirmatory phase aimed at developing a model for the instrument from the emergent codes, and validating it. There were two surveys administered for this purpose. The first was used to narrow the range of statements from $K = 73$ to $K = 44$, by identifying the response-model via exploratory factor-analysis (EFA) alongside other statistical measures. The second was used to verify the model via confirmatory factor-analysis (CFA) alongside other statistical measures. This two phase approach was chosen because the variables (e.g. dissenter statements) necessary for instrument design were unknown.

2.1. Dissenter statement reconnaissance

The internet is becoming an ever-increasing source of Americans' scientific information. One study estimates that ~40 million Americans use the internet as their primary source of information on science, and an even greater number of Americans (~128 million) are estimated to use the internet as a scientific research tool (Horrigan 2006). When asked where they would go for scientific information on climate change, this same study found that 59% respondents said the internet (Horrigan 2006). Reports such as this provide good reason for using internet sources to determine what dissenter messages exist in the echo-chamber.

The first phase of this study involved a qualitative analysis of ACC dissenter videos hosted on YouTube. YouTube, one of the world's most visited free video hosting websites, can be seen as a double-edged sword for educators. Many educational videos are hosted on YouTube by organizations like The Public Broadcasting Service, The National Aeronautics and Space Administration (NASA), CrashCourse, TEDx, The Discovery Channel, and the British Broadcasting Network. Using YouTube successfully as an educational tool is well documented (Burke and Snyder 2008; Burke, Snyder, and Rager 2009; Carlisle 2010; Cayari 2011).

However, what makes YouTube unique compared to traditional televised media, is that anyone can produce and publish videos. Videos produced by amateurs, businesses, policy groups, educators, media outlets, think-tanks, and bloggers are all equally likely to be viewed or 'go viral.' This unregulated environment makes YouTube an ideal place for studying misinformation found in the public sphere. Hossler and Conroy (2008) found YouTube to be an unreliable source of information concerning the safe use of

tanning beds; these authors found that most videos of this subject contained misinformation concerning tanning bed safety, and only a quarter of the videos examined reflected the recommendation of the majority of dermatologist in taking a negative stance on tanning beds. A similar study conducted by Keelan et al. (2007) found that of the 153 vaccination videos examined on YouTube, 52% took an anti-vaccine or ambiguous stance. Furthermore, these researchers found that videos which took a stance against vaccination were more likely to have higher ratings and more views. These studies demonstrate the usefulness of using YouTube to study scientifically inaccurate information that the public might be exposed to, and give reason to believe that YouTube is an ideal site for exposing ACC misinformation.

To conduct this portion of the study, a list of search terms that would result in dissenter videos was compiled (e.g. 'climate change hoax,' 'global warming hoax,' 'climate change is fake,' etc.). Then, before searching for these terms on YouTube, an in-browser web proxy was loaded to keep the researcher's internet protocol (IP) address anonymous. Anonymous browsing, which prohibited YouTube from skewing search results based on previous visits, was used in an effort to uncover videos that would be found by a first-time visitor to this subject. Results from anonymous browsing were narrowed down to relevant videos (videos whose topic match the search query), and those with high views (>15,000). These videos were then loaded into NVivo, and subjected to numerous rounds of emergent coding. Initial coding consisted of highlighting statements that directly refute ACC (i.e. 'Climate change is not real *because*…'). This initial 'high bar' coding scheme evolved through repetitive views to include more nuanced codes that involved highlighting sections of videos that point to reasons why scientists, politicians, or others wanted ACC to be real (e.g. financial gains, political power, world domination, etc.). All codes were flexible throughout analysis and evolved through repeated examination of the videos. The first author completed all coding. After compiling codes, a coding comparison query was conducted with a second researcher (not an author). The initial coding comparison query resulted in an average Cohen's *κ* of 0.72 indicating substantial agreement between researchers (Landis and Koch 1977).

A total of 3 h of videos was used for analysis. These videos constitute over 2,000,000 combined views on YouTube. A total of 41 echoed messages were uncovered, which were divided into two major themes. Approximately 30% of video runtime used by dissenters to refute ACC contained scientific statements. For instance, in one video the speaker states, 'We have from the geological evidence absolutely no evidence that carbon dioxide has driven climate,' and later states 'The major driver of climate is that great ball of heat in the sky which we call the sun.'

Approximately 22% of the video runtime used by dissenters utilized non-scientific arguments to challenge climate change. For example, one well known blogger asserts,

> Scientists will even tell you there is a political agenda behind this [ACC] rather than dealing with the science and the environment, this is politics, that's what it is. This whole global warming thing is going to get your tree huggers out there and it's going to get people riled up.

Another example comes from an anti-ACC documentary where an interviewee says 'Scientists need for there to be a problem in order to get funding.' The remaining 48% of the video runtime contained conversation unrelated to this study (e.g. filler conversation, questions, runtime containing no talking). Table 1 includes the full list of dissenter messages, number of sources in which the topics were found, the number of times that topic was mentioned, and the total time spent discussing the topic.

We note that several of the statements in Table 1 are scientifically accurate. However, in the context of these videos, all of these statements are utilized to convince individuals that human activities have not contributed to the recent warming of Earth's oceans and atmosphere. Testing the scientific validity of each statement was not a focus of this study, as our goal was to simply identify anti-ACC arguments used in the public sphere. This is further discussed in Section 3.1.

2.2. Instrument design and data collection

The survey was initially populated with 73 six-point Likert items (the 44 items in Table 2 plus additional items) derived from the qualitative phase of this study. When compared to a four- and five-point scale, six-point and 11-point scales followed a more normal distribution (Leung 2011). A six-point scale was chosen

Table 1. Dissenter statement reconnaissance results.

Code	Number of sources	Number of references	Minutes of coverage
Carbon dioxide based arguments countering ACC			
Carbon dioxide is not at fault for climate change	4	14	5.46
Changes in Earth's climate change carbon dioxide levels, and not the other way around	4	6	3.64
Human-produced carbon dioxide is irrelevant because nature produces so much more carbon dioxide than we do	2	3	1.75
Carbon dioxide is natural; therefore, it is safe	3	3	0.98
Carbon dioxide is not driving climate because it only constitutes a small portion of the atmosphere	3	3	0.94
Carbon dioxide is good for plants and helps farmers grow food	3	3	0.83
Total			12.66
Framing ACC as other than scientific			
ACC is an issue because of media hysteria	3	7	4.52
ACC is a political issue, not a scientific one	3	8	2.05
ACC is a religion or dogma	3	6	1.05
Climate change is extremist	2	2	0.32
Total			7.94
Non- Carbon dioxide explanations for a changing climate			
The sun is at fault for climate change	3	7	4.08
Galactic solar radiation is at fault for climate change	3	3	2.81
Volcanoes are at fault for climate change	3	4	1.61
Water vapor is at fault for climate change	2	3	0.98
Milankovitch cycles are at fault for climate change	2	2	0.49
Tectonic plate locations are at fault for climate change	1	1	0.35
Total			10.32
Non-science talking points			
Climate science is corrupt; scientists unethically modify data to get the results then want	4	7	8.98
Climate change is a hoax to generate money for scientists	7	14	6.22
Scientists are not in agreement on climate change	4	11	5.48
Climate change is a hoax to help the environmental movement	4	9	4.09
Al Gore is used as a strawman	6	17	1.58
ACC skeptics are in hiding or skeptics cannot come out of hiding because of a fear of ridicule	1	3	1.51
Climate change is a hoax used to progress the nuclear agenda	1	1	1.07
'Climategate' is mentioned	1	1	0.68
Refer to global warming or climate change as a debate, rather than a science	3	5	0.43
Total			30.04
Statements that point to recent warming as only a tiny portion of a larger cycle			
Medieval warm period used as an example to refute ACC	5	7	5.86
Little Ice Age used as an example to refute ACC	5	6	4.66
Climate is a cycle; it is always changing; we might be cooling	5	8	3.34
Homeostasis used as an example to refute ACC	1	1	1.97
Scientists are only examining part of a sine wave	1	1	1.59
Holocene Maximum used as an example to refute ACC	1	1	0.66
The past has been warmer than today	1	1	0.29
Total			12.51
Other scientific arguments refuting ACC			
Climate models are wrong	2	7	5.24
Weather and climate are conflated	2	3	1.88
The upper atmosphere is not warming	1	1	1.60
Antarctica sea ice is not shrinking; ice sheets are growing	2	2	1.26
Pacific decadal oscillation causes climate change	1	1	1.19
Methane is not to blame for ACC	2	2	0.77
The current rise in temperature is not detrimental to us or the planet	1	1	0.66
Feedback loops do not occur	1	1	0.55
Negative feedback loops fix climate change	1	1	0.35
Total			13.50

to cut down on survey completion time and eliminates a neutral position. Providing no neutral position on a statement pushed participants to take a stance (albeit a small position) for each item. Response options were 'strongly agree,' 'agree,' 'slightly agree,' 'slightly disagree,' 'disagree,' and 'strongly disagree.'

Table 2. Items and item loadings on the anthropogenic climate change dissenter message inventory.

Item #	Item loading	Item
Factor 1. Naïve statements refuting the science of ACC		
64	0.94	Climate scientists change their data to get the results they want, not the results the data produces
13	0.94	Climate change science is not a science; it is a political propaganda
73	0.92	Climate scientists purposefully leave out past cooling events such as the Little Ice Age from their climate models in order to produce the results they want
26	0.90	Climate scientists made up the concept of climate change to order to make money from environmental companies
59	0.89	Climate scientists made up the concept of climate change to receive grant money for research
63	0.89	Climate scientists made up the concept of climate change to order to make money from alternative energy companies
52	0.87	The recent rapid warming of earth's atmospheres and oceans is only a result of natural climate cycles
3	0.87	Climate scientists made up the concept of climate change in order to increase their revenue streams
56	0.87	Climate scientists remove collected data from their models in order to make the graphs look the way they want
31	0.86	The reported number of climate scientists that believe humans are causing Earth's climate to change is inflated to convince more people to believe in climate change
32	0.85	The recent cold weather is evidence that the climate is not warming
4	0.85	The number reported of climate scientists that believe humans are causing Earth's climate to change is inflated to convince more people to believe in climate change
29	0.85	Climate change is fabricated by the media so they can increase their viewer ratings
60	0.84	Naturally occurring Earth cycles prevent mankind from being able to change Earth's climate
34	0.84	Carbon dioxide is natural, so we should not worry about how much is in the atmosphere
11	0.83	A large number of climate scientists do not believe that global warming is happening, but cannot make their beliefs public because they would be ridiculed by climate scientists who do believe in climate change
58	0.83	The winter of 2014, one of the coldest in decades in the northeastern United States, proves that Earth is not getting warmer
61	0.83	Climate change is designed to convince people to vote democrat
72	0.83	Climate models do not accurately depict earth's climate through time
10	0.83	Artic sea ice is not shrinking in volume
49	0.81	Climate scientists who do not believe in human caused climate change cannot speak out because disagreeing with the majority could cost them their job
71	0.81	The level of carbon dioxide in Earth's atmosphere is not related to Earth's overall climate
19	0.79	Earth's overall temperature has nothing to do with the level of carbon dioxide in the atmosphere
57	0.78	The upper layers of Earth's atmosphere are not warming
37	0.78	Meteorologists cannot accurately predict the weather more than few days in advance, thus it is impossible to accurately predict Earth's climate years into the future
14	0.74	Climate scientists do not change their mind on climate change when presented with new scientific evidence
27	0.72	Natural Earth processes will keep our climate from changing
Factor 2. Sophisticated scientific statements that distance ACC blame from mankind		
20	0.84	The release of carbon dioxide from volcanoes is responsible for the recent warming of Earth's oceans
44	0.82	A change in the energy output of the sun is responsible for the recent rapid warming of Earth's oceans
48	0.78	The location of earth's continents is driving earth's recent warming
30	0.78	The recent rapid warming of Earth's climate is caused by a change in Earth's tilt
68	0.77	Radiation from supernova events is responsible for the recent warming of Earth's atmosphere
36	0.77	Changes in Earth's tilt or orbit are responsible for the recent rapid warming of Earth's atmosphere
7	0.72	A change in the energy output of the sun is responsible for the recent rapid warming of Earth's atmosphere
33	0.71	Radiation from distant supernova events control Earth's climate
Factor 3. The 'natural' statements		
18	0.81	Every year mother nature produces more carbon dioxide than humans
40	0.7	The Earth produces more carbon dioxide than mankind
9	0.67	Natural Earth processes keep Earth's climate stable
Factor 4. Items stating the beneficial aspects to ACC		
21	0.81	An overall increase in Earth's average temperature would be better for mankind than the current average temperature
28	0.8	A warmer Earth would be better for mankind than the current average temperature
25	0.78	Increasing the level of carbon dioxide in the atmosphere would allow farmers to grow more food
Factor 5. Statements that assert ACC is simply part of a larger cycle		
17	0.74	The recent warming of earth's atmospheres and oceans is a result of natural climate cycles, and our climate is headed into an ice age
22	0.66	Earth's climate may not be warming, but instead be headed into another ice age
47	0.41	Increases in carbon dioxide in the atmosphere is the result of changes in Earth's climate

Individual codes had multiple statements written from them when applicable. Writing multiple statements based on each code helped assure that a range of specific examples authentically grounded in the YouTube videos were generated from each broader code. When possible, actual phrasing and examples from the YouTube videos were used in generating survey items. Demographic questions designed after Leiserowitz, Maibach, and Roser-Renouf (2009) (e.g. age, income, political affiliation, gender, career, and religiousness) were also included in this initial survey.

The original 73 item survey and demographic questions were shown to three education researchers with expertise in public communication of science for review and face validation. Based on their recommendations, several items were modified to be more appropriate for general public reading level, and several demographic questions were revised to be more inclusive of individual identity (e.g. the addition of a transgender option for gender). Modifications were completed before the survey was administered.

Mechanical Turk, an online service operated by Amazon.com, was utilized to recruit participants and to administer this survey. Amazon's Mechanical Turk consists of over 100,000 users from across the world and was developed to crowdsource tasks that cannot be completed by computers (e.g. read graphical or handwritten text, describe photograph contents; Buhrmester, Kwang, and Gosling 2011). Mechanical Turk users earn compensation for every human intelligent task (HIT) completed. This compensation can range from a few cents to a few dollars depending on the length and cognitive demand of the HIT.

Increasingly, the social sciences have utilized Amazon's Mechanical Turk as a quick and inexpensive means of surveying large numbers of individuals. The reliability of survey data produced by Mechanical Turk workers has been independently verified (Buhrmester, Kwang, and Gosling 2011; Ipeirotis, Provost, and Wang 2010; Paolacci, Chandler, and Ipeirotis 2010) and successfully utilized to conduct research concerning individuals' viewpoints of climate change issues (Tingley and Tomz 2013).

The use of Amazon's Mechanical Turk is not without limitations. Internet-only surveys have the potential to under-represent some groups, and over-represent others. The Pew Research Center (2015) found that those over 65 years old constitute the majority (56%) of traditional mail-in survey respondents, but only make up a quarter of internet survey respondents (24%). This same study found that White, non-Hispanic respondents made up 10% more of the total respondents when compared to traditional mail-in surveys. The opposite was true of those who identify as Black, non-Hispanic. Wealthier family incomes constitute a greater proportion of respondents on internet surveys compared to less wealthy families. However, the Pew Research Center (2015) found that the political ideology of respondents differed little between online and more traditional survey techniques.

2.3. Exploratory factor-analysis

We invited 150 Mechanical Turk workers to complete the original 73 item survey. Inclusionary criteria were location, age, and Mechanical Turk success rate. Individuals who reside in the United States and are over the age of 18 were included in order to attain the target population of US adults. Inclusion also required workers to have completed over 100 Mechanical Turk HITs at a success rate of 95% or higher. HIT success rate reflects the quality of work; a HIT may be rejected for reasons such as failing to complete the HIT in the allotted time, failing to answer attention checks correctly, incoherent responses, or generating random data in order to fill out HITs quickly. The successful completion rate criterion was implemented to safeguard against unscrupulous individuals who complete HITs without reading items or instructions.

Before analysis, the data were sanitized. Surveys were removed if they had a completion time under 6 min, or incorrect responses to two attention checks (two items instructed users to 'Select Strongly Agree'). Six minutes was chosen as the minimum amount of time needed to read and respond to all items, based on the responses of a volunteer test subject. Of the 150 surveys returned from Mechanical Turk users, 133 were used for analysis for a retention rate of ~86%. The demographic information for the EFA is presented in Table 3. For reference, the median household income in the United States is $53,657 (DeNavas-Walt and Proctor 2015), and the poverty level for a family of four is a household income of less than $24,250 (Dickon 2015).

Table 3. Demographic information for EFA and CFA.

	ACCDI- EFA	ACCDI-CFA	National average
Gender (% female)	51	44	50[a]
Age (mean, SD)	40, 12	35, 12	37.8[a]
Political affiliation			
Democrat (liberal) (%)	42	43	28[b]
Independent (%)	27	32	42[b]
Republican (conservative) (%)	21	15	28[b]
Other (%)	10	10	2[b]
Income			
Up to 24 k (%)	30	25	21[c]
25–39 k (%)	23	19	18[c]
40–59 k (%)	20	25	21[c]
60–84 k (%)	19	17	17[c]
85 k+	8	15	23[c]
Education			
GED or equivalent (%)	4	2	13[c]
Secondary degree (%)	25	30	32[c]
Associates degree (%)	23	17	28[c]
Post-secondary degree (%)	39	36	–
Masters or PhD (%)	8	14	28[c]

[a]Averages from Central Intelligence Agency (2013).
[b]Averages from Gallup (2015).
[c]Averages from Leiserowitz, Maibach, and Roser-Renouf (2009).

EFA was completed using PSPP, a free open source alternative to IBM's SPSS. Likert items were subjected to Cronbach's *α* and item-total correlation. Likert items that returned values less than 0.3 for item-total correlation were eliminated per convention. The elimination of these items resulted in an overall Cronbach's *α* of 0.98. Likert data was then subjected to principal component factor analysis (PCA). The Kaiser criterion was applied, and the number of factors was reduced until all had an eigenvalue greater than or equal to one (Beavers et al. 2013). The number of factors were further reduced iteratively for sake of parsimony using Cattel's scree method and the variance explain criteria (VCE ~50%; Beavers et al. 2013). Likert items with factor loadings less than 0.5 were eliminated from the survey. Further Likert items were eliminated to shorten the survey. Likert items with lower factor loadings that originated from the same code were eliminated. PCA and item elimination resulted in a five factor model containing 44 Likert Items (given in Table 2). Each of these factors contain at least three items with factor loadings ~ >0.6.

The resulting 44 item Likert instrument (Table 2) was subjected to Cronbach's *α* and item-total correlation. All 44 items scored over 0.3 on their item-total correlation, and the overall Cronbach's *α* score was 0.98. PCA was conducted again on the 44 Likert item list and all the items re-factored into their original groups.

2.4. Confirmatory factor-analysis

CFA was calculated using the statistical software package R. The script for CFA used within R, known as lavaan, was written by Yves Rosseel (2012). We invited an additional 190 Mechanical Turk workers to participate in the CFA stage using our updated survey developed from the EFA stage. Data sanitation procedures were identical to those used in the EFA stage except for the completion cut-off time, which was shortened because of the reduced number of items used in the CFA stage. After data sanitation, 151 surveys remained for analysis for a retention rate of ~79%. The demographic information for the CFA is presented in Table 3. For reference, the median household income in the United States is $53,657 (DeNavas-Walt and Proctor 2015), and the poverty level for a family of four is a household income of less than $24,250 (Dickon 2015).

3. Results and discussion

The five-factor model developed in the EFA stage was loaded into R and subjected to the lavaan script. The CFA model is depicted in Figure 1, and the items with loadings are presented in Table 2. All loadings and covariances in Figure 1 are significant ($p \leq .05$). No Heywood cases were found. With the exception of item 47, items loaded into their respective factor with values >0.6. Residual covariance were examined to determine if the model needed to be modified. Item 47 failed to meet the 0.6 factor cut-off value with only a value of 0.41. Item 47's lower loading is likely due to the difficulty of interpretation on part of the participants or could be a type I error. Future iteration of this survey will use a slightly reworded statement in order to rectify the possible confusion and low factor loading for this specific item. The standardized root mean square residuals (SRMR) of the five-factor model during CFA was 0.69, which is considered well fitting (Hu and Bentler 1999). The root mean square error of approximation (RMSEA) of the five-factor model was 0.101 which falls into the 90% confidence interval (0.095–0.107) considered sufficient for low N confirmation (Hu and Bentler 1999; MacCallum, Browne, and Sugawara 1996). Subsequent checks of the model fit will be conducted in future distributions of the instrument.

3.1. Five factor model description

ACC dissenter statements uncovered in the qualitative phase of this study, when given to a population of U.S. adults, factored into five distinct categories. The largest category contains what we describe as the
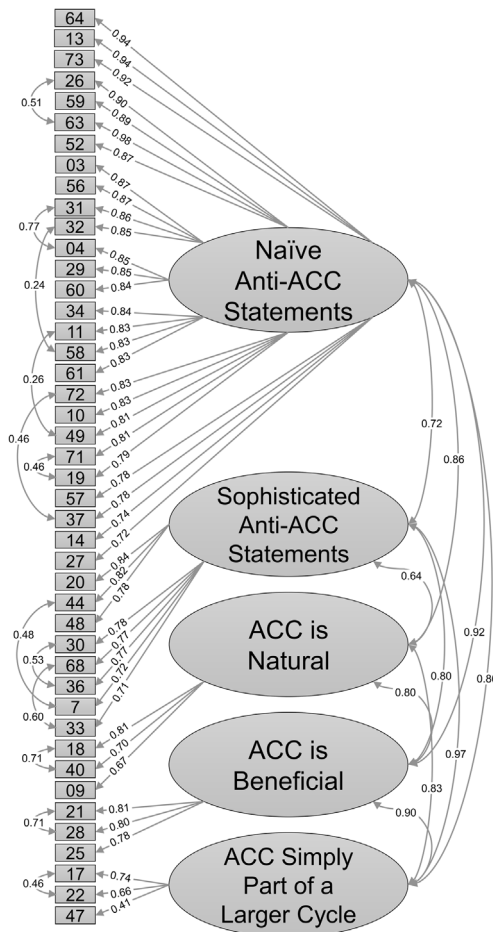

Figure 1. ACCDI factor model. All loadings and covariances are significant at $p \leq .05$.

naïve statements refuting ACC. These naïve statements include those who contain a scientific sounding rebuttal for ACC, and those that include misunderstandings on how the process of science works. It is feasible that these items factored together because individuals who have a poor understanding of the basic tenants of climate science are also likely to have a poor understanding of how science operates. We recognize that this large group of statements may be unwieldy to tackle at once in the science classroom. We recommend that when teachers discuss this factor in the classroom they should teach the nature of science and basic scientific knowledge separately.

Naïve scientific statements are those whose assertion(s) would likely be identified as fundamentally incorrect to anyone with a basic understanding of earth science. Leading examples include items 71 and 19, which outright dismiss the connection between atmospheric carbon dioxide and warming. Naïve scientific statements within this factor also include items that actually support the science of ACC, but were likely meant to be misleading. Item 57, which states that the upper atmosphere is not warming, stands as a good example of a scientifically accurate statement that is actually evidence supporting the theory of ACC. If the upper atmosphere was warming, or warming faster than the lower atmosphere, the change in temperature could be contributed to changes in solar output. However, if the lower atmosphere is warming faster than the upper atmosphere, its likely due to an abundance of greenhouse gases at the surface (Santer et al. 2003).

Naïve statements that attempt to refute ACC based on explanations outside of scientific explanation are also include within this factor. For example, items 13 and 61 assert that climate change is not science, but rather part of some political ideology. Similarly, items 64 and 73 both state that scientists purposefully alter their data to get the results they want. This factor also contained items that attempt to dismiss the scientific consensus. In general, these non-scientific statements demonstrate distrust in both scientists and the scientific process. Recent studies have demonstrated that trust in science has been decreasing among Republicans since the rise of the New Right (Gauchat 2012); however looking for this relationship was beyond the scope of instrument development.

McCright and Dunlap (2000) uncovered similar naïve statements in previous studies of dissenter literature. For example, in their category entitled 'The evidentiary basis of global warming is weak and even wrong,' they include 'global warming is merely a political tool of the Clinton Administration,' and 'the scientific evidence for global warming is highly uncertain' (McCright and Dunlap 2000, 510). The appearance of these messages in the current echo-chamber, as well as McCright and Dunlap's (2000) study, suggests that either organized climate change denial is still using these types of messages, or that old messages persist.

The second factor in this study contains what we consider to be sophisticated scientific statements that refute ACC. The term 'sophisticated' is used because in many ways these statements are 'half-true.' The energy output of the sun (items 7 and 44), the location of continents (item 48), volcanic activity (item 20), and changes in Earth's tilt (items 30 and 36) all affect climate, but are not driving Earth's recent rapid warming. These items attempt to remove anthropogenic carbon dioxide as an explanation for the recent increase in Earth's temperature, or remove mankind's role. These statements may appeal to individuals who have a basic understanding of earth science. Early studies of anti-ACC literature did not include sophisticated scientific explanations of climate change and instead dismissed its existence (McCright and Dunlap 2000). The use of these sophisticated scientific statements may indicate a transition from dismissing ACC to 'explaining away' climate change in the organizations that supply messages to the echo-chamber.

The third factor in this model contains statements that only use 'natural' explanations for a changing climate. Unlike the sophisticated scientific explanations found in the second factor, these items are unique in that they frame 'Earth' or 'Mother Nature' as the sole driving force of carbon dioxide emissions. These types of statements were not identified in either the McCright and Dunlap (2000) or the Boussalis and Coan (2016) studies of dissenter literature. Thus these items may not arise from organized climate change denial, but may come from individuals within the echo-chamber. This sentiment may be grounded in a worldview, whereas 'Mother Nature' takes the position of climate controller. This sentiment may also be a part of the 'appeal to nature' ideology that has grown in recent years with the increasing

number of people who dismiss vaccines and genetically modified foods (GMOs). A quick examination of this literature shows they reject scientific advancement on the ground that natural is better (e.g. see www.NaturalNews.com). Individuals who hold this ideology may be producing or supporting statements found within this factor. While there are other 'natural' arguments elsewhere we decided to keep this factor because *only* 'natural' arguments factored into it. Some of the descriptions of the factors runs parallel to the coding done in the first portion of this project and we found that the 'natural' argument is fluid and can be paired to other arguments. For instance, there were some instances in the videos where individuals would argue that the current warming is natural, current cooling is natural, CO_2 is natural, or that human activities themselves are natural. Thus, based on our prior experience with these arguments in usage we decided to keep this factor even though similar items fall into other factors. We recognize that this factor may dissolve into others upon further distributions of the instrument.

The fourth factor in the model contains items that promote the beneficial nature of ACC. This topic was one of the main themes in McCright and Dunlap's (2000) study of conservative counter claims, but is not found in a more recent study by Boussalis and Coan (2016). Its existence here may indicate that organized climate change denial has moved on from using this type of argument, but it is still persisting in the echo-chamber.

The fifth factor in this study contains items suggesting that the current warming of Earth's climate is only part of a larger cycle and that we may be headed into another ice age. This type of message, when documented in the qualitative phase of this study, is often paired with diagrams of ice age cycles. These type of statements may appeal to those who want to ignore the issue of climate change in hopes that eventually it will correct itself. These types of messages were uncovered in Boussalis and Coan's (2016) study, but not McCright and Dunlap's (2000) study, suggesting that these messages are part of the current organized climate change denial repertoire.

4. Implications, limitations, and future work

It is clear from part one of this study that groups and individuals are producing information that acts against the efforts of science education. The confirmation of our factor model indicates that ACC dissenter statements distil into five types of arguments: (1) naïve statements which either *use scientific misconceptions* to dismiss ACC or *attack the science* of ACC; (2) sophisticated scientific statements which imply *warming is not anthropogenic*; (3) arguments that assert recent changes are *natural or out of our control*; (4) statements that highlight *benefits of a warming climate;* and (5) arguments that imply *current warming is simply part of a larger cycle*.

An understanding of the factors from this study is potentially useful to formal and informal ACC educators. First, educators need to be aware of the types of anti-ACC messages, especially those that disguise themselves as science, so that these are not inadvertently passed on to students, as was the case in Matkins and Bell (2007). These educators may be able to dispel ACC skepticism, or inoculate students from misinformation, by addressing these five categories of arguments while teaching the science of ACC. For example, when discussing the scientific evidence for ACC, an educator could discuss how funding and publishing is conducted in the science community. An understanding of these processes has the potential to increase students' confidence level towards scientific findings, and inoculate students from the naïve depiction of science used by dissenters. Educators could also convey the factors that are *not* causing Earth's recent warming alongside the factors that *are* causing Earth's recent warming. And understanding of what is not causing the planet to warm inoculates students from most of Factor 2 (Sophisticated scientific statements that distance ACC blame from mankind).

These factors could also be covered in non-science education courses. For instance, environmental policy and environmental journalism educators could incorporate this information into their curriculum when highlighting the discourse surrounding this socioscientific topic. Environmental Journalism students should be particularly aware of dissenter statements so that they do not inadvertently incorporate them into their coverage of ACC. Similarly, environmental policy students should be inoculated from this type of rhetoric if they plan on engaging in political debate regarding ACC.

The use of this validated instrument on a population has the potential to guide the inoculation portion of an educators ACC curriculum for students and teacher professional development. For example, if administered to a group, this instrument can inform the educator where the misunderstandings of ACC lie and can potentially identify where individuals are most susceptible to dissenter arguments. This information may provide educators with a knowledge base to help them identify and reject misleading anti-ACC information. It is also reasonable to assume that successfully inoculated students are less likely to pass on ACC misinformation, limiting the reach of the 'echo-chamber.'

Asserting a connection between an individual's scientific knowledge and acceptance of a scientific consensus is known as the knowledge deficit model. This model states that individuals will make the correct personal choices concerning scientific topics (i.e. accept ACC as reality) if they have an accurate understanding of the topic. We recognize that ACC knowledge is not the best predictor of ACC acceptance. However, we find that this is often because ACC knowledge is not accurately assessed.

Kahan et al. (2012) asserts that the deficit model is insufficient in terms of ACC concern, but utilized an assessment that focuses on physics and biology knowledge as a proxy for overall scientific literacy. It is reasonable to believe that a deep understanding in biology and physics does not necessarily translate to ACC literacy. Whitmarsh (2011) asserts that demographic variables, particularly political ideology, better predicted ACC skepticism over knowledge. However, Whitmarsh (2011) utilized self-assessed instead of attempting to assess actual ACC knowledge. Self-assed knowledge as a proxy for actual knowledge will lead to inconclusive results because of the Dunning-Kruger effect. Those with a poor understanding of a subject overestimate their knowledge of that subject (Kruger and Dunning 1999). The Dunning-Kruger effect may be amplified for topics which have readily available and wildly spread contrarian knowledge. Individuals whose schema contains anti-rhetoric will likely believe they have a firmer understanding of the topic than they actually do.

The effects of contrarian knowledge and the Dunning-Kruger effect may be evident in Kellstedt, Zahran, and Vedlitz (2008) study of the relationship between personal efficacy and attitudes towards ACC. In this study the authors assessed individuals' ACC knowledge with the following prompt, 'how informed do you consider yourself to be [about global warming and climate change]' (Kellstedt, Zahran, and Vedlitz 2008, 118). Kellstedt, Zahran, and Vedlitz's (2008) found that, 'Directly, the more information a person has about global warming, the less responsible he or she feel for it; and indirectly, the more information a person has about global warming, the less concerned he or she is for it' (Kellstedt, Zahran, and Vedlitz 2008, 122). The authors go on to say that the knowledge deficit model is insufficient for understanding the public's attitudes towards ACC. However, the results presented by Kellstedt, Zahran, and Vedlitz (2008) are expected when taking into account the Dunning-Kruger effect and organized contrarian knowledge. Those individuals who think they know the subject well are likely to be those who know the least about ACC, and thus hold less concern for ACC.

One limitation to this instrument is the ever-evolving arguments against ACC. Highlighted above are the differences between dissenter statements of the past and those found in the echo-chamber today. Thus, this instrument may have an undetermined shelf life, and will likely need updating on a regular basis as new dissenter arguments enter popular media or as old arguments become less favored. A second limitation to this study is the number of participants, in the future we may find that more participants may alter the number and descriptions of the factors.

Future work with this instrument could take a number of directions. Refining the instrument could be accomplished by eliminating redundant items, thus creating a more streamlined survey. Subsequent iterations of the new streamlined survey could also be validated with different student populations. The instrument could be tried pre- and post-intervention to determine if it is useful as a tool to evaluate the efficacy of teaching approaches. This instrument, paired with questions regarding participant preferred news source, could establish links that proposed by Dunlap and McCright's (2011) echo-chamber. In other words, does the flow of contrarian arguments exist between new sources and participants? Or are contrarian arguments more likely to move through discourse between individuals?

Our current efforts focus on determining if any of the five types of anti-ACC arguments are more effective on any particular demographic. In other words, do relationships exist between the types of

arguments used against ACC and an individual's demographic variables? An individual's perception of ACC can be affected by variables such as gender, age, education, income, political affiliation, ethnicity, geographical location and religion (Brody et al. 2008; Dunlap and McCright 2008; Flynn, Slovic, and Mertz 1994; Guth et al. 1995; Semenza et al. 2008). Thus, it would be important to understand how anti-ACC arguments influence particular groups of people if large and small scale education efforts are to be successful. This now validated instrument will be paired with a multitude of demographic questions and distributed in order to better understand these relationships.

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