Case Studies in Agnotology-Based Learning

Raising Climate Literacy through Addressing Misinformation

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Abstract

Agnotology is the study of how and why ignorance or misconceptions exist. Misconceptions are a challenge for educators, being extremely difficult to remove and interfering with the processing of new knowledge. This is especially the case with climate change, due to an abundance of climate misinformation. However, misinformation also presents an opportunity to improve climate literacy through agnotology-based learning. This involves the use of refutational lessons that challenge misconceptions while teaching scientific conceptions. Twenty years of research have shown that refutational texts are among the most effective forms of reducing misconceptions. In this paper, we present three case studies in improving climate literacy through agnotology-based learning. Two case studies involve agnotology-based learning in the college classroom and the third is a public outreach promoted through mainstream and social media. These real-world examples demonstrate effective ways to reduce misperceptions and improve climate literacy.

Key words: agnotology, scientific consensus, climate change, misinformation

INTRODUCTION

Agnotology is the study of ignorance. More specifically, it examines how and why ignorance or misconceptions exist (Proctor, 2008). Misconceptions, also known as alternative beliefs, naïve theories or alternative conceptions, are beliefs that conflict with currently accepted scientific explanations. Misconceptions occur for all types of students but are particularly evident in students learning from science text (Tippett et al., 2010).

For educators seeking to improve climate literacy, of which climate change literacy is an important subset, agnotology involves examining how and why there is ignorance or misconceptions about well-established facts regarding climate change. This is especially challenging due to an abundance of misinformation about climate change. The process of generating misinformation is known as agnogenesis (Proctor, 2008). There is now widespread evidence of a persistent campaign to sow confusion and doubt about climate science and anthropogenic global warming (AGW) (see, for example, Hoggan and Littlemore, 2009; Oreskes and Conway, 2010; Oreskes, 2010). A sharp increase in the number of publications promoting misinformation about climate science in the 1990s coincided with international efforts to reduce carbon emissions (McCright & Dunlap, 2000). This increase in agnogenesis literature coincided with an increase in public skepticism about global warming, suggesting that the campaign to disseminate climate misinformation has been effective (Nisbet and Myers 2007).

The agnogenesis campaign is not only problematic given the societal impacts of climate change but also for science literacy. Misconceptions are highly resistant to change and interfere with the processing of new knowledge (van den Broek & Kendeou, 2008). However, the presence of climate misinformation also presents an educational opportunity.

Refutational texts are text structures that challenge readers' misconceptions, with the purpose of promoting conceptual change. They achieve this by explicitly acknowledging misconceptions about a topic, directly refuting them and providing an alternative scientific conception. Conceptual change occurs when learners update previously held conceptions or replace them with new conceptions.

Research into cognitive psychology and refutation-style education show that explicitly addressing misinformation provides an opportunity for achieving conceptual change. Refutational texts have been found to be one of the most effective text-based means for modifying readers' misconceptions (Tippett et al., 2010).

This paper describes several case studies in agnotology-based learning that explicitly address climate misconceptions and study climate misinformation in order to improve climate literacy.

COGNITIVE RESEARCH INTO MISINFORMATION

Misconceptions and misinformation are extremely difficult to remove. When people are presented with refutations of misinformation, they often continue to be influenced by the misinformation even when acknowledging the correction. This is known as the continued influence effect (Johnson & Seifert, 1994). An explanation of the persistence of misinformation is that people build mental models with the myth integrated into the model. When the myth is invalidated, people are left with a gap in their mental model. If nothing is provided to replace the gap, then people may continue to rely on the myth.

In some cases, refutations can actually reinforce misconceptions, a reaction known as a backfire or boomerang effect. One such example is the familiarity backfire effect (Cook &

Lewandowsky, 2011). The more familiar people are with information, the more likely they will consider it to be true. One study found that showing participants a flyer debunking vaccine myths after a delay resulted in an increase in people thinking the myths were facts (Skurnik, Yoon, Park, & Schwarz, 2005). The backfire effect was strongest among older people.

Another adverse reaction to refutations is the overkill backfire effect, which occurs when refutations are too long or complex. When people were asked to generate three counter-arguments against a belief, their level of belief decreased. However, when asked to generate 12 counter-arguments, their belief was reinforced (Schwarz et al., 2007). This is because people prefer simple explanations over complicated ones (Lombrozo, 2007). When it comes to refutations, less is more.

There are several elements to an effective refutation. The risk of a familiarity backfire effect can be reduced if an explicit warning is provided before the myth is presented (Ecker et al., 2010). This puts the person cognitively on-guard so they are less likely to be influenced by the misinformation. Another important feature of an effective retraction is an alternative explanation that fills the gap created by the retraction (Johnson & Seifert, 1994). The alternative explanation should be plausible, explain the causal qualities in the initial report, and explain why the misinformation was initially thought to be correct (Seifert, 2002). The risk of an overkill backfire effect is reduced if the alternative explanation is simpler (or at least not more complicated) than the myth (Chater & Vitanyi, 2003).

A succinct encapsulation of the cognitive research into misinformation comes from Heath & Heath (2007) who advise communicators to ‘fight sticky ideas with stickier ideas’. The authors explore the concept of ‘sticky ideas’ – messages that are compelling and memorable. One feature of a sticky message is that it arouses curiosity then satisfies it. This is achieved by

opening a gap in people's knowledge, then filling the knowledge gap (Loewenstein, 1994). This sequence of "create a gap, fill the gap" is a natural fit for refutations which require creating a gap in a person's model of an event, then filling the gap with an alternative explanation. The very structure of an effective refutation lends itself to compelling, sticky messages.

AGNOTOLOGY-BASED LEARNING: ADDRESSING MISINFORMATION IN EDUCATION

Correcting misconceptions is a significant aspect to education, as "Comprehending why ideas are wrong matters as much as understanding why other ideas might be right" (Osborne, 2010, p. 328). Misconceptions among students abound in all disciplines. For example, students beginning a psychology degree possess a number of misconceptions such as "humans only use 10% of their brains" or "Mozart's music increases infant intelligence" (Kowalski & Taylor, 2009). Because misconceptions interfere with new learning, reducing their influence is imperative.

However, does explicitly refuting myths run the risk of making students more familiar with the myth and causing a familiarity backfire effect? A growing body of evidence indicates that refutational lessons, also known as agnotology-based learning, are one of the most effective means of reducing misconceptions (Muller, Bewes, Sharma, & Reimann, 2008; Kowalski & Taylor, 2009; see Tippett et al., 2010 for a review). Refutational style lectures explicitly mention misconceptions as well as communicate factual information. In contrast, non-refutational lessons teach accurate information without explicit reference to the misconception. Refutational text has been shown to effect long-term conceptual change across a wide range of grade levels over a period of weeks to several months (Guzzetti, Snyder, Glass, & Gamas, 1993).

There are additional benefits to refutational teaching. They have been shown to increase students' argumentative skills and to raise awareness of the relevance of evidence to argument (Kuhn & Crowell, 2011). They foster critical thinking, encourage students to assess evidence and to draw valid conclusions (Berland & Reiser, 2008; Kuhn & Crowell, 2011). Refutational texts provoke more interest, being preferred by students to traditional textbook text (Manson, Gava, & Boldrin, 2008). Refutation resolves to some degree the issue that knowledge is often imparted as a set of unequivocal facts with a lack of argument in the classroom (Osborne, 2010).

However, there are conditions where refutational lectures can backfire. When students do not properly engage with the text, they can find evidence for previously held misconceptions within the refutation and thus strengthen their false beliefs (Guzetti, Williams, Skeels, and Wu, 1997). Guzetti et al. (1997) also found that refutations were ineffective when poorly constructed and lacking in clarity.

Understanding why refutation texts are effective enables educators to design educational material to maximize the chances of conceptual change. The 'conceptual change model' suggests four requirements to achieve knowledge revision (Posner, Stike, Hewson, & Gertzog, 1982). One must cause dissatisfaction with the existing misconception. A replacement to the misconception must be intelligible (e.g., understandable), plausible (e.g., provide believable examples) and fruitful (e.g., potentially lead to new insights and discoveries). This model is consistent with cognitive research finding that to refute misinformation, one must create a gap in the subject's understanding then fill the gap with an alternative narrative.

Further, research indicates that correct and incorrect conceptions must be activated together (van den Broek & Kendeou, 2008). If readers fail to recognize a discrepancy between their incorrect preconceptions and the correct conception, they are less likely to achieve

conceptual change learning. The misconception and correct conception should be in close proximity to increase the likelihood of simultaneous co-activation (Kendeou & van den Broek, 2007).

To conclude, there are a number of reasons why agnotology-based learning is desirable. Refutational learning is a very effective means of reducing misconceptions, fosters critical thinking, improves argumentative skills, and increases interest in educational material.

THREE CASE STUDIES IN AGNOTOLOGY-BASED LEARNING

This paper outlines three case studies in agnotology-based learning. Two examples are classroom based, applied in US college classrooms. One is a community college and the other a non-selective four year university with an additional community college mission and a small number of master's programs. Institutions such as these educate a large proportion of US post-secondary students, with associate's degree-granting institutions alone accounting for an estimated 49% of all US post-secondary student enrollment in 2008 (National Center for Education Statistics).

The third example was a public outreach conducted by Skeptical Science, a website that adopts an agnotology-based learning approach by explaining climate concepts while refuting common myths. The agnotology-based content at this website has already been adopted in several university textbooks and curriculum (Cresser et al., 2012; Pipkin et al., 2014). The website content has also been adopted by a number of educators – in a survey of over 1,500 high school and college instructors (spanning 50 U.S. states), Skeptical Science was mentioned as a common resource for teaching about global change. In particular, two year college instructors reported that Skeptical Science was the third most commonly used resource after the government

177 resources from NASA and NOAA (personal communication, Berbeco 2013). The public
178 outreach in this third example was designed to reduce the public misperception that climate
179 scientists still disagree on human-caused global warming.
180
181 **Agnotology and climate change literacy at Weber State University**
182 Weber State University is a non-selective, four year university located in northern Utah in
183 the western US. It also offers a small number of master's degree programs, and is charged by the
184 state with providing community college services to the region. Many of the students are among
185 the first in their families to attend college. The student body is drawn almost entirely from Weber
186 County, Utah, and surrounding counties, and reflects the region's socially and politically
187 conservative culture. As several studies have recently documented, skepticism about the basic
188 tenets of human-induced climate change are well correlated with such conservatism (e.g. Dunlap
189 and McCright, 2008; McCright and Dunlap, 2011; Hamilton, 2011, 2012), although not
190 necessarily as well correlated with simple political party affiliation (Leiserowitz, 2006; Kahan et
191 al., 2012). This situation presents a complex and delicate challenge to educators tackling the
192 potentially polarizing subject of climate change.
193 Agnotology-based teaching in this setting has been previously described by one of the co-
194 authors of this paper (Bedford, 2010). Students in an upper division, small enrollment weather
195 and climate class are required to read the late Michael Crichton's (2004) engaging but
196 misleading climate change themed thriller, *State of Fear*. They assess the veracity of the
197 arguments and claims therein, compared with the existing state of climate science as taught in the
198 class up to that point through more traditional means of lecture and readings from textbook and
199 selected outside materials (including the peer-reviewed literature). By requiring students to

reflect on earlier course material, engage with the arguments in *State of Fear*, and, critically, argue their own position, this approach represents an active learning strategy.

More recently, the agnotology approach has been extended to a new introductory-level class on global warming, GEOG PS 1400 The Science of Global Warming: Myths, Realities and Solutions, which students may also use to meet university general education requirements for physical science. The class has been taught twice as of this writing, with enrollments of around 30 students each time. Agnotology in this class has been applied principally to address the issue of fake experts, or at least experts speaking beyond their areas of expertise. This is a common approach in science denial movements, as described by Diethelm and McKee (2009), and climate change is no exception. However, particular care is taken in this assignment to avoid alienating students with conservative social and political outlooks—that is, many of the students at Weber State University—by providing an initial case study of fake expertise and flawed arguments regarding a Democratic partisan political issue, the alleged improprieties around the 2004 US Presidential election which purportedly allowed George W. Bush to defeat the Democratic candidate, John Kerry. These allegations were ultimately picked up by high-level operatives of the Democratic Party, such as Robert F. Kennedy, Jr., and repeated across the popular media (e.g. Kennedy, 2006). However, as described by the careful journalism of Farhad Manjoo (2008), the case for election improprieties largely relies on naïve interpretations of election data by individuals with backgrounds in statistics but little or no background in political science or the nuances of exit polling. Comparison with expert knowledge reveals the weak foundations on which allegations of a 'stolen' election are built, and the case collapses.

By beginning the assignment with a reading, and associated questions, addressing the tendency of *Democrats* to engage in motivated reasoning—finding evidence to fit existing

strongly-held convictions, even where none really exists—the intention is to allow more conservative (and, in Utah, typically Republican) students to accept the general idea that motivated reasoning exists. Because so much research on the public understanding and acceptance of climate change has focused on conservative/Republican rejection of the mainstream scientific position, it would be easy for an initial strong emphasis on this issue to be perceived as an attack on students' core values, which could easily result in their shutting out any further information. Thus, by demonstrating the tendency for other groups to engage in motivated reasoning and the use of questionable expertise, the goal is to allow students to accept consideration of the same issue as it applies to climate change.

The initial discussion of motivated reasoning via the 2004 US Presidential election is then followed with a reading of, and associated questions about, a piece of climate change misinformation and its debunking. The precise readings have varied on the two occasions the class has been taught: in the first year, students read Bjorn Lomborg's entertaining but misleading book *Cool It!* (Lomborg, 2007), and compared its claims with the arguments listed at the website lomborg-errors.dk. In the second year, students read an opinion column in the *Wall Street Journal* (Allegre et al., 2012) and its point-by-point rebuttal (Nordhaus, 2012). The rebuttal is especially powerful because it was written by an economist whose own work was misused in the *Wall Street Journal* column to help reach a conclusion which a correct interpretation of the work does not justify.

By requiring students to think about why the misinformation is incorrect, this exercise constitutes an active learning strategy. Active learning has been shown to be a more effective approach than simply lecturing to students (see Prince, 2004, for a review). Although the number of students who have undertaken this agnotology exercise is too small for meaningful

quantitative assessment of its effectiveness, qualitative, anecdotal evidence suggests students find the exercise both educationally useful and satisfying. Some have spoken of a feeling of empowerment, resulting from a heightened ability to detect and respond to false information.

Effective Refutation of Climate Change Myths at Suffolk County Community College

Suffolk County Community College (SCCC) is a publicly supported, open enrollment, multi-campus community college located in Suffolk County, New York, that provides educational opportunities to the local population. With three campuses and two downtown centers serving more than 50,000 students, SCCC is the largest two-year college in New York State and the largest undergraduate institution in the State University of New York system. SCCC offers low tuition rates, small class-sizes, a high ratio of faculty to students, and 67 programs of study with Associate in Arts, Associate in Science, and Associate in Applied Science degrees. In addition, SCCC provides joint admissions and articulation or transfer agreements with more than 30 four-year institutions. More than half the students attend full time and about 75% are under age 25. Most students are underprepared for collegiate work upon entrance. Almost 75% of first-time, full-time freshmen arrive with a poor high school GPA (below 80%), low SAT scores (below 400), or lack a New York State Regents diploma. 60% require one or more developmental reading, writing, or mathematics course. 86% of full-time students are employed, 61% work off campus more than 20 hours per week and 18% spend 20 or more hours each week caring for dependents, thereby limiting their ability to engage with their studies to the extent that might be desirable, or might be possible at more elite institutions. 25% are the first generation in their family to attend college and have no parental experience to

provide guidance. The three-year graduation rate for students is 20% while an additional 18% transfer prior to graduation (Strengthening Institutions Program, Title III, 2010).

MET103 Global Climate Change is a three credit lecture course that serves as a science elective for this general student population. First year high school algebra is the only prerequisite. MET103 has been shown to be an effective model for teaching a climate change elective science course at the community college level (Mandia, 2012). The impact of global climate change is far-reaching, both for humanity and the environment. MET103 provides students with the scientific background to understand the role of natural and human-forced climate change so that they are better prepared to become involved in the discussion. Students learn how past climates are determined and why humans are causing most of the observed modern day warming. The technical and political solutions to climate change are also addressed. MET103 was first offered as a special topics course (MET295) in Summer 2011 and after successfully running for two semesters was approved as a permanent course offering in Spring 2012. To date, the course has been offered six times to a total 169 students. Informal surveys distributed on the first day of class reveal that a large majority of students are aware that the planet is warming but very few understand that human activities are largely responsible for this warming.

Student learning outcomes are assessed by a series of lecture exams featuring short answer questions, bi-weekly homework assignments where students locate and summarize current climate-related news stories, and by submitting a research paper near semester's end. The research paper features an agnotology-based learning approach. The SkepticalScience.com website is used as the primary student resource for the research paper. Students choose a topic from the list of refutations appearing on the web page titled *Global Warming & Climate Change*

Myths – a collection of climate myths followed by the scientific refutation and sorted by recent popularity. The more often the myth is cited, the higher it appears on this list., A series of tabs modeled after ski slope difficulty divides the content into Basic (green circle), Intermediate (blue square), and Advanced (black diamond), although not all myths have all three levels of difficulty. MET103 students are required to carefully study all the information appearing in these tabs and to summarize, in their own words, the information learned from researching the topic. A scoring rubric is made available to students on day one of the course to clearly define the desired learning outcomes (Rubric For Research Paper Evaluation, 2013).

The rubric has been designed so that higher scores (80% and above) will be achieved when students describe the myth and its relevance to climate change, clearly articulate why the myth persists, and offer an accurate science-based refutation by connecting the information at the SkepticalScience.com site with MET103 course notes. Effective refutation techniques to correct misperceptions are modeled throughout the semester by the lecturer and students are encouraged to read *The Debunking Handbook* (Cook & Lewandowsky, 2011) to guide them in an effective refutation of their chosen myth. Of the 169 students who completed the courses, 156 submitted research papers. 58% of these students achieved a high score (above 80%) while 37% mastered the content (scoring above 90%).

Necci (2013), Santalucia (2013), and Buonasera (2013) are three recent examples of MET103 students who have effectively refuted climate change myths while also demonstrating a mastery of course content. All three research papers featured the effective refutation technique described by Johnson & Siefert (1994) of offering an alternative explanation to fill the gap left behind by the refutation. All three also provided a relatively simple alternative explanation deemed to be an effective refutation technique by Schwarz et al. (2007), Lombrozo (2007) and

Chater & Vitanyi (2003). Necci (2013) also incorporated a third refutation technique by providing an explicit warning before presenting the myth, thus reducing the familiarity backfire effect described by Cook & Lewandowsky (2011) and Ecker et al. (2010).

This assignment requires students to reflect on and actively process the course content in order to understand why any given climate change myth is wrong, thereby constituting an active learning strategy, as discussed above, and making use of learner-generated content (Lee and McLoughlin, 2007). Further, by providing students with training in effective climate-change myth debunking, students are equipped with the skills necessary to address such myths after graduation, potentially encouraging lifelong learning.

Closing the Consensus Gap using Social and Mainstream Media

Arguably, one of the most significant climate misperceptions involves the level of agreement among climate scientists about AGW. A number of studies have sought to measure the scientific consensus, with surveys of the climate science community finding around 97% agreement among publishing climate scientists that humans are causing global warming (Doran & Zimmermann, 2009; Anderegg et al., 2010). An analysis of 928 papers matching the search 'global climate change' from 1993 to 2003 found zero papers rejecting AGW (Oreskes, 2004).

Despite numerous studies finding an overwhelming scientific consensus, the public perception is that the scientific community continues to disagree over the fundamental question of AGW (Leiserowitz et al., 2012; Pew, 2012). This misperception has significant societal consequences – when the public think scientists disagree on AGW, they are less likely to support policy to mitigate climate change (Ding et al., 2011; McCright & Dunlap, 2013). Perception of consensus is also linked with acceptance of AGW, and presenting consensus information has

been shown to partially neutralize the biasing effects of worldview (Lewandowsky et al., 2013). The 'consensus gap' is therefore a significant roadblock delaying meaningful climate action.

The persistence of the consensus gap is likely the result of an agnogenesis campaign lasting over two decades designed to cast doubt on the consensus. In the late 1980s, the number of popular publications attacking the scientific consensus sharply increased (McCright & Dunlap, 2000). In 1991, fossil fuel company Western Fuels Association conducted a half-million dollar campaign designed to 'reposition global warming as theory (not fact)' (Oreskes 2010, p. 138). In syndicated opinion pieces written by conservative columnists from 2007 to 2010, the most common climate myth was "there is no scientific consensus" (Elsasser and Dunlap 2012).

The Skeptical Science team of volunteers undertook a crowd-sourced project, involving scientists and volunteer researchers, with the purpose of continuing and extending Oreskes' 2004 analysis of 928 'global climate change' papers published from 1993 to 2003. The literature search was expanded to include papers matching the term 'global warming' from 1991 to 2011, increasing the sample to 12,464 abstracts. The study found that among abstracts expressing a position on AGW, over 97% endorsed the consensus. The study also found that scientific consensus had already formed in the early 1990s and strengthened over the 21 year period. This result was consistent with earlier research.

A public outreach was designed to leverage the peer-reviewed published research (Cook et al., 2013) to publicly promote the scientific consensus with the purpose of reducing the public misperception that climate scientists still disagreed about AGW. The press release promoting the publication of the research was designed to co-activate both the conception of scientific consensus and the misperception of disagreeing scientists. Specifically, the scientific conception

was the quantitative information that a 97% consensus exists among climate papers expressing a position about AGW. The myth that scientists disagreed that humans were causing global warming was activated by citing research finding that the public held the misperception of a 50:50 debate (Pew, 2012). An explicit warning prior to activating the myth mentioned the "gaping chasm between the actual scientific consensus and the public perception".

Press releases were issued by the universities of several of the paper's co-authors, based in Australia, the UK, and the USA. The Institute of Physics, publisher of the journal Environmental Research Letters, also issued a press release. Most news reports covered both the key results of the paper and the misperception, ensuring that co-activation of both misconception and scientific conception maximized chances of reducing the misconception. One day after the paper's release, the paper was promoted on President Obama's twitter account, which features over 31 million followers (BarackObama, 2013). This resulted in over 2,650 retweets and additional media coverage about the tweet (Hannam, 2013). The paper received global exposure with media coverage divided by country shown in Figure 1.

FIGURE 1

A major goal of the outreach was to reach beyond the "choir" of blogs and organizations already engaged with the climate issue. The mainstream media attention as well as President Obama's tweet significantly contributed to this goal. Also encouraging was coverage in a diversity of media outlets and blogs, on topics as far ranging as finance, health, general science, and farming. The research was even reported in conservative newspapers known for expressing dissenting views on climate change such as The Australian (AAP, 2013) and the Telegraph (Pearlman, 2013).

To make the peer-reviewed research accessible to the lay-public, a website theconsensusproject.com was developed pro-bono by New York based design and advertising agency SJI Associates. The website featured shareable images to facilitate viral marketing, which were reposted in numerous blogs and Facebook pages. Several samples are shown in Figure 2, with the second figure demonstrating co-activation of accurate perception and misperception.

FIGURE 2

Criticisms from blogs that reject the scientific consensus on climate change were anticipated and a pre-emptive FAQ (http://sks.to/tcpfaq) was published simultaneously with the paper publication. This approach is recommended for scientists publishing climate research that is likely to attract criticisms from climate dissenters. It was observed that many of the criticisms of Cook et al. (2013) adhered to the five characteristics of movements denying a scientific consensus, namely cherry picking, fake experts, logical fallacies, impossible expectations of what research can deliver, and conspiracy theories (Diethelm & McKee, 2009). Examination of the criticisms provided an opportunity to educate the public about patterns inherent in consensus denial (Nuccitelli, 2013).

In summary, public misperception about the scientific consensus on climate change was targeted in a communication outreach that sought to reinforce the overwhelming agreement in climate research and to reduce the consensus gap. The outreach received global exposure across a diversity of media outlets. Importantly, mainstream media covered both the key results of the paper and the misperception in a manner consistent with the co-activation structure of refutation texts. It remains to be seen whether public perception of scientific consensus will have discernibly shifted in response.

DISCUSSION

Agnotology-based learning has some limitations, particularly in public outreach outside of the classroom. Political ideology has been shown to be one of the strongest predictors of climate attitudes with conservatives more skeptical of AGW (Heath & Gifford, 2006). It has been shown that higher levels of education tend to increase climate skepticism among Republicans while decreasing skepticism among Democrats (Pew, 2007). Similarly, there is a strong correlation between political ideology and perception of consensus. For example, 58% of Democrats think scientists agree on AGW while only 30% of Republicans think scientists agree (Pew, 2012). This indicates political belief has a strong influence on public perception of consensus. Nevertheless, even among Democrats, there is a significant consensus gap indicating that political bias only partly explains the consensus gap and that general lack of awareness is an ongoing issue.

Two aspects to effectively communicate climate change science are required to close these gaps, especially in the case of public outreach – two-channel science communication that combines information content (Channel 1) with cultural meanings (Channel 2; Kahan et al., 2012). The two channel approach may not be as relevant in an educational setting although educators are advised to be aware of the biasing influence of ideology when climate science is involved.

In conclusion, twenty years of scholarly research have found that refutational texts are one of the most effective means of reducing misconceptions. We have outlined three case studies that use agnotology-based learning to reduce misconceptions, two in educational settings and one using public outreach. However, despite extensive research indicating the effectiveness of refutation text, textbooks typically contain little refutation text. Therefore, publishers and authors are encouraged to adopt refutation text structure in science educational material. Similarly,

educators and teachers are encouraged to adopt agnotology-based learning approaches in the classroom. It is hoped that the case studies presented here demonstrate the potential effectiveness of refutational learning and possible approaches for educators.

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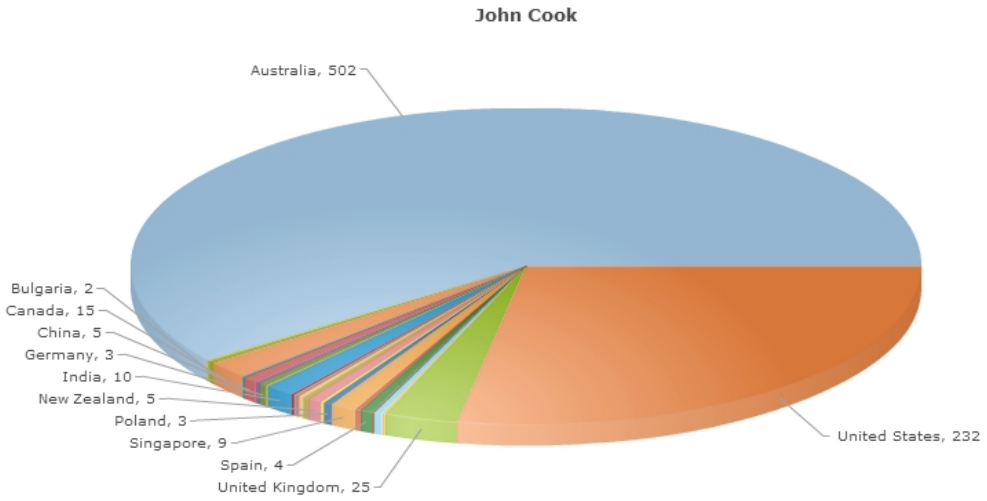

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680 Figure 1. media coverage of Cook et al. (2013), divided by country. Source: Meltwater.

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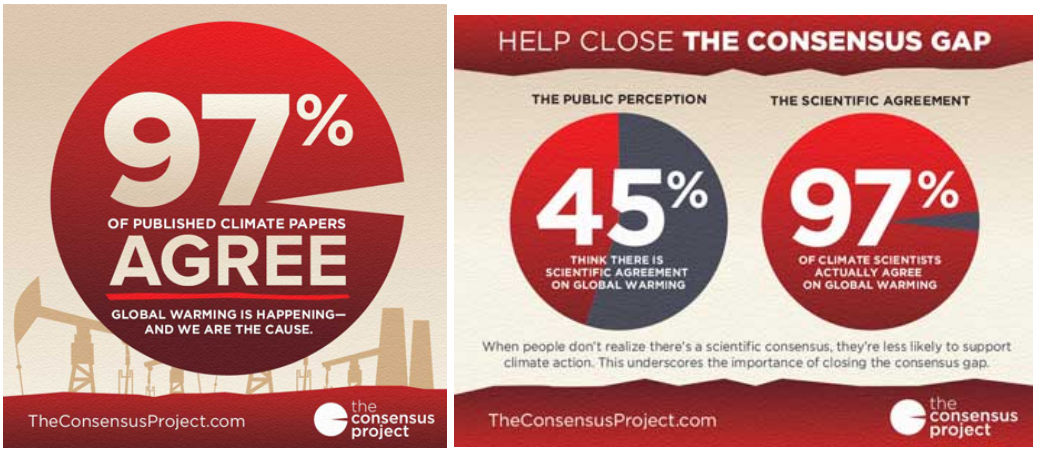

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683 Figure 2: Images from theconsensusproject.com designed for viral sharing via social

684 media. Source: SJI Associates.

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