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Consensus Messaging Using Scholarly Literature: Impacts on Students' Conceptions of Global Climate Change

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ABSTRACT

Despite near-unanimous consensus among climate scientists, the misconception of substantial scientific disagreement over the reality of human-induced global climate change persists among members of the general public. Within the research literature on climate science, there exists robust work which quantifies and reviews the scientific consensus on human-induced climate change. This study evaluated the efficacy of using such research literature as a tool for consensus messaging among undergraduates taking an introduction to biological research course at a large, private, research-intensive university in the northeastern United States. Outcomes investigated include the potential impact that reading and discussing such research literature may have had on students' perceptions of the scientific consensus on human-induced climate change among climate scientists, students' key beliefs about climate change, students' support for threat-reduction actions and climate policy, and students' confidence in their own ability to communicate to others about the degree of scientific consensus on climate change. The findings suggest that using scholarly literature as a mode of consensus messaging is effective at aligning participants' perceptions with the actual level of scientific consensus around climate change as well as their self-reported confidence in communicating the consensus. There was also an overall increase in the degree to which participants were worried about climate change and evidence of increased acceptance of human-induced climate change after reading and discussing these articles. Additional findings include that participants overwhelmingly perceived benefits from participation in the introduction to biology course itself, which focuses on primary literature and interacting with biology research faculty about their scientific work. Participants' self-reported benefits included improved biology content knowledge, enhanced data analysis skills, and improved ability to read and understand primary literature.

CONSENSUS MESSAGING USING SCHOLARLY LITERATURE: IMPACTS ON STUDENTS' CONCEPTIONS OF GLOBAL CLIMATE CHANGE

by

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DEDICATION

I dedicate this work to my soon-to-be wife, Kristin Renée Letsch. Kristin Renée has stood by my side through thick and thin. I honestly do not know where I would be today without her, and I am more than excited to see what our next chapter brings. Thank you, Kristin Renée, for being you.

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CHAPTER 1: INTRODUCTION

Overview

This introduction discusses the disparity between climate scientists' conceptions of human-induced climate change and those of the general public. Based on studies that investigate the so-called "gateway belief" to acceptance of human-induced climate change and support for threat-reduction actions, as well as those that evaluate the outcomes of using scholarly literature in undergraduate science courses, research questions regarding the efficacy of using scholarly literature which quantifies and explicates the scientific consensus on human-induced climate change as a mode of consensus messaging toward conceptions of climate change are proposed.

Statement of the Problem

Several methods have been used to quantify the level of consensus among climate scientists regarding human causation of climate change. One such method is meta-analysis of the relevant data and results found in existing databases and published research (Oreskes, 2004; Cook et al., 2013). The most recent and rigorous meta-analysis of human-induced climate change (there referred to as anthropogenic global warming, or AGW) found that among almost 12,000 peer-reviewed climate change papers, 97.1% of the abstracts that took a position on AGW endorsed the consensus position that human activity is the dominant cause (Cook et al., 2013). Surveys of climate scientists have revealed similar levels of consensus (Bray & von Storch, 2007; Doran & Zimmerman, 2009; Farnsworth & Lichter, 2012; Verheggen et al., 2014; Stenhouse et al., 2014; Carlton, Perry-Hill, Huber, & Prokopy, 2015). Furthermore, a mathematical analysis of citation patterns found that while there was initial contestation over the issue, a consensus was rapidly generated by the early 1990s (Shwed & Bearman, 2010).

Climate change is expected to bring dire consequences for society. Indeed, many of these have already begun, as climate change has already brought increased risk of flooding, landslides, and forest fires (Revi, 2005; Awuor, Orindi, & Adwera, 2008; Adelekan, 2010; Keywood et al., 2013). It is projected to result in an increase in heat-related deaths (Christidis et al., 2012), negative impacts on food quantity and quality (Battisti & Naylor, 2008), an increase in levels of poverty (Ahmed, Diffenbaugh, & Hertel, 2009), and diminishing clean water supplies (Hadipuro, 2007). Furthermore, climate change has been implicated in an increased frequency of vector-borne diseases, such as Lyme (Bennet, Halling, & Berglund, 2006; Ogden et al., 2008), malaria (Kelly-Hope, Hemingway, & McKenzie, 2009; Alonso, Bouma, & Pascual, 2009; Omumbo, Lyon, Waweru, Connor, & Thompson, 2011), and dengue fever (Beebe, Cooper, Mottram, & Sweeney, 2009; Pham, Doan, Phan, & Minh, 2011; Astrom et al., 2012). It has also been associated with a greater frequency of allergic diseases (Beggs, 2010) and mental health resulting from natural disasters (Ahern, Kovats, Wilkinson, Few, & Matthies, 2005; Ronan et al., 2008; Berry, Bowen, & Kjellstrom, 2010). Moreover, climate change is expected to lead to forced displacement and migration, which would in turn likely lead to increased instances of undernutrition, food- and water-borne diseases, diseases resulting from overcrowding, and sexually transmitted diseases (Gemenne, 2011; McMichael, Barnett, & McMichael, 2012).

Despite the near-unanimous consensus among the world's experts in climate science, as well as the potentially devastating consequences of climate change, understanding and concern among the American public is troublingly low. Fewer than half of Americans hear about global warming in the media at least once per month, and only a quarter of the population hear people they know discussing global warming at least monthly (Leiserowitz et al., 2017). Only six in ten Americans are worried about global warming (Leiserowitz et al., 2017). Perhaps most discouragingly, only about one in seven Americans understands that almost all climate scientists (above 90%) have concluded human caused global warming is happening (Leiserowitz et al., 2017). This statistic is particularly troublesome given that perceived consensus appears to be a "gateway belief" to acceptance, support for action and climate policy, and injunctive beliefs (or beliefs that certain individuals and entities should be doing more to address global warming) Ding, Maibach, Zhao, Roser-Renouf, & Leiserowitz, 2011; McCright, Dunlap, & Xiao, 2013; van der Linden, Leiserowtz, Feinberg, & Maibach, 2015).

Americans' lack of understanding of and concern about climate change is a direct result of concerted efforts to undermine climate science by the so-called "Climate Change Denial Machine" (Dunlap & McCright, 2011). Each of the cogs of the Climate Change Denial Machine—the fossil fuel industry, Corporate America, conservative foundations, conservative think tanks, front groups, the echo chamber (consisting of media, politicians, and blogs), and astroturf organizations and campaigns—have targeted political conservatives for their message as conservatives are predisposed to be skeptical of anything that raises the specter of governmental regulation. The goal of the Climate Change Denial Machine has been to manufacture doubt as to the veracity of the scientific consensus on human-induced climate change in order to undermine support for climate policy (Dunlap & McCright, 2011).

Of the studies that explore the Gateway Belief Model (GBM; see "definitions") towards climate change conceptions, only van der Linden et al. (2015) provides causational evidence of perceived consensus as a gateway belief. This study collapsed three modes of consensus messaging (simple statements of the level of consensus, metaphors, and pie charts) into one treatment. Participants were those who completed online surveys. Whether scholarly literature can be an effective mode of consensus messaging in the context of an undergraduate biology course remains unknown.

Theoretical Framework

Many outcomes of using scholarly literature in undergraduate science classrooms have been documented, including improved content knowledge. For example, DebBurman found that students self-reported that experiential research projects using scholarly literature, including a journal club, increased understanding of why and how cells are the units of life and strengthened cell biology concepts learned in lecture and laboratory (2002). When students read scholarly literature and completed an associated assignment, students self-reported that the paper and assignment helped them understand the topics of the paper—glycolysis, protein transport, and cell cycle regulation—individually and collectively (Yeong, 2015). When scholarly literature was the exclusive curriculum material for an ecology and evolution special topics course, 83% of the students self-reported content knowledge gains in ecology and evolution, specific species, or science in general. In the first study of the C.R.E.A.T.E. method in an upper level biology course, student concept mapping of course content became significantly more complex after studying scholarly literature (Hoskins, Stevens, & Nehm, 2007). Alumni of the Howard Hughes Undergraduate Research Program indicated that they believed participation in the journal club had a positive effect on their knowledge of scientific content outside their majors or main areas of research (Kozeracki, Carey, Colicelli, & Levis-Fitzgerald, 2007). Students exposed to scholarly literature through Process-Oriented Guided Inquiry Learning (POGIL) in a biochemistry sequence self-reported improvement in their understanding of course topics throughout the year and that each article and activity helped their learning of biochemistry

(Murray, 2014). These results indicate that scholarly literature holds the potential to help students learn a great deal about the content in the papers.

As previously stated, there is evidence that perceived consensus is a gateway belief to acceptance of human causation, support for action and policy, and injunctive beliefs. The first iteration of the GBM was explored by Ding and colleagues (2011). The authors conducted an online survey of a nationally representative sample of United States adults and tested whether perceived scientific agreement was a predictor of climate policy support and injunctive beliefs, as well as whether this effect was mediated by five key global warming beliefs: belief certainty, human causation, collective efficacy, harm timing, and harm extent. The authors' hypothesis was supported, suggesting that correcting the widespread misconception of a lack of consensus among climate scientists can be a particularly effective way to increase support for climate policy. However, causational evidence from this study was lacking.

The second iteration of the GBM extended the first by Ding and colleagues (2011) by including political and environmental identity variables (political ideology, party identification, and environmental movement identity) as predictors for perceived scientific agreement (McCright et al., 2013). Data came from the Gallup Organization's annual environmental poll, based on telephone interviews with a nationally representative sample of US adults. The authors' hypothesis was supported, suggesting again that perceived consensus plays a pivotal role in predicting support for emissions reduction policies. Once again, however, causational evidence was lacking (McCright et al., 2013).

The third and most recent iteration of the GBM was the first to provide causational evidence (Figures 1 and 2; van der Linden et al., 2015). Data came from an online survey of a nationally representative sample of US adults. Participants were asked about their perceived consensus, key beliefs (belief in climate change, worry about climate change, and belief in human causation) as well as their support for public action. They then were exposed to one of three modes of consensus messaging: a simple statement of the level of consensus, a metaphor, or a pie chart. The same data were then again collected. The authors found that highlighting the level of consensus caused a *change* in the participants' perceived consensus, key beliefs, and support for action. Because of the strength of this causational evidence, the present study is based on this iteration of the GBM.

Given that there is substantial evidence that exposure to scholarly literature in undergraduate science courses improves understanding of the content in those papers, there is reason to believe that scholarly literature that quantifies and reviews the scientific consensus on climate change may be a particularly effective mode of consensus messaging.

Purpose of the Study

The purpose of this study was to contribute to the body of literature on effective ways to communicate the scientific consensus on climate change by exploring whether the use of scientific journal articles which quantify and explicate the consensus on climate change may impact students' perceived consensus in the context of an undergraduate science course at a private research university in the Northeastern United States. Furthermore, the study explores impacts of reading and discussing such literature on students' key beliefs about climate change and their support for threat-reduction actions and policy. Based on the evidence that the use of scholarly literature in undergraduate science courses improves students' understanding of the content discussed in those papers, as well as the evidence that perceived consensus is a gateway belief, the working premise of this study was that the use of scholarly literature that quantifies and reviews the consensus on climate change should positively impact students' perceived consensus, key beliefs, and support for threat-reduction actions and policy.

Importance of the Study

Climate change is a particularly urgent issue that needs to be addressed both nationally and internationally. The American Association for the Advancement of Science stated, "The scientific evidence is clear: global climate change is occurring now, and it is a growing threat to society" (2006). Similarly, the American Chemical Society stated, "Comprehensive scientific assessments of our current and potential future climates clearly indicate that climate change is real, largely attributable to emissions from human activities, and potentially a very serious problem" (2004).

However, polls of American adults paint a dismal picture of understanding of the phenomenon and support for action to reduce it. Only about one in seven Americans correctly estimates the current level of scientific agreement, and only about four in ten Americans say their family and friends make at least a moderate amount of effort to reduce global warming (Leiserowitz, Maibach, Roser-Renouf, Rosenthal, & Cutler, 2017). Furthermore, Americans generally rank climate change as a low priority—it is the sixth most important out of 23 issues for liberal Democrats, but 13th for moderate/conservative Democrats, 21st for liberal/moderate Republicans, and 23rd (last) for conservative Republicans (Leiserowitz, Maibach, Roser-Renouf, Feinberg, & Rosenthal, 2016).

Highlighting the level of scientific consensus holds the potential to improve support for policy and action to reduce climate change (Ding et al., 2011; McCright et al., 2013; van der Linden et al., 2015). This study will contribute to existing knowledge on effective ways to communicate the consensus. In particular, it will reveal whether scholarly literature is an effective way to communicate the scientific consensus in the context of an undergraduate biology course. Given the urgent need to address and reduce climate change, improving public support for threat-reduction actions and policy is necessary—and consensus messaging appears to be a very effective way to do this.

Definitions

The following terms are defined as follows for use in this study:

Biology 200: A special topics course offered to undergraduate students who have completed introductory biology. The special topics course described in this dissertation was an introduction to biological research course. Scholarly literature produced by laboratories on campus constituted the curriculum materials, and each week the primary investigator of the laboratory came to class to describe their research interests and answer questions. The goal of the course was to prepare students to engage in undergraduate research.

Climate Change: A change in regional or global climate patterns, particularly apparent from the mid to late 20^{th} century onward, caused by human activity—including the burning of fossil fuels.

Consensus Messaging: Communicating the degree of scientific consensus on a topic. Here, this term is used to refer specifically to communicating the degree of scientific consensus on human-induced climate change.

Gateway Belief Model (GBM): As defined by van der Linden and colleagues (2015), this term describes a two-step cascading effect: "First, the effect of consensus messaging on key beliefs about climate change is fully mediated by the perceived level of scientific agreement.

Second, the effect of the induced increase in perceived scientific consensus is fully mediated onto support for public action via the key beliefs about climate change." In other words, perceived consensus functions as a gateway belief to other key beliefs about climate change, which in turn influence support for public action.

Nature of Science: The history, philosophy, and sociology of science

Primary Literature: Scholarly literature that presents original data for the first time.

Scholarly Literature: Literature that is written by researchers who are experts in their field and published in peer-reviewed journals.

Research Questions

This study addressed the following questions:

1. Does consensus messaging using scholarly literature impact perceived scientific consensus of human-induced climate change, as predicted by the GBM?
2. Does consensus messaging using scholarly literature impact key beliefs about climate change, including belief in climate change, worry about climate change, and belief in human causation, as predicted by the GBM?
3. Does consensus messaging using scholarly literature impact support for action, as predicted by the GBM?

Delimitations

This study confined itself to undergraduate students who attended a private, four-year research university in the Northeastern United States. Because this study aimed to evaluate the efficacy of scholarly literature as a mode of consensus messaging, it would not have made sense for data to be collected from a course primarily about climate change as the students who already accept it and support threat-reduction actions would likely self-select for enrollment. Therefore, the decision was made to offer and collect data from an introduction to biological research course (which will be described in detail later in this dissertation). The author was the primary instructor of the course, and before students read original research articles produced by labs from the university, they were asked to read two other articles of a different format – one meta-analysis (Cook et al., 2013, which quantified the level of consensus about human-induced climate change) and one review (Cook et al., 2016, which reviewed it). The students were required to complete one "Figure Facts" document (which will also be described later in the dissertation; Round & Campbell, 2013) for each paper to ensure that they read. Participation in the research was delimited to students who were enrolled in the course and completed the surveys before and after exposure to the climate change consensus literature.

Due to the lack of any previously validated instruments to measure components of the GBM, this study borrowed language from van der Linden and colleagues (2015) who were the first to provide causational evidence of the GBM. The data collected were thus limited to perceived consensus among members of the climate science community, belief in climate change, worry about climate change, belief in human causation, and support for action. The prompts from van der Linden and colleagues (2015) asked participants to self-rate their belief in climate change, belief in human causation, worry about climate change, and support for public action from 0-100. This is considered a delimitation as it may have been difficult for participants to self-rate reliably with 101 different options. Data concerning support for climate policy were also collected as Ding and colleagues (2011) provided evidence of perceived consensus as a gateway belief to support for policy. Finally, data concerning confidence in communicating the degree of scientific consensus on human-induced climate change were collected, as an increase in confidence could potentially translate to the participants performing their own consensus messaging and influencing the perceived consensus, key beliefs, and support for public action for those they interact with outside of class. The prompt about confidence in communicating the consensus was modeled after the other prompts used by van der Linden and colleagues (2015). This study did not consider other variables such as knowledge of climate change or factors influencing acceptance of human-induced climate change or support for action. This study also did not utilize a comparison group, so it is not possible to rule out the possibility that factors other than the treatment described could have influenced climate change conceptions.

Due to the nature of the discussion-based course, only eleven students were enrolled. This delimited the quantitative analyses performed to nonparametric Wilcoxon signed-rank tests. Unlike previous studies that explored the GBM (Ding et al., 2011; McCright et al., 2013; van der Linden et al., 2015), mediation analyses or structural equation modeling could not be used.

Because the study population consisted of students attending a private research university in the Northeastern United States, the participants were likely younger than most Americans, making them more likely to be accepting of climate science to start with (Pew Research Center, 2015, "Americans, Politics and Science Issues"). This raised the possibility of a ceiling effect. For this reason, other data concerning potential benefits the students may have experienced—including increased biology content knowledge, enhanced data analysis skills, improved ability to read and understand primary literature, and improved understanding of the nature of science—were collected. Each of these benefits has been documented to result from the use of scholarly literature in undergraduate science courses (see Chapter 2). The present study is about another course that utilized scholarly literature, though unlike the others described in Chapter 2, this course was an introduction to biological research course that featured weekly in-person interactions with scientists. The present study sought to investigate whether each of these outcomes could be achieved in the context of an intro to biological research course that featured weekly in-person interactions with scientists.

Limitations

A limitation of this study was that the primary instructor of the course was a graduate student with limited experience in many of the diverse areas of research explored. This was addressed by inviting the primary investigators (PIs) of the labs to visit the class each week and review the paper(s) the students read, as well as other work their labs were concerned with.

The sampling procedures used for this study decreased the generalizability of the findings. Results were not generalizable to the general public, nor to all undergraduate students in private research universities, public universities, or two-year colleges. The overall sample size was small (N = 11 students).

While all of the students completed all of the surveys, the study was limited by the willingness of the participants to answer questions honestly and to the best of their ability. It is possible that students may not have put forth the necessary effort to answer questions about their conceptions of climate change, understanding of the nature of science, or their experiences with the course.

Another limitation of the study involved students’ completion of assessments designed to measure their understanding of the nature of science. While students completed these assessments on their personal computers in class to discourage them from using the internet to search for correct answers, the instructor was not able to make certain that no students were searching for correct answers online.

Furthermore, it is possible that while students were required to read the two climate change consensus papers in class and complete the associated Figure Facts documents, there is no way to guarantee that every student read every word of each article. It is a possibility that students only read enough of the articles to complete the Figure Facts and participate in the online and in-person discussions.

Conceptual Assumptions

To determine the effects of using scholarly literature that quantified and reviewed the level of scientific consensus on human-induced climate change, this study assumed that the language used by van der Linden and colleagues (2015) to measure components of the GBM reliably reflect participants' understandings and beliefs. An additional assumption is that students completed surveys to the best of their abilities and did not search online for answers about the nature of science.

Outline of the Remainder of the Dissertation

The remainder of this dissertation consists of the five following chapters. Chapter 2 contains a review of the documented benefits of using scholarly literature in undergraduate science courses and predictions for participants' experiences with the scholarly literature and course in general. Chapter 3 describes the methods and procedures used for this project. Chapter 4 contains analyses and the findings of this study as well as a discussion of those findings. Chapter 5 includes analyses of additional findings discovered during the course of this project, including participants' perceived benefits of participating in the course, and a discussion of those findings. Chapter 6 presents a summary of the dissertation and recommendations.

CHAPTER 2: LITRATURE REVIEW

Overview

This chapter contains a review of the documented benefits of using primary literature in undergraduate science courses and discusses how these benefits informed predictions about the participants' experiences in the present study.

Improved Content Knowledge

Improved content knowledge is one of the most widely cited outcomes of using primary literature in undergraduate science courses. For example, DebBurman (2002) reported that students perceived improvements in their understanding of cell biology after exposure to primary literature as part of a sophomore level course that integrated five mock experiential research projects with a lecture and laboratory. These five projects represented specific activities that are common among science professionals, including (in sequence): 1) Journal Club; 2) Medical News Journalism; 3) Disease Review Article; 4) Disease Symposium Seminar; and 5) Laboratory Report Written as a Primary Article. The first two projects focused on comprehension and communication of a single journal article, the second two focused on integrating and communicating information from several related articles, and the final project required students to author their own primary articles based on experiments performed in class. According to post-course surveys, students believed that the research projects helped them achieve content-specific course goals and strengthened cell biology learning (DebBurman, 2002).

Yeong (2015) also used primary literature in a cell biology course. The author chose a specific paper (Yalcin et al., 2009) because it explored the functional interactions of seemingly unrelated processes, including glycolysis, protein transport, and cell cycle regulation. Students were asked to read this article and answer several questions in essay format related to how proteins involved in these different processes functionally associated with one another. Students indicated in a post-intervention survey that the assignment helped them understand the three above-mentioned cellular processes individually and collectively (Yeong, 2015).

Content knowledge was also reported to improve when a journal club was integrated into a senior seminar on evolutionary biology (Muench, 2000). During the first half of this course, the instructor selected papers for group discussion. During the second half, students wrote their own papers based on articles they chose themselves and then presented their papers to the class. The course was designed such that the leadership of the group discussions was gradually transferred from the instructor to the students. Students self-reported that the course helped them understand primary literature better than they were able to before and they learned more from writing the paper based on primary articles than they learned from writing in other courses (Muench, 2000).

A novel approach created by Hoskins and colleagues defines specific steps that students should take as they read journal articles, and has shown promising results regarding content knowledge (Hoskins, Stevens, & Nehm, 2007). The C.R.E.A.T.E. (Consider, Read, Elucidate hypotheses, Analyze and interpret data, Think of the next Experiment) method requires students to read four articles from the same authors in sequence to study the evolution of scientific knowledge over time. The method takes a data-centric approach, requiring instructors to withhold large portions of the text from students as they first answer questions related to the article's figures. In their article that first introduced the C.R.E.A.T.E. method, Hoskins and colleagues concluded that using the C.R.E.A.T.E. method in an upper-level biology elective resulted in increases in students' conceptual understanding of course content based on increases in complexity of concept maps from pre- to post-instruction (Hoskins et al., 2007).

Content knowledge was also reported to improve when the C.R.E.A.T.E. model was used in a special topics ecology and evolution course at Syracuse University for which primary literature was the only source of content material (Carter & Wiles, 2017). Students in this course participated in online discussions where they posted summaries of the papers, responses to them, and potential next experiments. They were also asked to comment on one another's responses. While scores on the biological concept inventory (a general biology content knowledge instrument) did not significantly improve from the beginning to the end of the semester, 83 percent of the students in the course indicated that they believed their biology content knowledge improved after taking the course.

Kozeracki and colleagues also found evidence of improved content knowledge resulting from an intensive, literature-based teaching program known as the Howard Hughes Undergraduate Research Program (HHURP) (Kozeracki, Carey, Colicelli, & Levis-Fitzgerald, 2006), a collaboration between an undergraduate College of Letters and Science and the same university's Medical School. Juniors who are engaged in undergraduate research and interested in pursuing graduate degrees are encouraged to apply. It is highly competitive and consists of a weekly journal club, research presentations, seminar speakers, career guidance, and a scholarship. The weekly journal club is considered the central component of the program, and each week a different student selects a paper to present and develops questions about key techniques and scientific principles discussed in the article. Prior to the class discussion, these questions are distributed to other HHURP scholars such that each scholar is assigned one question that they must respond to during the presentation. Alumni of the program indicated in a survey that they believed participation in the journal club had a positive effect on their knowledge of scientific content outside their majors or main areas of research.

Additionally, content knowledge was reported to improve when Process Oriented Guided Inquiry Learning (POGIL) was used in a majors biochemistry sequence (Murray, 2014). POGIL engages students in small groups on materials provided by the instructor intended to develop process skills in addition to content. Students are typically given a model (figures, tables, etc.) and tasked with exploring the model, developing related concepts, and applying them to new situations. Murray used figures and tables from primary research articles for four POGIL activities throughout the academic year. Students self-reported gains in their understanding of course topics throughout the academic year as well as that each article and activity helped their learning, suggesting that using POGIL to read and understand primary literature increases students' knowledge of relevant content (Murray, 2014).

Enhanced Research and Data Analysis Skills

Other commonly reported benefits of using primary literature in undergraduate science classrooms are enhanced research and data analysis skills. Evidence of this comes from a study by Round and Campbell in which the authors introduced a new data-centric approach to reading primary literature called "Figure Facts" (2013). The Figure Facts template is a Microsoft Word document that students fill in as they read a paper. A small portion of the template is related to the introduction of the paper where students write out the broad topic, specific topic, what is known, and the experimental question. Most of the template, however, is related to the figures themselves. For each figure panel, students write out which technique the authors used and what the conclusion was for that panel. Generally speaking, this method is more streamlined than

C.R.E.A.T.E. (though both take data-centric approaches); students receive the whole paper at once, they can read multiple unrelated papers, and perhaps most importantly, this approach is flexible enough that it can be used in any science course with primary literature of any topic. Round and Campbell used Figure Facts in an advanced cellular neuroscience course and administered data interpretation skills tests at three times during the semester. For these tests, students were given two figures containing microscopic images of neurons as well as graphs of averaged data sets. They were then asked to examine the figures and identify true statements from a list of possible conclusions. The students experienced statistically significant improvement in their data interpretation skills as measured by their test scores between weeks 1 and 9 of the semester, with further improvement between weeks 9 and 15 that did not reach statistical significance (Round & Campbell, 2013).

The C.R.E.A.T.E. method has also shown promising results regarding research and data analysis skills (Gottesman & Hoskins, 2013; Hoskins, Lopatto, & Stevens, 2011; Hoskins et al., 2007). Students involved in the first study on C.R.E.A.T.E. self-reported improved skills in designing experiments as well as relating methods used to data obtained in survey responses (Hoskins et al., 2007). Students involved in a later study at the same institution exhibited statistically significant improvement from the beginning to the end of the semester in their self-assessed abilities to interpret data (Hoskins et al., 2011). Additionally, although previous efforts with C.R.E.A.T.E. focused on upper-level courses, Gottesman and Hoskins adapted the method for an introduction to scientific thinking course for first-year students (2013). The first-year students in the course initially read and analyzed popular press articles based on journal articles to help them develop the skills necessary to read primary literature later in the course. Students in the first-year university course, as well as those in a contemporaneous upper-level

C.R.E.A.T.E. course, completed the Survey of Student Self-Rated Abilities, Attitudes, and Beliefs (SAAB) at the beginning and end of the semester. Results indicated statistically significant improvement in self-assessed abilities to interpret data for students in both courses. Scores on the Experimental Design Ability Test (EDAT) also improved significantly for the first-year university students from pre- to post-semester.

Stover also reported improved data analysis skills when primary literature and Penn & Teller's Showtime TV series *Bullshit!* were used in a current topics in biology course to distinguish between science and pseudoscience (2016). Students in the course began with a blog post on a scientific issue (recognizing that this was not a form of primary literature and could not be considered reliable), and then moved on to case studies, observational studies, experimental studies, and systematic reviews. Most of the papers described experimental studies, and for each of these papers students were asked complete a form summarizing the gap in knowledge the research question addresses, overall hypothesis, prediction, methods, results, conclusion, and next research question(s). Before class discussions of each topic, the topic was introduced in an episode of *Bullshit!* in which Penn & Teller (who are magicians and comedians) reinforce their opinions on the topics with scientific evidence. Students were encouraged to critique the reasoning Penn & Teller used to reinforce their opinions. Stover reported that students learned to recognize the type of study presented in a journal article and how to analyze the data accordingly, although no analysis of data analysis skills was presented or discussed. Stover also reported that students became more cognizant of reasoning errors used by the general public to reject scientific evidence.

Janick-Buckner has also conveyed that her students' research and analysis skills improved after taking an advanced cell biology course based on the critical reading of primary literature (1997). For this course, students were required to read journal articles and submit reviews responding to questions posed by the instructor, including why the study was done, what techniques and procedures were used, the purpose of the figures, etc. Student responses to survey questions at the end of the semester indicated that that the course helped them with their own undergraduate research in that they felt their ability to design their own experiments and interpret their own data improved. Students also indicated that they felt their analytical skills improved as a result of their experience in the course.

Similarly, Glazer reported that students who took a developmental biology course with a journal club component experienced improvement in their data interpretation skills (2000). Students in this course read primary literature before class and then worked in small groups to prepare specific topics for presentation during class. The students emphasized data analysis as well as major theories in their presentations to the class. Glazer stated that “the journal club proved to be a successful vehicle for introducing a variety of new skills” (p. 324), including data interpretation skills, although it is unclear whether she based her conclusion off of student surveys, her observations of the students, or something else (2000).

Three of the studies described in the previous section also reported improved research and/or data analysis skills. Students who took the sophomore cell biology course that utilized primary literature self-reported significant improvement in scientific process skills, including their abilities to communicate contemporary research and primary literature (DebBurman, 2002). Additionally, when an instructor asked students to read primary literature to help them make connections among different cellular processes, student comments revealed that they believed the course helped them learn how to analyze research data (Yeong, 2015). Furthermore, alumni of the HHURP program self-reported that participation in the weekly journal club improved their abilities to critique scientific research, formulate probing questions about scientific journal articles, explain their own research to others, and design and implement their own undergraduate research (Kozeracki et al., 2006).

Improvement at Reading and Understanding Primary Literature

Related to improved data analysis and research skills, it is also often reported that exposure to primary literature in undergraduate science classrooms improves their ability to read and understand primary literature. Quantitative evidence of this longitudinal effect comes from a study on the use of primary literature modules in a biochemistry lab, molecular biology lab, and microbiology lab (Sato et al., 2014). The modules consisted of instructor-led modeling of how scientists approach journal articles for three papers. For the first paper, students were tasked with answering four general questions about the study (why the experiment was performed, how the experiment was performed, what results were obtained, and what conclusions were made). For the second paper, students were required to write summary paragraphs of selected figures. For the third paper, students were allowed to choose which of these two approaches to use. After the third paper, students in all three courses were given a paper quiz (each one unique) that featured an article unfamiliar to them and questions based on levels one through six of Bloom's taxonomy (a hierarchy of cognitive skills used to represent educational objectives; Ennis, 1993). Statistical analyses of quiz scores showed that returners, or students who took one of the labs involved in the study in an earlier quarter and enrolled in a different lab at a later time, scored significantly higher on this quiz than first-time students. This suggests that using primary literature in undergraduate lab courses results in a longitudinal increase in the ability to understand primary literature (Sato et al., 2014).

There is also evidence that the C.R.E.A.T.E. method can improve students' confidence in their abilities to understand primary literature. For example, after C.R.E.A.T.E. was first used in an upper-level biology elective, students in the course self-reported increased confidence in their ability to read and understand science in survey responses (Hoskins et al., 2007). Additionally, when C.R.E.A.T.E. was used again in an upper-level biology elective at the same institution, results of pre- and post-course surveys indicated statistically significant improvement in students' self-assessed abilities to decode primary literature (Hoskins et al., 2011). Furthermore, when C.R.E.A.T.E. was adapted for a first-year university science course, survey responses revealed statistically significant improvement in self-assessed ability to decode literature for both the first-year course and upper-level C.R.E.A.T.E. course (Gottesman & Hoskins, 2013). Finally, after C.R.E.A.T.E. was used in a special topics biology course with primary literature as the exclusive source of content, students stated that the course improved their abilities to read and interpret primary research articles (Carter & Wiles, 2017).

Figure Facts has also been associated with improved confidence in approaching scientific literature (Round & Campbell, 2013). After it was used in an advanced cellular neuroscience course, 80 percent of students either agreed or strongly agreed that Figure Facts helped them structure their reading of primary literature and 90 percent agreed or strongly agreed that it helped them focus on the data of the paper. The authors also administered surveys at the beginning and end of the semester regarding stress and frustration while reading research papers. At the beginning of the semester, 47 percent of students agreed or strongly agreed that reading primary literature was often a stressful experience for them and 58 percent stated that reading primary literature would make them frustrated. At the end of the semester, these percentages dropped to 12 percent and 19 percent, respectively, presumably indicating that reading and understanding these papers became easier for them as a result of their experience in the course (Round & Campbell, 2013).

A few of the other studies discussed in previous sections revealed a positive impact of exposure to primary research articles on students' abilities to read and understand scientific literature. High-achieving students who participated in the HHURP, which included a weekly journal club, self-reported as alumni that the program improved their abilities to understand scientific journal articles (Kozeracki et al., 2006). After POGIL was used to help students read primary research articles in a majors biochemistry sequence, students self-reported gains in their ability to read and learn from primary literature as well as their confidence in interpreting the results of biochemical experiments (Murray, 2014). Students who took an advanced cell biology course based on the reading of primary literature self-reported improved confidence in their abilities to analyze primary literature (Janick-Buckner, 1997). Finally, Glazer reported that students who participated in the journal club component of a developmental biology course learned how to read and understand primary literature, although (as with the benefits Glazer reported that were discussed earlier), it is unclear how she came to this conclusion (2000).

Enhanced Critical Thinking Skills

There is also a great deal of evidence that the use of primary literature in undergraduate science courses can boost students' critical thinking skills. For example, Hoskins and colleagues found evidence of improved critical thinking skills after students were involved in the first C.R.E.A.T.E. implementation in an upper-level biology elective (2007). The critical thinking test administered before and after the course contained six questions based on the Field-tested Learning Assessment Guide (FLAG; http://archive.wceruw.org/cl1/flag/default.asp). Each question required students to interpret figures, identify trends in data, and determine whether the conclusion stated fit logically with the results shown. The test was scored based on whether a student agreed, disagreed, or had no opinion on each conclusion and the number of logical and illogical justifications used by the student. Students gave a statistically significantly greater number of logical statements for four of the six questions on the post-test as compared to the pre-test and a statistically significantly lower number of illogical statements for three of the six questions on the post-test as compared to the pre-test, with the other questions showing no significant differences pre-test to post-test. These results suggest that exposure to primary literature improves students' abilities to think critically about data and whether conclusions drawn from data are logical (Hoskins et al., 2007). Similarly, when C.R.E.A.T.E. was adapted for a first-year science course, scores on the Critical Thinking Ability Test (Stein et al., 2012) showed that students enrolled in the course experienced significant improvement in their critical thinking abilities pre-course to post-course, with a large effect size (Gottesman & Hoskins, 2013).

Stevens and Hoskins also found that students from many different types of institutions experienced critical thinking skills gains after exposure to the C.R.E.A.T.E. method (2014). Previous efforts with the C.R.E.A.T.E. method had all been through the City College of New York (CCNY), and the authors were interested in whether similar benefits could be seen by implementing C.R.E.A.T.E. at other types of institutions in the New York/New Jersey/Pennsylvania area. Faculty from these institutions attended monthly workshops in New York City to assist with their implementation of the strategy. The critical thinking test administered before and after the course contained four questions from the critical thinking test used in the original C.R.E.A.T.E. study (Hoskins et al., 2007). For many of the individual implementations, statistically significant increases and decreases were observed in the number of logical and illogical statements, respectively. Pooled data from all of the C.R.E.A.T.E. implementations showed that students overall exhibited statistically significant increases in their logical statements for all four test questions, suggesting improvement in their abilities to critically analyze data. The authors also examined critical thinking test scores for full-semester implementations versus partial-semester implementations of C.R.E.A.T.E. and found that gains were seen on more of the test questions and with larger effect sizes for the full-semester implementations as compared to the partial-semester implementations. This suggests that the more students are exposed to primary literature, the greater the improvement in critical thinking skills (Stevens and Hoskins, 2014).

Segura-Totten and Dalman were interested in whether the critical thinking gains experienced by students involved in C.R.E.A.T.E. were specific to the C.R.E.A.T.E. method (2013). They compared scores of students in a modified C.R.E.A.T.E. section of cell biology to those in a section that used a more traditional method of exploring primary literature. The approach design of the traditional discussions was reported to be based on conversations with various faculty with experience in leading article discussions. Each discussion emphasized a handful of instructor-generated questions about the articles, while the modified C.R.E.A.T.E. approach utilized concept mapping, figure-by-figure diagrams, and potential follow-up experiments. The authors designed their own critical thinking test consisting of six questions, with two designed to measure performance at the analysis, evaluation, and synthesis levels of Bloom’s taxonomy each using the Blooming Biology Tool (Crowe, Dirks, & Wenderoth, 2010). The test was administered at the beginning and end of the course, and students in both groups showed equal gains in analysis and synthesis questions but not evaluation questions. The authors also assessed improvements in students' article critique assignments from the beginning to the end of the semester and between the two different groups. They found while there was significant improvement throughout the semester across the board, there was no significant difference in scores between the groups (Segura-Totten & Dalman, 2013). These results may indicate that critical thinking gains are not specific to the C.R.E.A.T.E. model, but they should be interpreted with caution: Hoskins and Kenyon argue that the modified version of C.R.E.A.T.E. used by Segura-Totten and Dalman eliminated some of the essential aspects of the original C.R.E.A.T.E. method such as grant panel discussions and reading four sequential papers from each lab in order; plus, the study misrepresented what a traditional approach to teaching primary literature is, making comparisons difficult (Hoskins & Kenyon, 2014).

Smith also found evidence of critical thinking gains when he used primary literature in an ecology and evolution course, the first course in the introductory sequence for biology majors at the study institution (2001). Because these students were beginner biology students, they were gradually introduced to primary literature throughout the course through various literature explorations. The first two contained edited versions of original papers with summaries of the introduction and methods sections written by the instructor, selected figures and tables, and the author's summary of relevant statistical analyses. Students were asked questions that required them to interpret and draw conclusions from the figures, tables, and statistics. The second two explorations provided more of each actual paper, with shortened introduction, methods, and results sections. Students were asked about the authors' hypotheses as well as to draw conclusions from the results. For the final exploration, students were given the whole original paper and asked questions similar to those posed in previous explorations. The students also completed a library project during the semester for which they had to find their own primary sources to investigate a question in ecology or evolution. At the end of the semester, students were asked whether they believed specific biology department goals were advanced by the literature explorations through a Likert-style survey. For all goals, including the ability to think critically as a scientist, the mean was significantly different (better) than a null hypothesis of three out of five, suggesting that students perceived their critical thinking skills to improve as a result of the literature explorations (Smith, 2001). Of course, whether the students' own conceptions of their critical thinking gains matched their actual critical thinking gains is unknown.

Two of the studies discussed in previous sections also reported improved critical thinking abilities resulting from working with primary literature. When a primary literature module was used in biochemistry, molecular biology, and microbiology lab courses, and students completed a quiz based on levels one through six of Bloom's taxonomy, returners scored higher on the quiz than first-time students (Sato et al., 2014). Because the returners had previously taken another one of the lab courses with the primary literature module, and because the quiz was designed to measure higher-order thinking, these results suggest that using primary literature may result in longitudinal gains in the ability to think critically. Furthermore, when students participated in a weekly journal club, some self-reported that the program pushed them to think critically and gave them confidence in criticizing research papers, a task that certainly requires critical thinking (Kozeracki et al., 2006).

Improved Scientific Literacy and Information Literacy

Information literacy refers to a general ability to locate, evaluate, and use information when it is necessary (Association of College and Research Libraries, 2006). A related concept is scientific literacy, or the ability to comprehend, analyze, and evaluate scientific data while integrating these data into a larger body of scientific knowledge (Gillen, 2006; National Research Council, 2006; Porter et al., 2010). Information literacy and scientific literacy require similar skills and cognitive abilities (Porter et al., 2010). There is some evidence that exposure to primary literature in different ways can hold benefits for both information literacy and scientific literacy. For example, Porter and colleagues found evidence that an integrated information literacy program (known as the Scientific Method and Information Literacy Exercise, or SMILE) within a general biology course holds the potential to improve both information literacy and scientific literacy for college students (2010). SMILE students attended two workshops—the first of which introduced information literacy concepts (such as how to use online databases to find and retrieve primary and secondary literature) and the second of which served as a modeling session on how to effectively read and analyze a research paper. Students later selected, retrieved, analyzed, and evaluated an article from the journal *Animal Behaviour*, which was selected because its articles are generally accessible to beginning biology students. They evaluated quantitative figures and used their understanding of the data to formulate a research hypothesis and experimental design. The students completed a pre-test before the workshops and a post-test at the completion of SMILE that were designed to assess perceived relevance and knowledge of information literacy and scientific literacy. The two tests were identical. The authors found that significantly more students changed their answers from incorrect to correct than from correct to incorrect on the question about the definition of a secondary article. Furthermore, 90 percent of students were able to correctly identify the definition of a primary article at the completion of SMILE. The authors interpreted these results to mean that SMILE helped students distinguish between primary and secondary scientific literature, a skill necessary for both information literacy and scientific literacy. There was also a significantly greater number of students who changed their answers from incorrect to correct than from correct to incorrect on the question about the definition of a figure. Finally, students perceived significantly greater relevance of both using online databases to access primary literature and the analysis of published data to their future academic careers at the completion of SMILE as compared to the pre-test (Porter et al., 2010).

Evidence of improved information literacy resulting from exposure to primary literature was also reported by Ferrer-Vinent and colleagues after they implemented primary literature modules in general chemistry I and general chemistry II for three consecutive years (Ferrer-Vinent, Bruehl, Pan, & Jones, 2015). The general chemistry I module began with formal library instruction from a science librarian, who introduced the students to online databases such as ScienceDirect and Web of Science and gave the students opportunities to practice their database search skills. The students took a literature searching skills test before and after the library instruction session. The students then used what they learned from the session to find and retrieve the full text of a peer-reviewed article and participated in a class discussion on the content of the paper. Students were then tasked with finding and reviewing three primary sources and writing proposals for follow-up experiments. For the general chemistry II module, students again were asked to design their own experiments using primary literature, but also had to work in the laboratory to design the actual procedures for the experiment. Throughout the academic year, students kept track of the number of resources they located and viewed. The authors proposed that because information literacy refers to the ability to locate and use information, the number of resources viewed is an indication of competency in these skills (Ferret-Vinent et al., 2015). However, this can be viewed as problematic because it is entirely plausible that students viewed resources that were not useful. A significant positive relationship was observed between final course grade and the number of resources viewed. Additionally, while 50 percent of the students self-reported never having used a scientific literature database before the course, only four percent self-reported not having used these tools since the completion of the course (these data were collected two years, one year, or three months after the students completed the course depending on the academic year during which the students were enrolled in general chemistry). The authors interpreted these results to mean that the students received a strong foundation in the information literacy skills necessary to locate and assess scientific literature, although they acknowledged that the general chemistry course likely did not cause students to use literature in later courses. Student survey responses revealed that they believed that all four categories of resources presented (online library guide, print resources, online resources, and library instruction) were useful in helping them find relevant information for their projects. Students also exhibited significant improvement in their literature searching skills as measured by their literature searching skills test scores before and after the library instruction session (Ferrer-Vinent et al., 2015).

Improved scientific literacy resulting from working with primary literature has also been reported in sources that were discussed earlier in this review. After primary literature explorations were used in an ecology and evolution course, students self-reported that the literature explorations were effective in advancing the departmental goal of biological literacy (Smith, 2001). Kozeracki and colleagues concluded that HHURP improved students' scientific literacy based on student answers to program assessment questions (2006), although how exactly this conclusion was drawn from the responses was not discussed. Glazer determined that a journal club integrated into a developmental biology course was a "successful vehicle to science literacy” (p. 324) because of the skills that the club was designed to help students develop (2000). For all three of these studies, however, any strong empirical evidence for improvement in scientific literacy skills is lacking.

Improved Understanding of the Nature of Science

The nature of science generally refers to the values and beliefs inherent to the development of scientific knowledge, although the term often encompasses a great deal more than one concise definition (Crowther, Lederman, & Lederman, 2005). It is often regarded as an essential component of scientific literacy (American Association for the Advancement of Science, 1990; Lederman et al., 2013). The recent study by Carter and Wiles provided empirical evidence that using primary literature may influence students’ conceptions of the nature of science (2017). Students’ conceptions were assessed using the recommendations for the VNOS-C as described by Lederman and colleagues at the beginning and end of the semester, and their responses to questions about various aspects of the nature of science were classified as naïve, mixed, or informed (Lederman, Abd-El-Khlaick, Bell, & Schwartz, 2002). The authors observed increases in informed responses and decreases in naïve responses in all nature of science categories except for the theory/law category, which the authors stated was never explicitly addresses in class. Student comments also revealed that the course helped them understand how science worked “in the real world” or “in real life” (p. 530), which the authors interpreted to mean that the students potentially viewed science as less abstract and better understood the processes of science (Carter & Wiles, 2017).

There have also been reports of improved understanding of the nature of science after exposure to the C.R.E.A.T.E. method in undergraduate science courses (Gottesman & Hoskins, 2013; Hoskins et al., 2007; Hoskins et al., 2011; Stevens & Hoskins, 2013). Students from the first C.R.E.A.T.E. study self-reported that C.R.E.A.T.E. helped them make gains in understanding "how science is done" (Hoskins et al., 2007, supplemental figure S4B) In a later study, researchers concluded that after working with the C.R.E.A.T.E. method, students experienced significant positive shifts in their conceptions of the certainty of knowledge, the creativity of scientists, whether scientists know what the outcomes of their experiments will be, whether scientists collaborate, and the motives that drive scientists (Hoskins et al., 2011). Gottesman and Hoskins reported that when C.R.E.A.T.E. was adapted for an Introduction to Scientific Thinking course for first-year students, the students exhibited shifts in their conceptions of the certainty of knowledge, the creativity of science, and scientists as people (2013). The students enrolled in an upper-level C.R.E.A.T.E. course who were also included in the study exhibited significant shifts in their conceptions of the certainty of knowledge, sense of scientists as people, and sense of scientists' motivations (Gottesman & Hoskins, 2013). Furthermore, pooled data from full-semester C.R.E.A.T.E. implementations across several different institutions showed significant shifts in students' views of the creativity of science and their sense of scientists and scientists' motivations, while pooled data from partial-semester implementations showed no shifts in any of these beliefs (Stevens & Hoskins, 2013).

Shifts in Attitudes Toward Science and Scientists

The C.R.E.A.T.E. method has been shown to improve students' attitudes toward science and scientists. For example, as part of the original study of C.R.E.A.T.E., students self-reported gains in their appreciation of biology, their enthusiasm for scientific research, and the extent to which they believed their interest in scientists would be remembered and carried with them into other classes or aspects of their lives (Hoskins et al., 2007). Similarly, when data from C.R.E.A.T.E. implementations at several different institutions were pooled, results indicated that students experienced significant positive shifts in their appreciation of the scientific field that they learned about in their respective courses (Stevens & Hoskins, 2014).

Summary

Primary research literature is a unique form of literature in its emphasis on how knowledge is developed. These articles generally begin with an introduction to the problem and then discuss in detail the methods, results, and conclusions of the study. It is likely because of its extensive discussion of the development of scientific knowledge that primary literature has been documented to improve science content knowledge in undergraduate science courses.

Given that the use of scholarly literature has been shown to improve knowledge of the content explored in the papers, it appears to be a uniquely efficient method of communicating content about a particular scientific topic. Furthermore, given the evidence that perceived scientific consensus on human-induced climate change is a “gateway belief” to acceptance of climate change and support for threat-reduction actions (Ding et al., 2011; McCright et al, 2013; van der Linden et al., 2015), consensus messaging using scholarly literature may be a particularly effective way to improve acceptance and support.

The present study has two major facets. First, it explores whether consensus messaging using scholarly literature is effective at improving perceived consensus, key beliefs about climate change, and support for threat-reduction actions, as predicted by the Gateway Belief Model (van der Linden et al., 2015). It also examines whether the consensus messaging impacts support for climate policy and confidence in communicating the degree of scientific consensus on human-induced climate change. The second facet of this study is concerned with the potential benefits that the students may have experienced by participating in the course. Because this course combined the use of primary literature with interactions with scientists (in a manner similar to, but distinct from, C.R.E.A.T.E.), the study probed whether students experienced some of the previously documented benefits of using primary literature and/or providing opportunities for discussions with scientists in undergraduate science courses. Potential benefits were selected based on the ease of collecting data related to these benefits and the likelihood that students would accurately self-assess any gains they may have made. The researcher selected improved biology content knowledge, enhanced data analysis skills, improvement at reading and understanding primary literature, and improved understanding of the nature of science as the potential benefits to be explored.

CHAPTER 3: METHODS AND PROCEDURES

Overview

This chapter begins with a description of the participants in this study, including participant demographics and recruitment procedures. The treatment, procedures, and treatment administration are then described. The instruments used are then presented and the instrument administration is discussed. Finally, data analyses and methodological assumptions are described.

Sample

Participants in this study were undergraduate students enrolled in BIO 200: Introduction to Biology Research at a large, private research university in the Northeastern United States. All of the students enrolled in the course completed all of the associated surveys.

A consent form (Appendix B) was sent via email to the students in the course. Students had the option of opting out of research participation with no penalty by emailing a non-instructor staff member in the Department of Biology without the knowledge of the instructor/researcher. Once final grades were submitted, the staff member informed the researcher that no students opted out of having their data used for research purposes.

Among the participants in this study, 91% (10 out of 11) were declared biology or biochemistry majors. One participant's major was undeclared. 64% (seven) of the students were sophomores, 18% (two) were juniors, and 18% were seniors. 82% (nine) of the students were United States citizens while 18% (two) were international students. All students indicated at the beginning of the semester that they were interested in joining a research laboratory as an undergraduate. Nearly two thirds (64%, or seven) of the participants indicated that they had not previously read or discussed primary research literature in another college science course, while 36% (four) indicated that they had.

Treatment

Participants in this study were undergraduate students enrolled in BIO 200: Introduction to Biological Research. This one-semester, two-credit course involved students reading, discussing, and writing about papers from research laboratories in the Biology Department at the institution offering the course each week. Prior to reviewing primary literature produced by the laboratories, students read and responded to two climate change consensus papers – one that quantified the level of consensus on human causation via meta-analysis (Cook et al., 2013) and one that reviewed several different consensus estimates (Cook et al., 2016). For these papers, as well as other papers covered in the course, students were required to complete a Figure Facts template (Round & Campbell, 2013) prompting them to take a data-centric approach to reading the papers and post a response to the papers in an online discussion. The students were also required to reply to two other students' responses. For their final papers, students were required to review five papers from a faculty research laboratory of their choice.

Under an IRB-approved protocol, participants were required to participate in activities that were a standard part of the course in which they were enrolled as a regular aspect of the course itself. However, any student wishing to opt out of having their standard coursework used for research purposes was able to do so without penalty or instructor knowledge by contacting a non-instructor administrative staff member from the Department of Biology (see "Sample" above).

Exposure to the climate change consensus papers in the course (including the students' reading of the papers and completing the associated Figure Facts outside of class and the small and large group class discussions) was the independent variable. The independent variable was hypothesized to potentially influence the dependent variables (perceived consensus, belief in climate change, belief in human-caused climate change, worry about climate change, support for public action, support for climate policy, and confidence in ability to communicate the degree of scientific consensus on human-caused climate change).

Procedures and Treatment Administration

At the beginning of the semester, students were directed to faculty web pages. Students were to peruse faculty profiles and research outputs with an eye toward their area of research interest. Students then ranked their top four choices for faculty research programs they wished to explore in more detail and communicated their choices to the instructor. The instructor used this information to determine which faculty members' research programs would be featured throughout the semester and invited the Principal Investigators (PIs) of those labs to class to present and discuss their work. In remarkably unified support of this effort and undergraduate research engagement, all PIs who were contacted expressed interest in visiting the class, and the schedule was made such that each PI could, and did, participate.

Prior to each class (beginning the third week), participants were to read one or two scholarly papers, complete the associated Figure Facts assignment, and participate in online discussions. For the first 35-40 minutes of each class period, the participants participated in small group discussions consisting of three or four participants. The participants were encouraged to review their Figure Facts, ask each other questions about the paper, and gather a set of questions to be discussed with the PI. For the next half hour, participants participated in a large-group discussion with the instructor of the course to review some of the major figures in the paper and review/refine the question sets that the students generated for the PI. The students then had a five-minute break while the PI arrived and set up for their presentation or discussion. The structure of the remaining portion of class was chosen by the PI. Most elected to give a formal presentation and then answer questions, while others joined the class for an informal roundtable discussion of their work.

The first class period was used to review the course syllabus and for initial data collection. Data collected included participants' estimates of the degree of scientific consensus, key beliefs about climate change, and support for public action according to the most recent iteration of the GBM (van der Linden et al., 2015). Additional data included their support for climate policy according to Ding and colleagues (2011) and their confidence in their ability to communicate the degree of scientific consensus. The second class was used for in-class discussions of the climate change consensus papers, for instruction on accessing primary literature, for final data collection for all quantitative climate change-related prompts, and to assess students' understanding of the NOS using the Myths of Science Questionnaire (MOSQ; Buraphan, 2009). Participants responded to qualitative climate change prompts online between the second and third classes. The final class period was also used primarily for post-course assessment and data collection related to understanding of the Nature of Science. All students participated in all data collection activities.

Instrumentation

The researcher used the same instrument used by van der Linden and colleagues (2015), who were the first and only researchers to provide evidence for the causal mechanisms of the GBM. The instrument includes prompts concerning perceived consensus about human-induced climate change, belief in climate change, worry about climate change, belief in human-caused climate change, and support for public action to reduce climate change. This instrument was also adapted to elicit qualitative responses to provide additional data. An extra item was created in a similar format to the GBM items to assess confidence in communicating the degree of scientific consensus on human-caused climate change. The researcher also used a six-part survey item from Ding and colleagues (2011) designed to assess support for different climate policies.

The Myths of Science Questionnaire (MOSQ; Buaraphan, 2009) was used to evaluate students' understanding of the NOS at the beginning and end of the semester. The MOSQ consists of 14 item statements, each with three multiple choice options: agree, disagree, or uncertain. According to Buaraphan (2009), understanding of the NOS can be categorized into four major groups: scientific knowledge, scientific method, scientists' work, and scientific enterprise. The MOSQ further breaks down those groups into each of the following subgroups:

Scientific knowledge: hypotheses, theories and laws addresses the misconception that the relationship between these constructs is hierarchical in nature. The misconception leads individuals to believe that theories are general propositions, more secure than hypotheses but less so than laws.

Scientific knowledge: tentativeness of science addresses the misconception that science is static in nature, with the goal being to collect data without questioning former findings.

Scientific knowledge: cumulative knowledge concerns whether advancement in science depends upon accumulation of supporting evidence and increasing observation or changes in theory.

Scientific knowledge: scientific model addresses the misconception that models are exact copies of reality rather than human representations of some natural phenomenon.

Scientific method: universal, step-wise method concerns the uninformed notion that all science follows one universal, step-wise method.

Scientific method: scientific experiment addresses the notion that experiments are necessary to advance scientific knowledge. Such a notion ignores the contributions of observation.

Scientists' work: theory-laden observation and subjectivity addresses the misconception that scientists are objective and that their observations and interpretations are not influenced by theories.

Scientists' work: creativity and imagination in science concerns whether scientists use creativity and their imagination in building scientific knowledge, such as when they design new experiments and build new technologies.

Scientific enterprise: social and cultural influences on science concerns whether scientists and scientific practice are influenced by the larger society or the culture of science itself, including professional organizations, funding sources, peer review, and conferences.

Scientific enterprise: interaction between science and technology addresses the misconception that technology is simply applied science without considering that while science provides the knowledge base for technology, technology also influences scientific advancement.

The validity of the MOSQ was established by tasking five science educators with evaluating the items for relevance to the dimensions of the NOS and suitability to the respondents (Buaraphan, 2009). It was revised according to the experts' feedback and piloted with 21 preservice and 11 inservice teachers in order to determine whether they understood the items. The items were further revised to address any perceived ambiguities.

For the qualitative portion of this study regarding the students' experiences with the course, questions were developed to probe for whether students experienced some of the documented benefits associated with the use of primary literature described in the literature. These concerned the students' content knowledge of the science that went into the papers, understanding of the NOS, data analysis skills, and ability to read and understand primary literature. Because the specific biological content covered in the course was determined by the students themselves and was unknown at the beginning of the course, and because no previously utilized instrument exists that measures content knowledge of the biology research performed in specific labs at the study institution, students self-reported any gains in content knowledge that they perceived—and described what about the course they believed to be most helpful in regards to these gains—at the end of the semester.

Procedures in Instrument Administration

All data were collected through the course management system (Blackboard), which is generally familiar to students as it has been adopted university-wide at this institution. Participants were asked to bring a web-enabled device (tablet or computer) to class for days when data collection activities would take place. The instructor brought two additional devices to class on these dates in case any participants were unable to obtain one; however, this accommodation was not utilized as all participants brought their own devices.

Participants completed both a pre-test and post-test to assess their beliefs associated with the GBM (van der Linden et al., 2015). They completed the pre-test using their personal computers at the end of the first class. Participants read the climate change consensus papers, completed the associated Figure Facts, posted a response, and replied to two other participants' responses in an online discussion throughout the next week. At the end of the second class, participants completed the GBM post-test and the MOSQ pre-test using their personal computers. Questions from van der Linden et al. (2015) were also adapted to elicit qualitative responses about the impact of the consensus messaging on the participants' GBM beliefs, and an online discussion was used for participants to answer these questions and reply to one another's answers throughout the following week.

Online class discussions during the last two weeks of the semester were analyzed. During the second-to-last week, participants were asked to reflect on the potential benefits they may have experienced from the course. The instructor used these responses to develop additional questions for the participants to answer during the final week of the semester. These probed topics such as how the course helped participants analyze data, how personal interactions with scientists helped the participants understand biological concepts, and their understanding of how scientific investigations are funded.

Data Analyses

Statistical analyses for the quantitative data related to the GBM were performed using SPSS 24. Wilcoxon signed-rank tests were used to determine whether there was a shift in consensus estimates, key beliefs, support for public action, support for climate policy, and confidence in communicating the degree of scientific consensus on human-induced climate change. The Wilcoxon signed-rank test is the nonparametric equivalent of the paired samples T-Test and is designed for use with small sample sizes when the data do not fit a normal distribution. Qualitative data related to the GBM were analyzed by scoring whether participants indicated that any of their beliefs were influenced by the consensus messaging. The Myths of Science Questionnaire was analyzed using the methodology provided by Buaraphan (2009). The percentages of participants agreeing, disagreeing, or uncertain about each myth were calculated for the pre- and post-test and participants were characterized as "informed" (p. 566), "uninformed" (p. 566), or uncertain about each myth based on their responses (Buaraphan, 2009).

Qualitative data were first coded based on whether participants did or did not believe they experienced particular benefits that have been associated with primary literature previously (e.g., improved biology content knowledge, enhanced data analysis skills, etc.). The percentages of participants answering "yes" and "no" were quantified. The participants' explanations for their responses were then coded based on what about the course they indicated was most helpful.

Methodological Assumptions

Wilcoxon signed-rank tests assume the following: the data consist of n values of the difference $D_i = X_i - Y_i$, where each pair of measurements (X_i, Y_i) is taken on the same subject or on subjects that have been paired with respect to one or more variables and each sample of pairs is random; the differences represent observations on a continuous random variable; the distribution of the population of differences is symmetric about their median; and the differences are independent.

For the qualitative portion of the study, it was assumed that participants accurately reflected their conceptions of how the consensus messaging impacted their beliefs related to the GBM and of how the course impacted their skills and beliefs related to science, allowing conclusions to be drawn from data. Although it is reasonable to assume that the beliefs expressed by participants bear similarities to those expressed by other undergraduate biology majors, the data may not be generalizable to other populations.

CHAPTER 4: CONSENSUS MESSAGING—ANALYSES AND DISCUSSION OF FINDINGS

Overview

This chapter presents the results of statistical and qualitative analysis used to answer each research question outlined in Chapter 1. The influence of the consensus messaging on perceived consensus is discussed using both qualitative and quantitative data. Next, the influence of the consensus messaging on the key beliefs (belief in climate change, belief in human-caused climate change, and worry about climate change) is explored, again using both quantitative and qualitative data. Next, the influence of the consensus messaging on support for public action is discussed using both quantitative and qualitative data, and the impacts on support for climate policy and confidence in communicating the consensus are described quantitatively. According to IRB protocol, participants are referred to using pseudonyms to protect their anonymity.

Analyses of Findings

Influence of Consensus Messaging on Components of the GBM

Does consensus messaging using scholarly literature impact perceived scientific consensus of human-induced climate change, as predicted by the GBM?

Prior to the consensus messaging, participants' perceived scientific consensus of human-induced climate change was assessed using language from van der Linden and colleagues (2015) as described in Chapter 3. The mean student estimate of the consensus was 76.82%. Values ranged from 10% (minimum) to 100% (maximum). The standard deviation was 27.68%.

After the consensus messaging via reading and discussing scholarly literature, participants' perceived scientific consensus of human-induced climate change was again assessed using the same methodology as the pre-test. The mean student estimate of the consensus for the post-test was 96.45%. Values ranged from 90% to 99%. The median and mode were both 97%, accurately reflecting the actual degree of consensus (Cook et al., 2013). The standard deviation was 2.34%.

A Wilcoxon signed-rank test was conducted to test whether there was a significant difference in consensus estimates between the pre-test and post-test. Results indicated that consensus estimates were significantly greater in the post-test than pre-test ($Z = -2.580$, $p = .010$; Figure 3).

When participants were asked via online discussion prompts whether the course had influenced their understanding of the degree of scientific consensus on human-caused climate change, 82% (9) answered in the affirmative, while 18% (2) said the course had no influence on their understanding of the consensus. Tony referred to Cook and colleagues (2013) in his answer, stating "Yes it has. Meta-analysis of the scientific community's consensus swayed my opinion." Elizabeth described where she believed the true debate should lie given the scientific community's consensus, answering:

> Yes this course has influence[d] my understanding of the scientific consensus on climate change. Before, I thought that it was more of a debate on whether climate change exists but scientists are over 90% in agreement on the human influence in climate change. This should no longer be a debate, rather a discussion on what can be done.

Does consensus messaging using scholarly literature impact key beliefs about climate change, including belief in climate change, worry about climate change, and belief in human causation, as predicted by the GBM?

Belief in Climate Change

Prior to the consensus messaging, participants' three key beliefs (belief in climate change, belief in human causation, and worry about climate change) were assessed using language from van der Linden and colleagues (2015) as described in Chapter 3. In the pre-test, ten out of the eleven participants indicated they fully believed in climate change with a score of 100. One participant reported a score of 70. The mean score was 97.27 and the standard deviation was 9.05. In the post-test, all eleven participants indicated they fully believed in climate change. Results of a Wilcoxon signed-rank test indicated there was no significant difference in belief in climate change between the pre-test and post-test ($Z = -1.000$. $p = .317$).

Participants were divided when asked whether the course influenced their belief that climate change is or is not happening. Of the participants who took a position, 50% (four) answered yes and 50% answered no. Responses supported the notion that the participants were already very accepting that climate change was happening before the consensus messaging. Tony answered, "No, I already knew it is happening." Hannah responded, "This course did not necessarily [influence] my belief that climate change is happening because I already knew that it was happening." Matthew stated, "I have a pretty strong footing in my stance that climate change is happening and the unpacking of research so far that we've done in this class has…helped to solidify my opinions on the matter."

Belief in Human-Caused Climate Change

In the pre-test, the mean score for belief in human causation was 77.64 out of 100, with a minimum of 50, maximum of 100., and standard deviation of 20.06. In the post-test, the mean score was 89.08, with a minimum of 50, maximum of 100, and standard deviation of 14.28.

Results of a Wilcoxon signed-rank test did not indicate that there was a significant difference in belief in human-caused climate change between the pre-test and post-test (Z = -1.584, p = .113).

Twice as many participants (six, or 67%) indicated that they perceived that the course had influenced their belief in human-caused climate change as those who indicated it did not (three, or 33%). Elizabeth professed, "Yes, I did not realize how much humans were affecting the climate we have now." Andrea inferred that she was already accepting of human-caused climate change but that the consensus messaging still influenced her belief when she stated, "Seeing the data and the increasing trends of scientific consensus only strengthened my beliefs on human-caused climate change." Nancy agreed that she was already very accepting before the consensus messaging, responding, "I already knew that humans were the number 1 cause of climate change, so reading these papers was no surprise to me."

Worry about Climate Change

In the pre-test, the mean score for worry about climate change was 66.82 out of 100, with a minimum of 0, maximum of 100, and standard deviation of 28.83. In the post-test, the mean score was 83.91, with a minimum of 50, maximum of 100, and standard deviation of 16.22. A Wilcoxon signed-rank test found a significant difference in worry about climate change between the pre-test and post-test (Z = -2.320, p = .020; Figure 4).

Of the participants who indicated whether the course had influenced their level of worry about climate change, 70% (7) of them answered in the affirmative, while 30% (3) stated that the course did not influence their level concern. Of the seven participants who answered that the course increased their level of concern, six of them indicated that their increased level of concern was due to the discussion in the papers of the general public's understanding of the issue. Alice stated, "[It's] made me more worried about climate change because a large percentage [of] the public does not understand that humans are the cause of climate change [and] that experts highly agree on this." Nancy answered, "I am slightly more concerned than I was previously, simply because seeing such a disagreement in the public is frightening to think about." Leanna responded, "Yes! This course made me realize the large gap between general public and the scientific community and has increased my worrying." Andrea agreed, stating, "Yes, this course definitely influenced how worried I am about climate change, given that most of the public is unaware of the high scientific consensus regarding human-caused climate change."

Does consensus messaging using scholarly literature impact support for action, as predicted by the GBM?

Prior to the consensus messaging, participants' support for public action to reduce climate change was assessed using language from van der Linden and colleagues (2015) as described in Chapter 3. In the pre-test, eight out of the eleven participants indicated they were fully supportive of public action to reduce climate change with a score of 100. The mean score was 92.27 and the minimum was 50. The standard deviation was 16.03. In the post-test, eight participants out of the eleven participants again indicated they were fully supportive of public action. The mean score was 95.91, the minimum was 80, and the standard deviation was 8.01. Results of a Wilcoxon signed-rank test did not indicate that there was a significant difference in support for public action between the pre-test and post-test ($Z = -.405$, $p = .686$).

Participants were slightly more likely to state that the course increased their support for public action to reduce climate change than to state that the course did not influence their level of support. Four (57%) of the participants who stated whether the course influenced their level of support indicated that their support increased, while three (43%) stated that there was no influence. Tony acknowledged, “Yes, I should advocate more for it.” Andrea stated, “Yes, I believe that people need to start being educated more on climate change - that there are facts that it is happening and it should not be left up to personal opinion…we need to be doing more to reduce climate change.” Michelle agreed, stating, “yes, people should be doing more to reduce climate change because we are the first cause.”

Additional Findings

Confidence in Communicating the Degree of Scientific Consensus on Human-Induced Climate Change

Confidence in communicating the degree of scientific consensus on human-induced climate change to others was assessed as described in Chapter 3. In the pre-test, the mean score was 60.91 out of 100, with a minimum of 20, maximum of 100, and standard deviation of 24.98. In the post-test, the mean score was 97.45, with a minimum of 90, maximum of 100, and standard deviation of 3.30. A Wilcoxon signed-rank test found that there was a significant difference in levels of confidence in communicating the consensus between the pre-test and post-test ($Z = -2.805$, $p = .005$; Figure 5).

Qualitative data suggest an overwhelming consensus on improved confidence in their ability to communicate the degree of scientific agreement on human-caused climate change as a result of the consensus messaging. Of the participants who took a direct position on whether the course influenced their confidence, 100% (ten) of them indicated that the course improved their confidence in their ability to communicate the degree of consensus. Hannah stated:

> This course has increased my confidence on communicating the degree of scientific consensus on human-caused climate change because now I know numbers and percents that relate to what scientists believe as the cause of global warming. Before this course, I would not have been able to accurately and confidently defend the consensus, but after reading Cook's articles I can say that I can easily defend the consensus.

Leanna agreed, responding, "Yes, I am more comfortable now as I am able to use knowledge of research and statistics regarding consensus among the scientific community to communicate to my peers." Andrea used her answer to counter an assertion made by the now-President of the United States via Twitter (personal communication, January 29, 2014):

> Yes, this course has made me more confident in my ability to communicate the degree of scientific consensus on human-caused climate change to others. Now that I know that the consensus is so high, I have facts and proof to back up my arguments about climate change. Other people think it is all just a hoax, but with this information I would be able to prove to them that it is, indeed, not a hoax.

Support for Climate Policy

Support for climate policy was analyzed using six different items from Ding and colleagues (2011) as described in Chapter 3. In the pre-test, the mean level of support for climate policy was 3.49 out of 4. The minimum was 3.00 and the maximum was 4.00, with a standard deviation of 0.31. In the post-test, the mean level of support for climate policy was 3.45 out of 4. The minimum was 2.83 and the maximum was 4.00, with a standard deviation of 0.36. Results of a Wilcoxon signed-rank test did not indicate that there was a significant difference in support for climate policy between the pre-test and post-test (Z = -.480, p = .631).

Discussion

The purpose of this study was to investigate whether scholarly literature that quantifies and reviews the scientific consensus on human-induced climate change could be effective at improving perceived consensus, key beliefs about climate change, and support for public action as predicted by the Gateway Belief Model (van der Linden et al., 2015). Language was borrowed from van der Linden and colleagues to quantify perceived consensus, the key beliefs, and support for public action before and after the consensus messaging in order to assess whether there were statistically significant gains in any of these constructs. Participants were also asked qualitative versions of these questions to assess any perceived gains.

Results indicate that scholarly literature can be used to effectively improve participants' perceived consensus among climate scientists on human-induced climate change, a so-called "gateway belief" (van der Linden et al., 2015). The mean estimate of the consensus before the consensus messaging was 76.82%. The mean estimate post-consensus messaging was 96.45%, very close to the actual 97% consensus as determined by the most rigorous and extensive meta-analysis to date (Cook et al., 2013). The median and mode in the post-consensus messaging group were both 97%. Results of the Wilcoxon signed-rank test demonstrate that the consensus estimates were statistically significantly different in the pre- and post-test (Z = -2.580, p = .010). Furthermore, 82% of the participants indicated in qualitative responses that the course influenced their understanding of the scientific consensus on human-induced climate change.

These results are consistent with prior findings suggesting that consensus messaging can improve conceptions of the consensus. van der Linden and colleagues tested three different modes of consensus messaging and found that all three were effective at improving consensus estimates (2014). These three modes were descriptive text, a pie chart, and metaphorical representations, and while all three were effective at significantly improving consensus estimates, the pie chart and metaphors produced superior recall. Results from this study are the first to indicate that scholarly literature, too, can be effective at improving estimates of the consensus on human-induced climate change—although how scholarly literature compares to other approaches to consensus messaging remains unknown.

The results of analyses on the impact of consensus messaging on belief in climate change were mixed. Participants were already generally very accepting that climate change is happening. The mean score on the pre-test was 97.27 out of 100 and the mean score on the post-test was 100. The Wilcoxon signed-rank test did not reveal a statistically significant difference between these scores ($Z = -1.000$, $p = .317$). Half of the participants indicated in their qualitative responses that the course influenced their belief in climate change, while the other half indicated that there was no influence. Participant responses support the notion that they were already very accepting that climate change is happening.

van der Linden and colleagues (2015) found that consensus messaging was effective at improving belief in climate change. It is important to note, however, that participants in that study were members of the general public with a modal age bracket of 35-44. A study by Ding and colleagues (2011), while not experimental in nature, found that perceived consensus significantly predicted belief in climate change (there described as belief certainty). The mean age of participants (also members of the general public) in this study was 47.9 years old. The present study was delimited by the participants being college students, who are generally younger and more accepting of climate change in general (Pew Research Center, 2015, "Americans, Politics and Science Issues"). Even though participants were as accepting of climate change as possible after the consensus messaging, there was no significant difference between scores on the pre- and post-test because ten out of eleven participants were fully accepting before the consensus messaging. Whether scholarly literature can be effective at improving acceptance that climate change is happening for members of the general public remains unknown.

Results of analyses on the impact of consensus messaging on belief in human-caused climate change (which can also be defined as acceptance of the whole scientific consensus) were also mixed. The mean scores for belief in human causation were 77.64 out of 100 on the pre-test and 89.08 on the post-test. The Wilcoxon signed-rank test did not reveal a significant difference between the scores on the pre-test and post-test ($Z = -1.584$, $p = .113$). It is important to note, however, that the study was delimited by the number of participants (11). Had there been a greater number of participants, the difference between scores on the pre-test and post-test for this metric may have reached statistical significance. Furthermore, twice as many participants indicated in qualitative responses that the course influenced their belief in human-induced climate change as those who indicated there was no influence. Some responses, again, indicated that participants were already accepting of human-induced climate change before the consensus messaging.

McCright and colleagues (2013) found that perceived consensus was a significant predictor of belief in human-induced climate change. The mean age of participants in this sample was 46.83. Ding and colleagues (2011) similarly found that perceived consensus was a significant predictor of acceptance of human-induced climate change. Lewandowsky, Gignac, and Vaughan (2012) found that consensus messaging using a text passage and graphic had a causal influence on acceptance of anthropogenic global warming for participants with a mean age of 30, and van der Linden and colleagues also presented experimental evidence of the direct impact of consensus messaging on acceptance of human-induced climate change (2015). Statistical analyses from the present study found that consensus messaging did not statistically significantly impact acceptance of human-induced climate change. However, the p-value is low enough such that with a greater number of participants (and more statistical power), a future study may reveal a significant difference—particularly if the age distribution of the participants more closely matches that of the participants in these other studies. The fact that twice as many participants indicated that there was a shift in their acceptance as those who indicated there was no shift also suggests that there is some influence of consensus messaging using scholarly literature on acceptance of human-induced climate change.

This study found a statistically significant influence of the consensus messaging on worry about climate change ($Z = -2.320$, $p = .020$). The mean scores for worry were 66.82 out of 100 on the pre-test and 83.91 on the post-test. Of the participants who provided a qualitative response for this metric, 70% answered in the affirmative. 86% of those who answered in the affirmative mentioned their new understanding of the disconnect between climate scientists' conceptions of human-induced climate change and those of the general public in their responses.

Perceived consensus of human-induced climate change has been found previously to be associated with worry about climate change. In the study by McCright and colleagues (2013), perceived consensus was found to be a statistically significant predictor of worry about climate change. In van der Linden and colleagues' study, the consensus messaging was found to have a significant causal influence on worry about climate change. The present study's findings regarding worry about climate change are consistent with those of McCright et al. (2013) and van der Linden et al. (2015), although this is the first study to find a significant influence of consensus messaging using scholarly literature on worry about climate change. Scholarly literature, by its nature, provides much more information than any other previously studied mode of consensus messaging. 86% of the participants who indicated there was a change in their worry about climate change discussed the disconnect between climate scientists' conceptions of climate change and those of the general public—information that is unique to scholarly literature as a mode of consensus messaging. Because the scholarly literature that was used provides this additional information and a majority of participants indicated the shift in their worry was because of this additional information, the use of scholarly literature (particularly the Cook et al. 2013 and Cook et al. 2016 papers) may be a particularly effective method of increasing worry about climate change.

Participants were very supportive of action to reduce climate change before the consensus messaging, and although there was an increase in support after the consensus messaging, this difference was not statistically significant ($Z = -.405$. $p = .686$). The mean scores were 92.27 out of 100 on the pre-test and 95.91 on the post-test. Participants were divided in their qualitative responses; of those who took a position, 57% (four) stated the course influenced their support, while 43% (three) stated that it did not.

Ding and colleagues found that perceived consensus on climate change was a significant predictor of injunctive beliefs (2011). van der Linden and colleagues presented experimental evidence for the influence of perceived consensus on climate change on support for public action (2015). That the present study did not find a statistically significant influence of the impact of consensus messaging on support for public action was likely due to a ceiling effect since participants were already supportive pre-consensus messaging. Future research may find that scholarly literature that quantifies and reviews the level of consensus on human-induced climate change does indeed influence support for action if the sample of participants are older on average or if there are a greater number of participants.

The present study also did not find a significant effect of the consensus messaging on support for climate policy ($Z = -.480$, $p = .631$). The mean score on the pre-test was 3.49 out of 4 and the mean score on the post-test was 3.45. McCright and colleagues found that perceived scientific agreement on climate change was a significant predictor of support for government action (2013). Ding and colleagues also found that perceived scientific agreement was a significant predictor of support for climate policy, using the same instrument as the one used in this study (2011). Aklin and Urpelainen used consensus messaging to communicate varying degrees of scientific consensus about a hypothetical problem related to water pollution, and found that support for environmental regulation was significantly greater for the “98% consensus” group as compared to the “80% consensus” or “60% consensus” groups. The present study did not find an influence of the consensus messaging on support for climate policy, though this also may be due to age restrictions in the study sample.

This study also investigated whether the consensus messaging affected participants’ confidence in their ability to communicate the degree of scientific consensus on human-induced climate change because an increase in such confidence may result in the participants performing their own consensus messaging with peers and families—thereby potentially improving others’ climate change acceptance and support for action in the process. The Wilcoxon signed-rank test revealed a statistically significant influence of the consensus messaging on confidence in ability to communicate the consensus ($Z = -2.805$, $p = .005$). Furthermore, 100% of the participants stated in qualitative responses that they experienced an improvement in confidence in their ability to communicate the degree of consensus. This study is the first to show that consensus messaging influences confidence in ability to communicate the scientific consensus on human-induced climate change. The results suggest that the participants are now better equipped to communicate the degree of scientific consensus on human-induced climate change to others, increasing the likelihood that they will effectively perform their own consensus messaging (and potentially influence others' beliefs about climate change and support for threat-reduction actions).

CHAPTER 5: STUDENT EXPERIENCES WITH THE COURSE—ANALYSES AND DISCUSSION OF FINDIGS

Overview

This chapter presents the results of analyses designed to assess the benefits that participants experienced by participating in the course. These include increased understanding of the NOS (using the MOSQ and qualitative measures), increased biology content knowledge, enhanced data analysis skills, and improved ability to read and understand primary literature.

Influence of the Course on Understanding of the Nature of Science

Scientific Knowledge

Items 1-4 and 8-9 contained statements about scientific knowledge. For both the pre-test and post-test, nine participants (81.8%) disagreed with the myth that hypotheses are only developed to become theories, one participant (9.1%) was uncertain, and one participant agreed. For the pre-test, two participants (18.2%) disagreed with the myth that scientific theories are less secure than laws, three participants (27.3%) were uncertain, and six participants (54.5%) agreed. The post-test showed an increase in the number of participants disagreeing with this myth and a reduction in the number of participants uncertain or agreeing: five participants (45.5%) disagreed, one participant (9.1%) was uncertain, and five participants agreed (Figure 6).

At the beginning of the semester, ten participants (90.1%) held the uninformed position that scientific theories can be developed to become laws. One participant (9.1%) disagreed and zero participants were uncertain. At the end of the semester, there were reductions in the number of participants disagreeing and agreeing with this myth and an increase in the number of participants uncertain about it, though there was a greater reduction in the number of participants agreeing with the myth than the number disagreeing. No participants disagreed, three (27.3%) were uncertain, and eight (72.7%) agreed.

For the pre-test, eight participants (72.7%) disagreed with the myth that scientific knowledge cannot be changed. One participant (9.1%) was uncertain and two (18.2%) agreed. For the post-test, there was a slight increase in the number of participants disagreeing and a slight decrease in the number uncertain with no change in the number agreeing: nine participants (81.8%) disagreed, zero were uncertain, and two (18.2%) agreed.

At the beginning of the semester, ten participants (90.9%) held the uninformed position that scientific knowledge is cumulative. One participant (9.1%) disagreed with this myth. At the end of the semester, the participant who disagreed with the myth at the beginning of the semester joined the rest of the participants in agreeing, reaching 100% agreement.

For the pre-test, two participants (18.2%) disagreed with the myth that a scientific model expresses a copy of reality. Four participants (36.4%) were uncertain and five participants (45.5%) agreed with the myth. For the post-test, there were increases in the number of participants disagreeing and agreeing with the myth and a decrease in the number of participants who were uncertain, though there was a larger increase in the number of participants disagreeing with the myth than the number agreeing. Four participants (36.4%) disagreed with the myth, one participant (9.1%) was uncertain, and six participants (54.5%) agreed (Figure 6).

Scientific Method

Items 5-7 concerned myths related to the scientific method. At the beginning of the semester, four participants (36.4%) held the uninformed position that the scientific method is a fixed step-by-step process. One participant (9.1%) was uncertain and six participants (54.5%)

disagreed. At the end of the semester, there was a slight decrease in the number of participants disagreeing with this myth and a slight increase in the number agreeing. Five participants (45.5%) disagreed, one participant (9.1%) was uncertain, and five participants (45.5%) agreed.

For the pre-test, seven participants (64.6%) disagreed with the myth that science and the scientific method can answer all questions, two participants (18.2%) were uncertain, and two agreed. For the post-test, there was a slight decrease in the number of participants disagreeing with this myth and a slight increase in the number agreeing. Six participants (54.5%) disagreed, two participants (18.2%) were uncertain, and three participants (27.3%) agreed.

At the beginning of the semester, two participants (18.2%) held the uninformed position that scientific knowledge only comes from experiments. Zero participants were uncertain and nine participants (81.8%) were informed. At the end of the semester, there was a reduction in the number of participants who disagreed with the myth and an increase in the number of participants who agreed. Seven participants (63.6%) disagreed, zero participants were uncertain, and four participants (36.4%) agreed.

Scientists' Work

Items 10 and 11 contained statements related to scientists' work. For the pre-test, eight participants (72.7%) disagreed with the myth that scientists do not use creativity and imagination in developing scientific knowledge. One participant (9.1%) was uncertain and two participants (18.2%) agreed with the myth. For the post-test, there was an increase in the number of participants disagreeing with the myth and decreases in the numbers of participants uncertain and agreeing. Ten participants (90.9%) disagreed with the myth, zero were uncertain, and one participant (9.1%) agreed (Figure 6).

At the beginning of the semester, zero participants held the uninformed position that scientists are open-minded without any biases. Nine participants (81.8%) disagreed with this myth and two participants (18.2%) were uncertain. At the end of the semester, there was a reduction in the number of participants who disagreed with this myth and increases in the numbers of participants who were uncertain and agreed. Four participants (36.4%) disagreed, four participants were uncertain, and three participants agreed.

Scientific Enterprise

Items 12-14 concerned scientific enterprise. For the pre-test, ten participants (90.9%) disagreed with the myth that science and technology are identical. One participant (9.1%) was uncertain and zero agreed. For the post-test, there was a reduction in the number of participants disagreeing with this myth and increases in the numbers of participants uncertain and agreeing. Seven participants (63.6%) disagreed, three participants (27.3%) were uncertain, and one participant (9.1%) agreed.

At the beginning of the semester, one participant (9.1%) held the uninformed position that scientific enterprise is an individual enterprise. Six participants (54.5%) disagreed and four participants (36.4%) were uncertain. At the end of the semester, there was no change in the number of participants disagreeing with the myth, but a slight increase in the number agreeing and a slight decrease in the number uncertain. Three participants (27.3%) were uncertain and two participants (18.2%) agreed.

For the pre-test, nine participants (81.2%) disagreed with the myth that society, politics, and culture do not affect the development of scientific knowledge. Two participants (18.2%) were uncertain and zero participants agreed. For the post-test, there was no change in the number of participants disagreeing with the myth, but a reduction in the number of participants uncertain and an increase in the number agreeing. Zero participants were uncertain and two participants (18.2%) agreed.

Self-Reported Influence of the Course on Understanding of the Nature of Science

Participants were asked through an online discussion prompt whether the course influenced their understanding of how science works, and if so, how. Of the eight participants who responded to this prompt, 100% answered in the affirmative. Two participants discussed how having the scientists come to class was helpful to their understanding of how science works. In fact, both of these participants particularly noted the benefit of the scientists discussing their backgrounds toward their understanding of how science works. Leanna explained:

> This course greatly influenced my understanding of how science works. To be able to hear personal stories of the professors and how they got to the specific experiment we read about helped greatly. It provided an understanding of the procedures, intellectually as well as physically that are necessary to be successful in researching.

Matthew also commented on how hearing about the scientists' backgrounds helped him learn how science works:

> Yes, like previously mentioned understanding the researchers [*sic*] backgrounds and how their livelihoods came about gave me a new understanding of the field of scientific research. Understanding that the path to scientific research is not always straight and narrow muddles the thought that scientific research is a very sterile

> and boring form of work. I've come to realize that science works based off of fascination and individual desires accumulating into this melting pot of a field.

Three participants discussed how the course influenced their understanding of the scientific “method,” though each of these three responses were very different. Elizabeth explained how the course taught her that there is no such thing as the single scientific method, as well as that she learned how real science is different than her previous classroom science experiences:

> I learned from this class that a lot of research results from unpredictable mistakes or random experiments that weren't supposed to show what they did. The research world is very different from the basic chem and bio labs we have where you're given a protocol to follow and you already know the result.

Andrea said that she learned about the scientific method, but her response reflects her belief in the myth of the singular scientific method:

> Yes, I believe that this course has influences my understanding of how science works because with each paper we read and with each professor that came into class, it became apparent that they all started their research the same way - starting with a question, formulation some hypothesis, designing and executing the experiment, and then analyzing the results.

Tony stated that the course influenced his understanding of the scientific method and how projects are funded: “I think I already had a strong foundation of the scientific method before the course, but after this class, now [I] understand where and how it is performed. Especially in terms of funding.” Nancy also mentioned her new understanding of how scientific projects are funded in an answer to a different prompt during the same week: “This course definitely influenced my understanding of research and also the politics that go into getting a project funded and how it needs to be applicable to humans or else it is largely ignored."

Because two participants discussed funding in their answers during the first week of discussion prompts, participants were then asked whether they agree with other participants who reported that the course influenced their understanding of how scientific investigations are funded, and if so, what they learned. Of the ten participants who responded to this prompt, 80% (eight) responded in the affirmative and 20% (two) gave responses that were scored as neutral. Of the eight participants who agreed, 37.5% (three) of them stated that they learned what is necessary for a project to be funded. Hannah commented, "This course helped me understand the process of getting an investigation funded based on the idea that most research that is funded has to some how [*sic*] relate to humans or benefit the study of humans." Leanna reported that the visiting scientists helped her learn about funding:

> This course helped me to understand some of the processes of gaining funding and the importance of it. I learned through the PIs conversations some of the big funding institutions and some of the processes of receiving the funding. A lot of researches talked about what is needed to be funded and I thought that was a beneficial conversation.

Nancy, who the previous week indicated that she learned that projects need to hold the potential to benefit human society in some way, repeated, "I had some idea about how science was funded but this course definitely made it more clear to me and helped me realize key aspects that are necessary to get money."

Other Self-Reported Benefits of Participating in the Course

Biology Content Knowledge

Participants were asked via online discussion prompts whether they experienced some of the benefits that have been previously documented to result from the use of primary research literature in undergraduate science courses. During the first round of prompts, participants were asked whether the course influenced their understanding of the biology research being performed on campus. 100 percent of the participants answered in the affirmative and two major themes emerged: the importance of reading the primary literature and the importance of their interactions with the scientists.

Of the eight participants who answered this first question, 50% (4) mentioned that reading the journal articles was helpful to their understanding of the biology research being performed on campus. Alice stated, "This course highly influenced my understanding of the biology research we explored because it allowed me to thoroughly read and interpret all the different papers by working through the different figures with the class and asking questions when needed."

37.5% (3) of the participants discussed the benefits of interacting with scientists in their answer to this first prompt. All of these participants tied the benefit of interacting with the scientists to the benefit of reading or discussing the papers. Andrea stated, "By reading different papers each week and listening to each professor, I was able to grasp the basic topics that each lab focuses on." Hanna responded,

> On my own, I don't believe I would have been able to understand some of the research, but being able to discuss with other students the papers we read and ask questions and even listening to the scientists themselves explain their research

> furthered and helped my understanding of the actual experimentation that was being [done] within the labs.

Alice agreed, stating, “Having the professor come in and explain their lab really helped to understand the paper we read from them.”

The following week, participants were asked whether they agreed with other participants who indicated that having the scientists come to class to discuss their research was beneficial to their understanding of biological concepts. 100% of the ten participants who responded to this question answered in the affirmative. 60% (six) of the participants indicated in their responses that the scientists helped to make the information in the papers more comprehensible and/or broke down the papers into simpler terms. Leanna said,

> There was probably at least one thing in every paper that I had questions about or simply did not have any previous knowledge on. The PIs were able to explain processes and the main concepts behind all of their research.

Alice stated, “It definitely helped when the scientists discussed their research because they broke down the…biology of their lab. It is more difficult to understand fully the biological concepts through just reading the paper.” Andrea responded, “Having the scientist come in to discuss their research made it easier to understand the biological concepts in their papers.” Tony explained, “Having the investigators come in was useful because they could explain exactly what they meant, what they were looking for, and how they did it in their own words.”

Two participants also noted that it was helpful when the scientists gave presentations about their research. Nancy stated, “Understanding the biological concepts definitely became easier when the scientists had powerpoints [*sic*] that broke down the specific concepts that were necessary to know for the paper.” Hannah wrote,

> I agree with this statement because a lot of the scientists, when they came, discussed the biological concepts that surrounded their research. Some scientists even gave almost a small background teaching lesson on the topics that were in their paper or that they focus their research on. These explanations really helped understand biological concepts because they went through and explained what the biological concepts were and why they are important to study.

Data Analysis Skills

Participants were asked through an online discussion prompt whether they believed the course influenced their data analysis skills, and if so, how. Of the participants who provided a response, 100% (10) answered in the affirmative. 60% (six) indicated that the level of exposure and practice was helpful. Matthew commented, “Weekly practice was not easy by any means, but it was 100% beneficial.” Andrea stated, “It became easier and easier to analyze the figures each week and actually understand what is happening in them.”

40% (4) of the participants noted that the course helped them target the most important data in the journal articles. Hannah noted that the weekly practice helped her find what to look for, stating:

> I feel that this course helped my ability to analyze data because when analyzing the figures each week, I noticed it started getting easier because after a while I kind of picked up on what to actually look for in the figures, and figuring out what the data showed started to become easier. It's almost just that I needed practice with analyzing data.

Tony also commented that the weekly practice helped him target the most important data: “From being exposed to so many scientific techniques, I've learned why certain data is especially valuable.”

50% (5) of the participants who responded to this question mentioned that the course helped them think through the figures in the papers. For this reason, the following week participants were asked whether they agreed with participants who indicated that the course helped them to be able to analyze data by helping them think through the figures used to present data, and if so, what about the course was helpful. Of the ten participants who responded to this prompt, 100% agreed. 80% (8) of them indicated that the Figure Facts were helpful. Andrea stated, “The more I read scientific papers and completed figure facts, the easier it became to analyze the data in these papers.” Leanna said, “The figure facts helped me due to the fact that it made me spend more time thinking about the data then if I were to simply read the paper on my own.” Hannah responded,

> I think the Figure Facts definitely helped understanding the data because I had to sit down and look at the data and try to figure out where exactly it came from and what exactly the data is supposed to show.

Michelle commented, “The figure facts help me to focus on the experimental data presented in each figure and identify specific conclusions that may be drawn from the results.”

60% (6) of the participants also indicated that the group discussions were helpful for strengthening data analysis skills. Nathaniel said, “I think a combination of the figure facts and then discussing them in a large group during class helped with this the most.” Tony wrote, “Talking about the figures with other classmates was especially helpful.” Andrea stated:

> I also think the group discussions helped with this because we were all able to focus on the important details of the paper. By doing so, it made it easier to find the important details when I read the papers on my own.

Elizabeth noted:

> I think the figure facts probably helped the most but there were some figures I did not understand until we came together for group discussion or the scientists came in and talked about what they meant.

40% (four) of the participants indicated that interacting with the scientists each week strengthened their ability to analyze data. Hannah related these interactions to the Figure Facts, stating:

> The conversations with the scientists also helped a lot because any questions that came about when trying to complete the Figure Facts were easily cleared up when the scientists spoke about what exactly they were trying to find with their research

Leanna discussed how these interactions were useful:

> Conversations with the PIs also helped as they were able to explain the way some of the data was compiled. If there were portions of the data we were not able to interpret on our own, they were able to explain that to us as well.

Nancy stated that both the group discussions and the interactions with the scientists were the most helpful: "I think what helped the most was discussion within the group and asking the scientists questions." Elizabeth noted that Figure Facts, group discussions, and conversing with scientists were all helpful, stating, "I think the figure facts probably helped the most but there were some figures I did not understand until we came together for group discussion or the scientists came in and talked about what they meant."

Ability to Read and Understand Primary Literature

Participants were asked through an online discussion prompt whether they believe the course influenced their ability to read and understand primary literature, and if so, how. Of the ten participants who responded to this question, 100% answered in the affirmative. 40% (four) of the participants mentioned that the group discussions were helpful in developing their ability to read and understand the literature. Tony stated, "I feel better equipped to read primary literature more so from discussing it with my peers in a guided discussion." Andrea discussed, "After reading and discussing the first couple of papers as a class, it made it easier to know what to look for when reading the other papers and even papers in the future." Nancy explained how group discussions were beneficial in this class and may later be beneficial in a lab setting:

> It made me realize that working in groups can be extremely beneficial in that we all may pay attention to different things and something that goes right over my head may have been perfectly clear to someone else and it helps me to look forward to working with a group in a lab setting to get multiple perspectives on a topic that at first seems merely black and white.

20% (two) of the participants discussed how learning how to analyze the figures in journal articles helped their ability to read and understand primary literature. Leanna commented:

> Being able to understand these figures, also furthered my understanding of the readings. I was able to use the figures to understand what was being discussed and why. Being able to read the literature and understand it may still be difficult but I was able to gain knowledge on how to read the papers in a way where I was able

> to understand the majority of literature and be able to access further information I did not understand.

Hannah explained what she learned to do when she has difficulty understanding the literature:

> This course definitely helped me in my ability to read and understand primary literature because I gained knowledge on how to attack papers where I may not know a whole lot on the topic, or the topic may be confusing. I learned that sometimes, in those difficult cases, you may have to read the paper a few times, or look at the figures first to understand what exactly is being studied.

Discussion

The present study investigated whether the participants experienced some of the documented benefits of using primary literature in undergraduate science courses. One such documented benefit is improved content knowledge. Because the course offered was an intro to biological research course, the content was the biology research discussed in the papers. 100% of the participants responded in the affirmative when asked whether they thought the course helped improve their understanding of the biology research performed on campus. 50% of these participants mentioned that reading the journal articles helped improve their understanding of the biology research performed on campus and 37.5% discussed the benefit of interacting with scientists in their answers. The following week, participants were asked whether they agreed with other participants who stated that interacting with scientists helped their understanding of biological concepts. 100% answered in the affirmative and 60% discussed how having the scientists break down their research into more comprehensible terms was helpful.

These results are consistent with those from other studies. When primary literature was used for five experiential research projects in a sophomore level cell biology course, students reported that the research projects helped them achieve content-specific course goals and strengthened cell biology learning (DebBurman, 2002). When primary literature was used to help students explore the functional interactions of glycolysis, protein transport, and cell cycle regulation, students indicated that the assignment helped them understand these processes individually and collectively (Yeong, 2015). Alumni of the HHURP indicated that the primary literature-based program improved their knowledge of scientific content outside their majors or main areas of research (Kozeracki et al., 2006). Furthermore, content knowledge was reported to improve when primary literature constituted POGIL materials in a biochemistry sequence (Murray, 2014). The present findings of improved content knowledge resulting from reading primary literature replicate the above-mentioned findings and extend them to include improve content knowledge in a course about biology research that utilizes Figure Facts (Round & Campbell, 2013).

Additionally, content knowledge was reported to improve from the use of the C.R.E.A.T.E. method—which, similarly to this course, involves discussions with authors of scientific papers. In the pilot study of the C.R.E.A.T.E. method in an upper-level biology elective, students demonstrated increases in their conceptual understanding of course content (Hoskins et al., 2007). When the method was used in a special topics ecology and evolution course, 83% of the students indicated that the course improved their biology content knowledge (Carter & Wiles, 2017). The present results are consistent with those presented by Hoskins et al. (2007) and Carter and Wiles (2017) in that 100% of the participants in this study agreed with the notion that interacting with scientists helped their understanding of biological concepts. It is important to note that the format of this course was different than C.R.E.A.T.E. in a number of ways, including that the discussions with scientists were in person (not over the phone) and that Figure Facts were used to help students break down the concepts and figures in the papers. Nonetheless, the present findings suggest that using primary literature, coupled with providing opportunities for students to interact with the authors of those papers, can be effective at improving biology content knowledge. They also suggest that the reason that interactions with scientific authors are effective at improving content knowledge is that they help to break down complex scientific terms and ideas into those more accessible to novice science learners.

Another documented benefit of using primary literature in undergraduate science courses is improved data analysis skills. 100% of the participants answered in the affirmative when asked whether the course influenced their data analysis skills. 60% of these participants indicated that the level of exposure and practice was helpful and 50% mentioned that the course helped them learn how to think through the figures presented in papers. The following week, participants were asked whether they agreed with others who indicated that the course helped them think through figures, and if so, what about the course was most helpful. 100% of the participants agreed. 80% said that the Figure Facts were helpful, 60% indicated that the group discussions were helpful, and 40% stated that the interactions with scientists were helpful.

Prior research has also found that primary literature can help enhance students' data analysis skills. The only prior study that utilized Figure Facts to date was that by Round and Campbell, who found statistically significant improvement at analyzing data throughout the semester as measured by scores on a data analysis test (2013). That study used Figure Facts in an advanced cellular neuroscience course, and the present study extends these findings to include improved data analysis skills resulting from the use of Figure Facts in an intro to biological research course. There is also evidence that the C.R.E.A.T.E. method can improve data analysis skills. Students enrolled in an upper level biology elective that used C.R.E.A.T.E. exhibited statistically significant improvement in their self-assessed abilities to interpret data (Hoskins et al., 2011). Additionally, students in both an introduction to scientific thinking course for first-year university students and upper level biology elective experienced statistically significant gains in their self-assessed abilities to interpret data (Gottesman & Hoskins, 2013). The results of the present study suggest that, similarly to C.R.E.A.T.E., Figure Facts can be used in conjunction with in-person interactions with scientists and group discussions to improve data analysis skills.

Ability to read and understand primary literature has also been shown to improve after using primary literature in undergraduate science courses. 100% of the participants in the present study indicated that the course improved their ability to read and understand primary literature. 40% mentioned that the group discussions were helpful in strengthening this ability and 20% stated that learning how to analyze figures was helpful.

In a previous study, Sato and colleagues found that students who were exposed to a primary literature module in a biochemistry lab, molecular biology lab, or microbiology lab scored significantly higher on a quiz about a new journal article the next semester than students who had not taken one of these labs with a primary literature module (2014). Hoskins and colleagues found statistically significant improvement in self-assessed ability to decode primary literature in an upper level biology elective (2011), and Gottesman and Hoskins also found significant improvement in self-assessed ability to decode primary literature in both an upper level biology elective and first-year university science course (2013). Carter and Wiles reported that students stated that a primary literature-based course improved their abilities to read and interpret primary research articles (2017). These findings are consistent with the present findings of unanimous perceived improvement in ability to understand primary literature. In the other study that used Figure Facts, Round and Campbell reported that 90% of students either agreed or strongly agreed that Figure Facts helped them structure their reading of primary literature and found large decreases in the percentage of students either agreeing or strongly agreeing that reading primary literature was stressful for them and would make them frustrated. The present study extends these findings by suggesting that the ability to understand primary literature can be improved by providing opportunities for group discussions of journal articles in an intro to biological research course.

Participants exhibited improvement in understanding of some aspects of the NOS and decreased understanding of others. Gains were made in understanding of the relative security of theories/laws, scientific models, and whether scientists use creativity and imagination. Three more participants disagreed with the myth that scientific theories are less secure than laws at the end of the semester than the beginning of the semester. Two more participants disagreed with the myths that a scientific model expresses a copy of reality and that scientists do not use creativity and imagination in developing scientific knowledge at the end of the semester as compared to the beginning of the semester. Decreased understanding was documented in whether scientific knowledge only comes from experiments, scientists are open-minded without any biases, and science and technology were identical. Two fewer participants disagreed with the myth that scientific knowledge only comes from experiments, five fewer disagreed with the myth that scientists are open-ended without any biases, and three fewer disagreed with the myth that science and technology are identical at the end of the semester as compared to the beginning of the semester.

The present results of increased understanding of the creativity of science after exposure to primary literature and interactions with scientists are consistent with previous research. Carter and Wiles found an increase in informed responses about the creativity of science after a primary literature-based ecology and evolution course (2017). Hoskins and colleagues (2011) and Gottesman and Hoskins (2013) found that students exhibited improvement in their understanding of the creativity of scientists and science after using the C.R.E.A.T.E. method in an upper-level biology elective and introduction to scientific thinking course, respectively. Each of these studies was consistent with the present study in that the courses featured frequent exposure to primary literature and interactions with scientists. The present study extends the findings of previous studies to include increased understanding of the creativity of science after exposure to primary literature and interactions with scientists in an introduction to biological research course, which required students to complete Figure Facts (Round & Campbell, 2013) as they read each paper.

The participants' improvement in understanding the relative security of theories and laws are somewhat inconsistent with the results presented by Carter and Wiles (2017), who found that understanding of theories and laws was the only NOS aspect to not improve after participating in a primary literature-based course. This discrepancy may be due to the course in the present study featuring weekly in-person interactions with scientists, who discussed theories that they were researching.

CHAPTER 6: SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

Background

There is a great deal of evidence that suggests that perceived consensus among climate scientists about human-induced climate change is a "gateway" belief to acceptance and support for action. There is also evidence that by providing students with an opportunity to explore how content knowledge is generated through reading scholarly literature, educators can help improve students' understanding of the content in these papers. For this reason, it is possible that scholarly literature that quantifies and reviews the scientific consensus on human-induced climate change may be a particularly effective way to communicate the degree of scientific consensus on human-induced climate change.

The present study sought to understand whether the use of scholarly literature as a mode of consensus messaging impacts participants' beliefs related to climate change, as predicted by the Gateway Belief Model. The study also explored how consensus messaging using scholarly literature influences support for climate policy and confidence in communicating the degree of consensus on human-induced climate change. Finally, the study examined student experiences with and perceived benefits of using primary literature in an introduction to biological research course.

Purpose

The purpose of this study was to explore whether scholarly literature can be an effective mode of consensus messaging. This was assessed by determining whether there were changes in participants' beliefs about climate change, including perceived consensus, belief in climate change, belief in human-caused climate change, worry about climate change, support for public action, support for climate policy, and confidence in communicating the consensus as a result of the consensus messaging. Based on the unique efficacy of scholarly literature at improving content knowledge and the evidence of perceived consensus as a gateway belief, the working premise of this study was that scholarly literature that quantifies and reviews the scientific consensus on human-induced climate change should impact perceived consensus, key beliefs about climate change, and support for threat-reduction actions and policy.

Research Questions

1. Does consensus messaging using scholarly literature impact perceived consensus of human-induced climate change, as predicted by the GBM?
2. Does consensus messaging using scholarly literature impact key beliefs about climate change, including belief in climate change, worry about climate change, and belief in human causation, as predicted by the GBM?
3. Does consensus messaging using scholarly literature impact support for action, as predicted by the GBM?

Methods and Procedures

Data were collected in the context of an introduction to biological research course at a private, four-year, research institution in the Northeastern United States. Treatment, instrumentation, and data analysis procedures are summarized in this section.

Treatment

The consensus messaging treatment involved reading and responding to two journal articles—one that quantified the scientific consensus on human-induced climate change (Cook et al., 2013) and one that reviewed it by providing several different consensus estimates (Cook et al., 2016). Participants responded to the papers in an online discussion post and completed one Figure Facts template (Round & Campbell, 2013) for each paper.

Instrumentation

The instrument used to measure the impacts of the consensus messaging is the same one used by van der Linden and colleagues (2015), who were the first and only researchers to provide evidence for the causal mechanisms of the GBM. These included questions about perceived consensus, belief in climate change, belief in human-caused climate change, worry about climate change, and support for public action. Each of these questions was also adapted to elicit qualitative responses. The researcher added two extra items: one to assess support for climate policy (Ding et al., 2011) and one to assess confidence in communicating the degree of scientific consensus on human-induced climate change.

The researcher used the MOSQ to assess conceptions of the Nature of Science by asking participants whether they agree with, disagree with, or are uncertain about 14 different myths of science. Total percentages of participants who agreed with, disagreed with, or were uncertain about each myth were quantified at the beginning and end of the course.

Finally, online discussion forums were used to assess whether participants experienced any benefits from participating in the course. These included questions about potential gains in biology content knowledge, data analysis skills, ability to read and understand primary literature, and understanding of the NOS.

Data Analyses

Statistical analyses of the quantitative data associated with climate change beliefs were performed using SPSS. The MOSQ data was analyzed by comparing the total percentages of participants agreeing with, disagreeing with, or uncertain about each myth at the beginning and end of the course. Qualitative data were analyzed using coding.

Selected Findings

The mean estimate of the scientific consensus on human-induced climate change prior to the consensus messaging was 76.82%. Values ranged from 10% to 100%. The mean estimate of the consensus after the consensus messaging was 96.45%, with a minimum of 90% and maximum of 99%. The median and mode on the post-test were both 97%, accurately reflecting the true degree of consensus (Cook et al., 2013). Results of a Wilcoxon signed-rank indicated a statistically significant improvement in perceived consensus, a so-called "gateway belief" (Z = -2.580, p = .010; van der Linden et al., 2015). Furthermore, 82% of participants indicated in qualitative responses that the consensus messaging influenced their understanding of the degree of scientific consensus on human-induced climate change.

Prior to the consensus messaging, the mean score for belief in climate change was 97.27. After the consensus messaging, the mean score was the maximum score of 100. A Wilcoxon signed-rank test did not reveal a statistically significant difference between these scores (Z - -1.000, p = .317). 50% of participants stated that the consensus messaging influenced their belief in climate change and 50% stated that there was no influence. Participant responses supported the notion that they were already very accepting of climate change before the consensus messaging.

The mean score for belief in human causation was 77.64 before the consensus messaging. The mean score after the consensus messaging was 89.08. A Wilcoxon signed rank test did not reveal a statistically significant difference between these scores at an alpha value of .05 ($Z = -1.584$, $p = .113$). However, twice as many participants (67%) indicated that the course influenced their belief in human-caused climate change as those who indicated that there was no influence (33%). Participant responses, again, indicated that they were already accepting of human-caused climate change before the consensus messaging.

The mean score for worry about climate change prior to the consensus messaging was 66.82. The mean score post-consensus messaging was 83.91. A Wilcoxon signed-rank test revealed a significant difference between scores the pre- and post-test ($Z = -2.320$, $p = .020$). 70% of the participants indicated in qualitative responses that the course influenced their level of concern about climate change and 30% answered that there was no influence. Of the seven participants who answered in the affirmative, six of them stated that their increased level of concern was because of their new understanding of the disconnect between climate scientists' conceptions of climate change and those of the general public.

Prior to the consensus messaging, the mean score for support for action to reduce climate change was 92.27. After the consensus messaging, the mean score was 95.91. A Wilcoxon signed rank test did not reveal a statistically significant difference between scores on the pre-test and post-test ($Z = -.405$, $p = .686$). A majority of participants who took a position on whether the course influenced their support (57%) indicated in qualitative responses that the course influenced their support.

The mean score for confidence in communicating the degree of scientific consensus on human-induced climate change on the pre-test was 60.91. The mean score on the post-test was 97.45. A Wilcoxon signed-rank test revealed statistically significant improvement in confidence in communicating the degree of consensus after the consensus messaging ($Z = -2.805$, $p = .005$). Of the participants who took a position on whether the course influenced their confidence in communicating the degree of consensus, 100% of them answered in the affirmative.

The present study also investigated whether participants enrolled in the BIO 200 course experienced some of the other documented benefits of reading primary literature in undergraduate science courses. The first potential benefit explored was improved understanding of the nature of science. This was assessed using both the MOSQ and a qualitative prompt. Results indicate that participant understanding improved for some aspects of the NOS and decreased for others. Participants' understanding of the relative security of theories and laws, scientific models, and the creativity/imagination used by scientists improved. Participants' understanding of whether experiments are required for science, scientists are people with biases, and science and technology are identical decreased. When asked whether the course influenced their understanding of how science works, 100% answered in the affirmative.

The second of these benefits explored was improved biology content knowledge. 100% of the participants indicated that the course helped improve their understanding of the biology research being performed on campus. 50% of the participants indicated that reading the journal articles was helpful to their understanding of the biology research and 37.5% stated that interacting with the scientists was helpful. When asked whether interacting with the scientists helped their understanding of biological concepts, 100% answered in the affirmative. 60% of these participants explained that the scientists were helpful in breaking down complex scientific ideas into more comprehensible ones.

Another potential benefit explored was enhanced data analysis skills. 100% of the participants stated that the course influenced their data analysis abilities. 60% indicated that the level of exposure and practice was helpful and 40% stated that the course helped them target the most important information in the papers. 50% discussed how the course helped them think through the figures used to present data in papers, and when participants were asked whether they agreed with others who stated this, 100% agreed. 80% of those who agreed that the course helped them think through the figures noted the importance of the Figure Facts and 60% stated that the group discussions were helpful.

A final potential benefit explored was improvement in the ability to read and understand primary research literature. 100% of the participants answered in the affirmative when asked whether they experienced this benefit. 40% discussed the importance of the group discussions in growing this ability and 20% discussed how learning to analyze figures was important.

Conclusions

The present study found that the consensus messaging had statistically significant impacts on participants' perceived consensus, worry about climate change, and confidence in communicating the degree of scientific consensus on human-induced climate change. It also found some evidence of the influence of the consensus messaging on acceptance of human-induced climate change. It is reasonable to conclude that consensus messaging using scholarly literature is effective at improving certain components of the GBM, as well as confidence in communicating the consensus, within our population.

Recommendations

Due to the level of science education received by biology majors, some may believe that these individuals are already "on board" with the scientific consensus on human-induced climate change and that therefore there is no need to communicate the degree of scientific consensus to them. However, the present results show that biology majors did not understand the degree of scientific consensus and were not confident in communicating it before the consensus messaging. After the consensus messaging, perceived consensus and confidence in communicating the degree of consensus significantly increased. Many of these participants may end up as teachers or may communicate science in some way to non-scientists in the future, and the present results suggest that they are better equipped to communicate the consensus on human-induced climate change. These results suggest that scholarly literature that quantifies and reviews the scientific consensus on human-induced climate change can be used in undergraduate science courses to improve students' perceived consensus and confidence in communicating the consensus. Consensus messaging using scholarly literature can be important for preparing students to make responsible decisions regarding their carbon footprints, but may be particularly useful to maximize learning in courses that explore the biological effects of climate change.

These data indicate that the expanded use of primary literature, in combination with opportunities to interact with scientists, is warranted in undergraduate science courses. The present results suggest that the participants' experiences in the course influenced their biology content knowledge, data analysis skills, ability to read and understand primary literature, and understanding of some aspects of the NOS. Further research should attempt to quantify these, and other, benefits of using primary literature and interacting with scientists in undergraduate science courses. Options for future research include the effects of using primary literature and interacting with scientists on students' scientific literacy, information literacy, and critical thinking skills, as each of these has been associated with the use of primary literature but have not been explored in the context of an introduction to biological research course that featured possibilities for interactions with scientists.

Appendix A

Recruitment Email

Greetings, undergraduates!

My name is Jeremy Sloane, and I am the instructor for BIO 200: Intro to Biological Research this fall! A few spots have opened up in this two-credit course and I wanted to give anyone interested the opportunity to enroll. The course will be held on Fridays from 3:00 - 5:00 in 435 LSC, beginning next week. The purpose of the course is to introduce you to and explore the many biology labs here at SU. The course will be particularly useful for those looking for research opportunities, but is appropriate for anyone interested in the biology research performed here at SU.

If you are interested, feel free to either enroll to reserve yourself a spot or send me an email if you have any questions at jdsloane@syr.edu. I look forward to seeing many of you on the 8th!

Regards,
Jeremy Sloane

Appendix B

Informed Consent Form

My name is Jeremy Sloane, and I am a graduate student at Syracuse University.

I am interested in learning more about how using primary literature (i.e., articles from scientific journals) may impact student understandings about scientific concepts and about science itself. You will be asked to participate in my research by completing some short written assignments, surveys, and class discussions as part of the course you are taking on Research Literature. The surveys will be completed during class time as formative assessments, but performance on them will not impact your grade in any way. There will be written assignments and class discussions about how you felt the use of primary literature impacted your understanding of science, but you may opt out of having this information being used for research purposes without penalty.

As a science education researcher, I often investigate aspects of the courses I teach as part of my research. I am inviting you to participate in a research study, but the activities involved in the research are normal aspects of the course itself. Use of the data collected through your assignments and in-class discussions for research reporting purposes is entirely voluntary. This means you can choose to not have your responses included in research reports, and you may withdraw from having your responses included among research data without penalty by informing Bev Werner in Life Sciences Complex 142 (or by email at bfwerner@syr.edu) at any time that you would like to opt out of having your data included in the research study. Also, use of your data for research purposes requires that you are age 18 or older. If you are under the age of 18, please inform Mrs. Werner so that your information will be withheld. Your instructor/researchers will not know which, if any, students opt out of the research until after grades have been reported.

Any research published as a result of this study will not contain any information that identifies you as a participant. If you have any questions, concerns or complaints about the research please contact me by email at jdsloane@syr.edu. Please note that whenever one works with email or the internet; there is always the risk of compromising privacy, confidentiality, and/or anonymity. Your confidentiality will be maintained to the degree permitted by the technology being used. It is important for you to understand that no guarantees can be made regarding the interception of data sent via the internet by third parties.

Jeremy D. Sloane
Signature of researcher

Date 9/7/2017

_____Jeremy D. Sloane____________________
Printed name of researcher

Appendix C

BIO 200 Course Syllabus

COURSE SYLLABUS (Fall 2017)
BIO 200: Intro to Biological Research
INSTRUCTOR: Jeremy Sloane : jdsloane@syr.edu
Office hours: By appointment
Class meeting time: TBD
Class Location: TBD

COURSE DESCRIPTION

In this course, students will learn about research performed in biology labs at Syracuse University. Students will explore the primary literature produced by these labs and learn how these studies are synthesized into our understandings of various phenomena. Students will also work throughout the semester to synthesize research from a specific lab into a scientific story. Class materials will consist of primary literature, and assessment will be based on participation in class and online discussions, written responses to scientific articles, "Figure Facts," and final research papers.

READINGS

Readings will be provided in pdf form on the course Blackboard site at least four days before they are covered in class.

TENTATIVE SCHEDULE

At the beginning of the course, students will decide which biology labs they are the most interested in. The instructor will then use this information to determine which labs will be covered throughout the semester. Each week, one or more papers from a lab will be discussed in class, and students may have the opportunity to interact with members of this lab.

GRADING

Your final grade will be based upon the following assignments:

Participation in class discussions:	25%
Online responses to primary literature:	25%
Figure Facts:	15%
Research Paper:	35%

ASSIGNMENTS

Participation in class is mandatory (and requires attendance). Expect to hear from the instructor if your participation is not adequate. In this case, no news is good news.
Online responses to primary literature: Of the readings for each week, the instructor will designate one for a short written response which will also inform online and class discussion. More information about the responses and online discussion will be given in class.

Figure Facts: Students will submit one Figure Facts (FF) template to Blackboard for each paper one hour prior to the start of class time. Students will also bring a copy of their template(s) to class. These templates will be used to guide small- and large-group discussions.
Research Paper: Students will complete a 4-5 page research paper, summarizing the knowledge accrued from at least five studies by an individual lab. The lab chosen can be one at Syracuse University or a different institution, but cannot include papers that were covered in class. Students must obtain permission from the instructor to research a specific lab at the beginning of the semester.

GRADING

The total percentages for the semester will be converted into letter grades as follows:

94%-100%=	A	73%-77% =	C+
90%-93% =	A-	68%-72% =	C
86%-89% =	B+	63%-67% =	C-
82%-85% =	B	55%-62% =	D
78%-81% =	B-	Below 55%=	F

Syracuse University Policies: Students should review the University's policies regarding Disability-Related Accommodation; Diversity and Disability; the Religious Observances Notification and Policy; the Academic Integrity Policy; and Orange Success, which can be accessed via the Office of the Provost's website at: http://provost.syr.edu/

Academic Integrity: Syracuse University's Academic Integrity Policy reflects the high value that we, as a university community, place on honesty in academic work. The policy defines our expectations for academic honesty and holds students accountable for the integrity of the work they submit. Students should understand that it is their responsibility to learn about course-specific expectations, as well as about university-wide academic integrity expectations. The policy governs appropriate citation and use of sources, the integrity of work submitted in exams and assignments, and the veracity of signatures on attendance sheets and other verification of participation in class activities. The policy also prohibits students from submitting the same work in more than one class without receiving written authorization in advance from both instructors. Under the policy, students found in violation are subject to grade sanctions determined by the course instructor and non-grade sanctions determined by the School or College where the course is offered as described in the Violation and Sanction Classification Rubric. SU students are required to read an online summary of the University's academic integrity expectations and provide an electronic signature agreeing to abide by them twice a year during pre-term check-in on MySlice.

Turnitin: This class will use the plagiarism detection and prevention system Turnitin for the final research paper. You will use Blackboard to submit the final research paper papers for this class directly to Turnitin, which compares submitted documents against documents on the Internet and against student papers submitted to Turnitin at Syracuse University and at other colleges and universities. I will take your knowledge of the subject matter of this course and your writing level and style into account in interpreting the originality report. Keep in mind that all papers you submit for this class will become part of the Turnitin.com reference database solely for the purpose of detecting plagiarism of such papers.

THE COURSE INSTRUCTOR RESERVES THE RIGHT TO CHANGE/ MODIFY THE COURSE SYLLABUS IF NEEDED.

Appendix D

Quantitative Climate Change Prompts

1. To the best of your knowledge, what percentage of climate scientists have concluded that human-caused climate change is happening? Answer between 0% and 100%.
2. How strongly do you believe that climate change is or is not happening? Answer between 0 and 100, where 0 = I strongly believe that climate change is not happening, 50 = I am unsure whether climate change is happening, and 100 = I strongly believe climate change is happening.
3. Assuming climate change IS happening: How much of it do you believe is caused by human activities, natural changes in the environment, or some combination of both? Answer between 0 and 100, where 0 = I believe that climate change is caused entirely by natural changes in the environment, 50 = I believe that climate change is caused equally by natural changes and human activities, and 100 = I believe that climate change is caused entirely by human activities.
4. On a scale from 0-100, how worried are you about climate change? Answer between 0 and 100, where 0 = I am not at all worried, 50 = neutral, and 100 = I am very worried.
5. Do you think people should be doing more or less to reduce climate change? Answer between 0 and 100, where 0 = much less, 50 = same amount, and 100 = much more.
6. How much do you support or oppose each of the following policies? Please answer 1, 2, 3, or 4, where 1 = strongly oppose, 2 = oppose, 3 = support, and 4 = strongly support.
    a. Regulating carbon dioxide as a pollutant.
    b. Signing an international treaty that requires the United States to cut its carbon dioxide emissions by 90% in 2050.
    c. Adding a surcharge to electrical bills to establish a fund to help make buildings more energy efficient and to teach US citizens how to reduce energy use.
    d. Requiring electric utilities to produce at least 20% of their electricity from renewable sources.
    e. Providing tax rebates for people who purchase energy-efficient vehicles or solar panels.
    f. Increasing taxes on gasoline (by 25 cents per gallon) and returning the revenues to taxpayers by reducing the federal income tax.
7. How confident are you in your ability to communicate the degree of scientific consensus on human-caused climate change to others? Answer between 0 and 100, where 0 = I am not at all confident, 50 = I am somewhat confident, and 100 = I am completely confident.

Appendix E

Qualitative Climate Change Prompts

1. Has this course influenced your understanding of the degree of scientific consensus on human-caused climate change? If so, please explain how.
2. Has this course influenced your belief that climate change is or is not happening? If so, please explain how.
3. Assuming climate change IS happening, has this course influenced your understanding of the cause(s) of this change? If so, please explain how.
4. Has this course influenced how worried you are about climate change? If so, please explain how.
5. Has this course influenced whether you believe people should be doing more or less to reduce climate change? If so, please explain how.
6. Has this course influenced your confident you are in your ability to communicate the degree of scientific consensus on human-caused climate change to others? If so, please explain how.

Appendix F

Other Qualitative Prompts

1. How did your discussions with scientists help you understand the science that went into the papers you read? What was most useful in these discussions? What/how did you learn from interacting with the scientists?
2. Do you believe this course influenced your understanding of the biology research performed in the various labs explored in the course? If so, how?
3. Do you believe this course influenced your ability to analyze data? If so, how?
4. Do you believe this course influenced your ability to read and understand primary literature? If so, how?
5. Do you believe this course influenced your understanding of how science works? If so, how?
6. Some students have reported that this course has helped them to be able to analyze data by helping them think through the figures used to present data in scientific papers. Do you agree with this statement? If so, what about the course helped you with this? (Be specific. Did the Figure Facts assignments help? Presentations by or conversations with the scientists? What helped the most?)
7. Some students have reported that having scientists come to class and discuss how they became researchers was helpful to them. Do you agree with this statement? If so, what about these discussions was helpful, and how specifically did they help you?
8. Some students have reported that having scientists discuss their research was beneficial to their understanding of biology concepts. Do you agree with this statement? If so, how were these discussions beneficial?
9. Some students have reported that interacting with scientists “humanized” science for them. Do you agree with this statement? If so, how specifically did these interactions humanize science?
10. Some students have reported that working in small groups in class helped them understand the paper(s) for the week. Do you agree with this statement? If so, what about working in small groups was helpful?
11. Some students have reported that this course helped their understanding of how scientific investigations are funded. Do you agree with this statement? If so, what did you learn about such funding?

Table 1.

Qualitative Climate Change Measures: Do You Believe the Course Influenced…

	Number Yes (Percent Yes)	Number No (Percent No)
Perceived Consensus	9 (82%)	2 (18%)
Belief in Climate Change	4 (50%)	4 (50%)
Belief in Human Causation	6 (67%)	3 (33%)
Worry about Climate Change	7 (70%)	3 (30%)
Support for Action	4 (57%)	3 (43%)
Confidence in Communicating Consensus	10 (100%)	0 (0%)

Figure 1.

The Gateway Belief Model

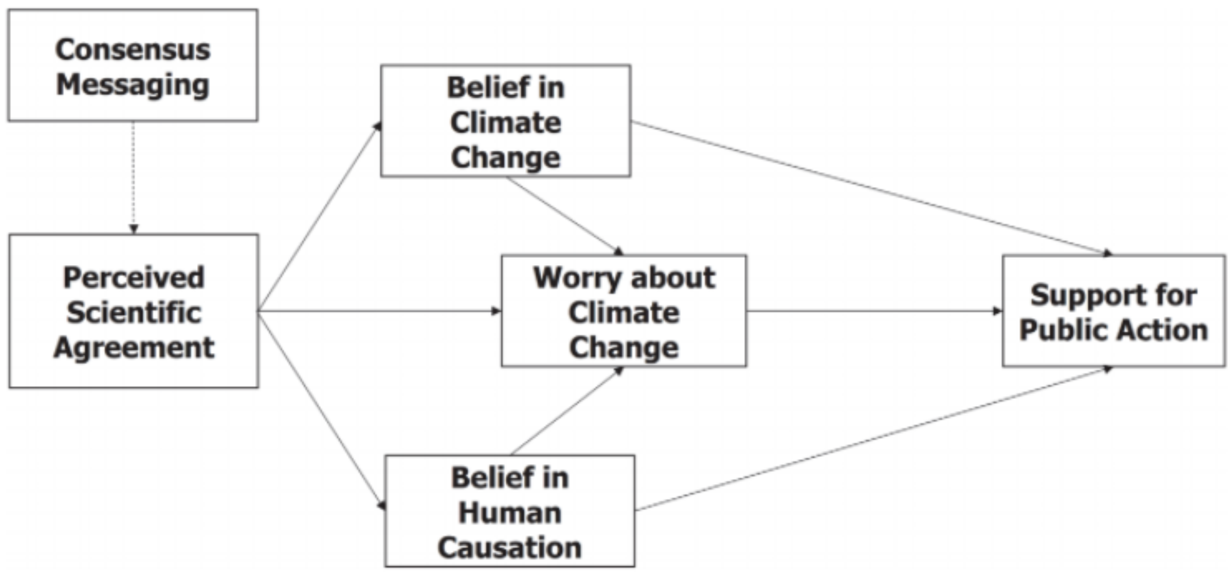

Figure 1. Visual depiction of the Gateway Belief Model, as defined by van der Linden and colleagues (2015).

Figure 2.

Evidence for the Gateway Belief Model

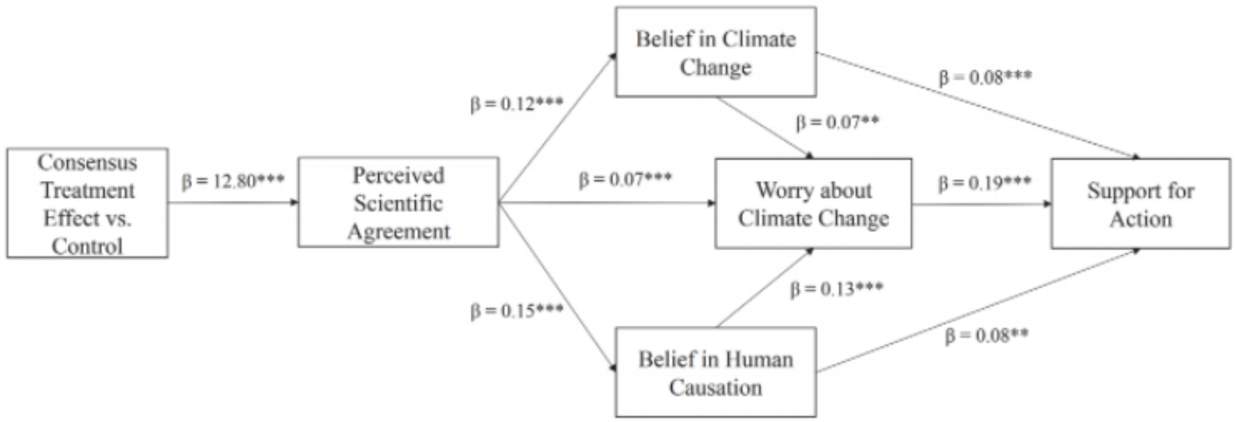

Figure 2. Visual depiction of the evidence for the Gateway Belief Model, from van der Linden et al. (2015).

Figure 3.

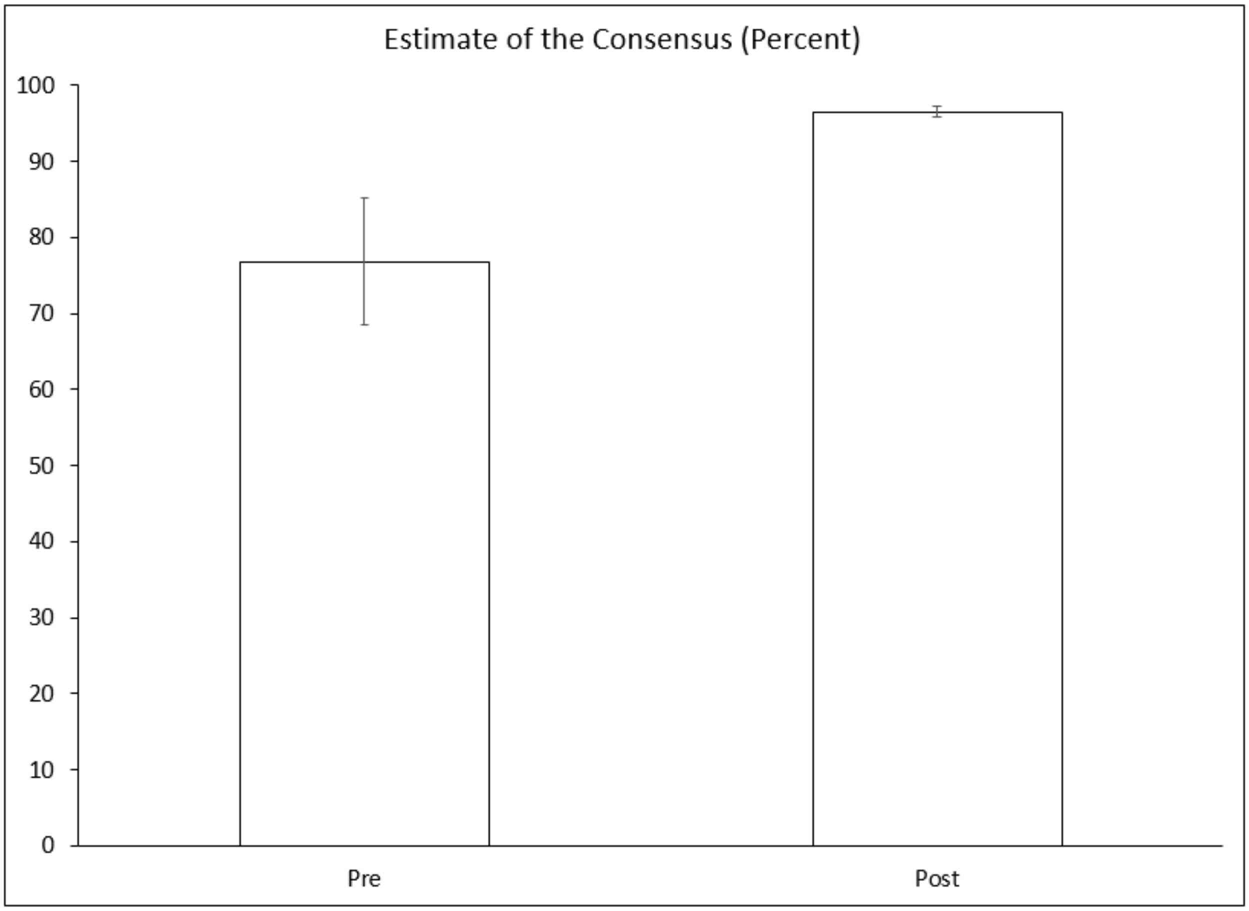

Figure 3. Estimate of the Consensus. The consensus messaging significantly influenced participants' perceived consensus (Z = -2.580, p = .010). Error bars represent standard error.

Figure 4

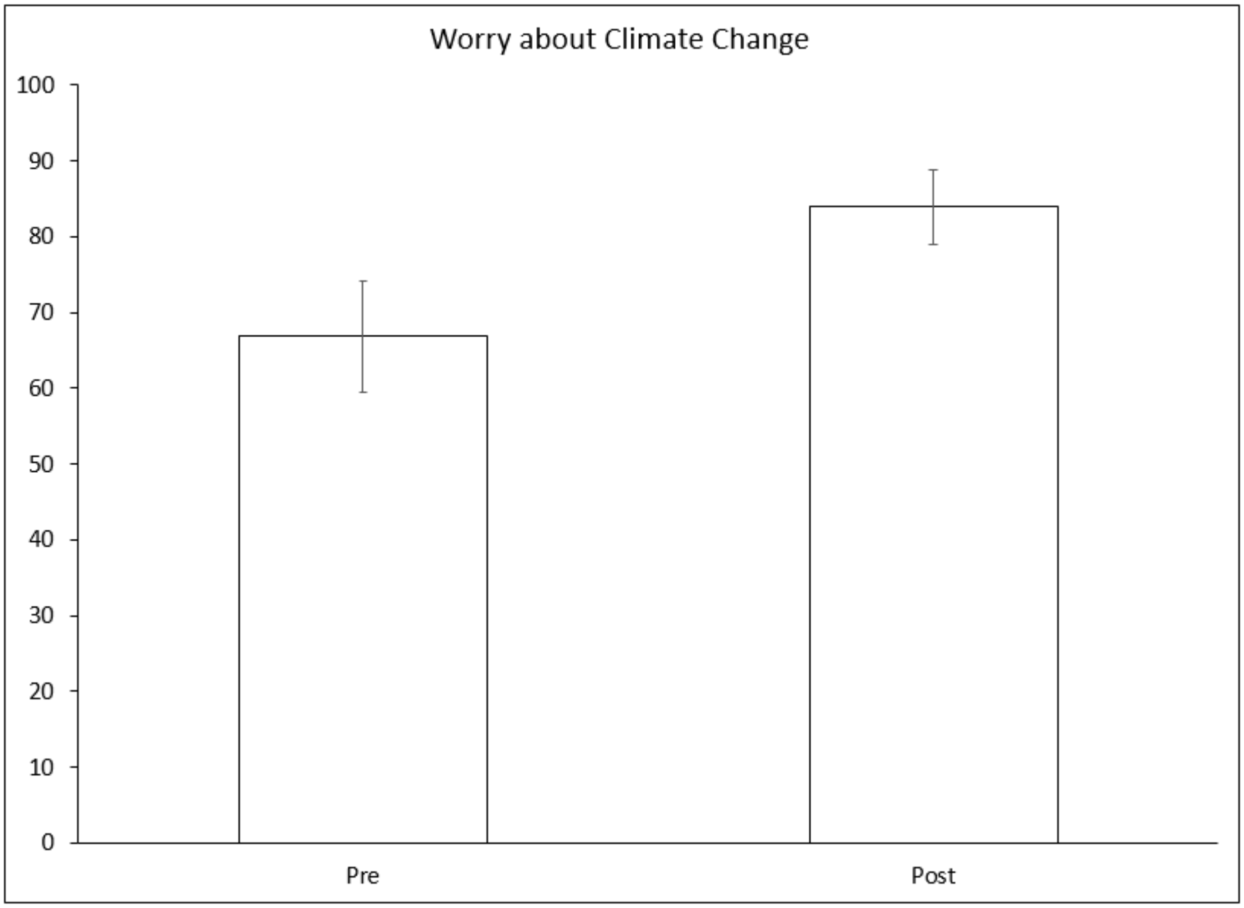

Figure 4. Worry about Climate Change. The consensus messaging significantly influenced participants' worry about climate change (Z = -2.320, p = .020). Error bars represented standard error.

Figure 5

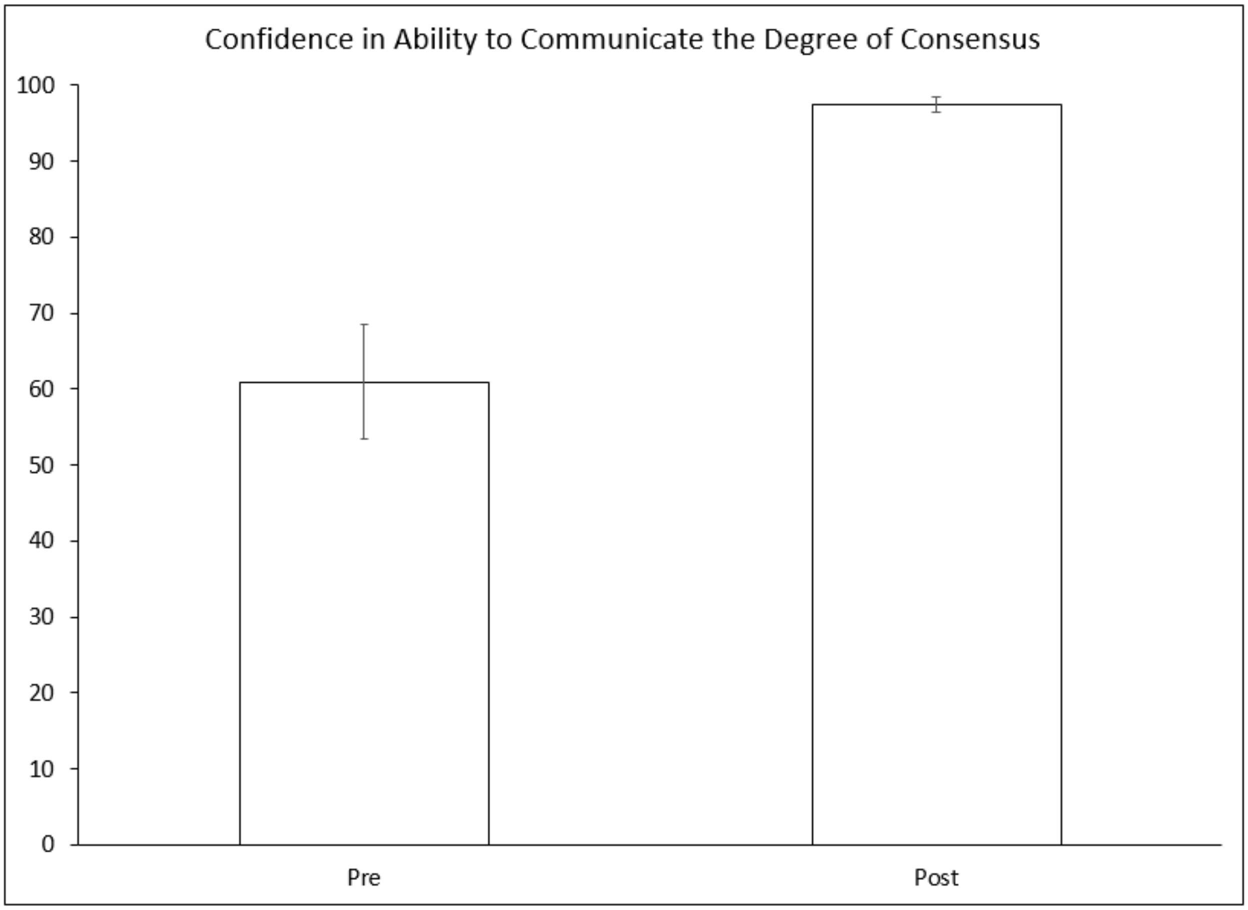

Figure 5. Confidence in Ability to Communicate the Degree of Consensus. The consensus messaging significantly influenced participants' confidence in their ability to communicate the degree of consensus on human-induced climate change ($Z = -2.805$, $p = .005$). Error bars represent standard error.

Figure 6

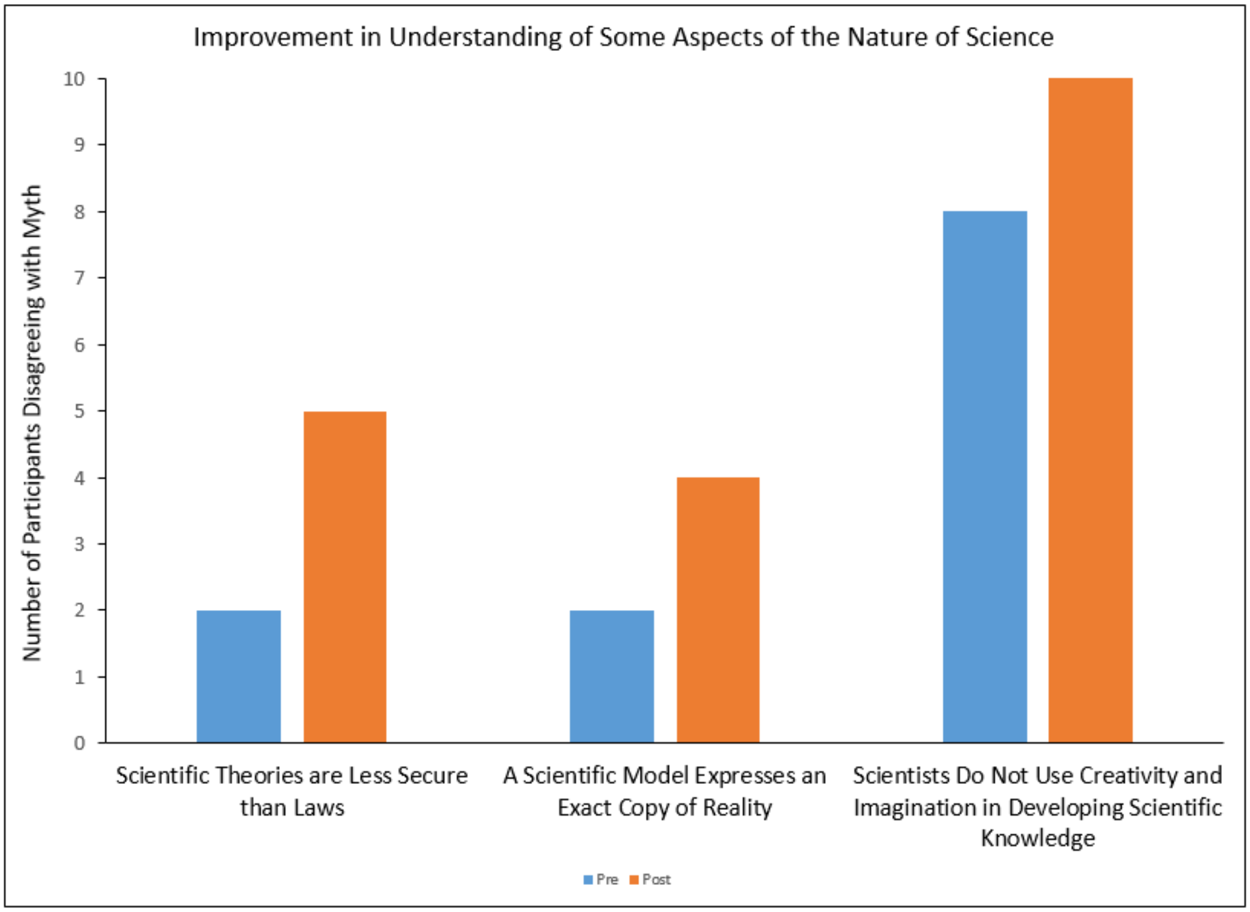

Figure 6. Improvement in Understanding of Some Aspects of the Nature of Science. The number of participants disagreeing with these three myths increased by two or more on the post-test as compared to the pre-test.

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Stover, S. (2016). Two Wrongs Make a Right: Using Pseudoscience and Reasoning Fallacies to Complement Primary Literature. *Journal of College Science Teaching, 45*(3), 23-27.

van der Linden, S. L., Leiserowitz, A. A., Feinberg, G. D., Maibach, E. W. (2015). The Scientific Consensus on Climate Change as a Gateway Belief: Experimental Evidence. *PLoS One, 10*(2): e0118489. doi: 10.1371/journal/pone.0118489

Yalcin, A., Clem, B., Simmons, A., Lane, A., Nelson, K., Clem, A., Brock, E., . . . Chesney, J. (2009). Nuclear Targeting of 6-Phosphofructo-2-kinase (PFKFB3) Increases Proliferation via Cyclin-Dependent Kinases. *J Biol Chem 284*(36), 24223-24232.

Yeong, F. M. (2015). Using Primary Literature in an Undergraduate Assignment: Demonstrating connections among cellular processes. *Journal of Biological Education, 49*(1), 73-90.

Jeremy D. Sloane
Curriculum Vitae

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Education

Ph.D. in College Science Teaching: Syracuse University - May 2018
Syracuse, New York.
Dissertation Title: Consensus Messaging Using Scholarly Literature: Impacts on Students' Conceptions of Global Climate Change
Committee: Supervisor: Jason Wiles, Associate Professor of Biology, Syracuse University
John Tillotson, Associate Professor and Chair of Science Teaching, Syracuse University
Julia Snyder, Research Assistant Professor of Science Teaching, Syracuse University
Ruth Phillips, Assistant Teaching Professor of Biology, Syracuse University
Robin Jones, Lecturer of Neuroscience, Syracuse University
Oral Examination Chair: Marion Bickford, Research Professor and Professor Emeritus of Earth Sciences, Syracuse University

Graduate Certificate in University Teaching: Syracuse University - 2017
Syracuse, New York. Awarded by the Graduate School and Department of Biology.

M.S. in Biology: Syracuse University - 2016
Syracuse, New York.
Thesis Title: "The Influence of Peer-Led Team Learning on Underrepresented Minority Student Achievement in Introductory Biology and Recruitment and Retention in Science, Technology, Engineering, and Mathematics Majors"

B.S. in Integrative Neuroscience: Binghamton University - 2013
Binghamton, NY. B.S. in Integrative Neuroscience with a Minor in Evolutionary Studies.

Teaching Experience

Instructor (Syracuse University), August 2017 – Present

- Introduction to Biological Research (BIO 200), Fall 2017. Primary instructor for discussion-based course utilizing primary research literature.

Teaching Mentor (Syracuse University), August 2016 – Present. Trained Syracuse University's new TAs; led microteaching exercises; delivered "Evidence-Based Teaching in STEM" session.

Graduate Teaching Assistant (Syracuse University)

- Quests and Questions in Physical Phenomena I (SCI 104), Fall 2016. Primary instructor for 24-student lecture section of general science course for future elementary school teachers.
- General Biology II (BIO 123/124), Spring 2014, Spring 2015, Spring 2016. Instructor for two 24-student lab and discussion sections each semester.
- General Biology I (BIO 121), Fall 2013, Fall 2014, Fall 2015. Instructor for two 24-student lab and discussion sections each semester.

Undergraduate Teaching Assistant (Binghamton University)

- Physiological Psychology (PSYC 362), Spring 2013. Held weekly office hours.
- Cellular Neurobiology (BIOL 313), Fall 2012. Led one 30-student discussion section. Reviewed homework problems and answered questions.

Research Experience

Biology education research group under Jason Wiles, Departments of Biology and Science Teaching, Syracuse University.
Studies students' experiences with primary research literature and impacts of consensus messaging using scholarly literature on student acceptance of human-induced climate change and support for threat-reduction actions; studied the influence of Peer-Led Team Learning on achievement in introductory biology and retention in STEM majors for specific student groups, including underrepresented minority students, women, and first generation college students
August 2014 – Present

Project manager and research associate for SUSTAIN (Strategic Undergraduate STEM Talent Acceleration Initiative), project funded by the National Science Foundation (Award #1644148, $999,719) under John Tillotson and Jason Wiles: Department of Science Teaching, Syracuse University.
Coordinated recruitment of high-achieving, low-income high school seniors interested in STEM; oversaw implementation of various SUSTAIN elements/interventions; collected data related to understanding of the nature of science and STEM socialization and identity.
January 2017 – Present

Neurobiology lab under Paul Gold and Donna Korol, Department of Biology, Syracuse University
January 2014 – August 2014
Individual project examining the influence of exercise on hippocampus-sensitive place learning and striatum-sensitive response learning in rats.

Neuroethology lab under Carol Miles. Biological Sciences Department, Binghamton University
Individual project examining the neural control of feeding behavior in *Manduca sexta*.
January 2012 – May 2013

Peer-Reviewed Publications

Sloane, J. D., Snyder, J. J., & Wiles, J. R. (In submission process – preprint 2017). Peer-Led Team Learning Improves Minority Student Retention in STEM Majors. bioRxiv doi: 10.1101/200071

Snyder, J. J., **Sloane, J. D.**, Dunk, R. D. P, & Wiles, J. R. (2016). Peer-led team learning helps minority students succeed. *PLoS Biology, 14*(3): e1002398.

Published Educational Materials

Snyder, J. J., **Sloane, J. D.**, & Wiles, J. R. (2016). Sensory and Motor Mechanisms PLTL Workshop Module. *Progressions: Peer-Led Team Learning*, Spring, 2016.

Snyder, J. J., **Sloane, J. D.**, & Wiles, J. R. (2016). Genetics and DNA Technology PLTL Workshop Module. *Progressions: Peer-Led Team Learning*, Spring, 2016.

Snyder, J. J., **Sloane, J. D.**, & Wiles, J. R. (2016). Animal Behavior PLTL Workshop Module. *Progressions: Peer-Led Team Learning*, Spring, 2016.

Snyder, J. J., **Sloane, J. D.**, & Wiles, J. R. (2015). Photosynthesis and Respiration PLTL Workshop Module. *Progressions: Peer-Led Team Learning*, Spring, 2015.

Snyder, J. J., **Sloane, J. D.**, & Wiles, J. R. (2015). Animal Structure PLTL Workshop Module. *Progressions: Peer-Led Team Learning*, Spring, 2015.

Snyder, J. J., **Sloane, J. D.**, & Wiles, J. R. (2015). Endocrine and Excretory Systems PLTL Workshop Module. *Progressions: Peer-Led Team Learning*, Spring, 2015.

Snyder, J. J., **Sloane, J. D.**, & Wiles, J. R. (2015). Internal Transport Systems PLTL Workshop Module. *Progressions: Peer-Led Team Learning*, Spring, 2015.

Snyder, J. J., **Sloane, J. D.**, & Wiles, J. R. (2015). Animal Nutrition PLTL Workshop Module. *Progressions: Peer-Led Team Learning*, Spring, 2015.

Snyder, J. J., **Sloane, J. D**., & Wiles, J. R. (2015). Plant Reproduction PLTL Workshop Module. *Progressions: Peer-Led Team Learning,* Spring, 2015.

Honors and Awards

Graduate Honors and Awards

- Outstanding Teaching Assistant Award: Syracuse University (2017). This award is given to the top 4% of TAs at Syracuse University annually.
- Carlock Award, Second Place: Association of College & University Biology Educators Conference (2016). This award is given to the top three graduate student presenters.
- Carlock Award, First Place: Association of College & University Biology Educators Conference (2015). This award is given to the top three graduate student presenters.

Undergraduate Honors and Awards

- Magna Cum Laude: Binghamton University (2013)
- Phi Beta Kappa Society: Binghamton University (2013)
- Undergraduate Award to Support Research and Creative Work: Binghamton University (2012)
- New York State Merit Scholarship Award (June 2009)

Service

- Teacher Professional Development Consultant, Fall 2016 – Spring 2017
    - Provided technical assistance to a team of middle and high school teachers from the Fayetteville-Manlius school district as they engaged in a yearlong, classroom-based action research professional development project.
    - Assisted with framing of research questions and study designs, supported teachers in conducting literature reviews related to their topic of study, provided small group and one-to-one consulting on statistical data analysis and qualitative data coding, and provided detailed feedback to teachers on their draft research manuscripts.
- College of Arts and Sciences Strategic Planning Group: Educational Excellence Working Group (Syracuse University), Graduate Student Representative, Spring 2017
    - Evaluated existing data on and recommended reforms for the First Year Forum, Liberal Arts Core, and Study Abroad Program.
- Teaching Mentor Selection Committee
    - Assisted with the selection of teaching mentors for the 2017-2018 academic year.

Conference Papers and Presentations

Sloane, J. D., Snyder, J. J., Dunk, R. D. P., Winterton, C. I., & Wiles, J. R. (2017). Peer-Led Team Learning and STEM Achievement, Recruitment, and Retention for Underserved Groups. Presented at the 2017 conference of the Society for the Advancement of Biology Education Research, Minneapolis, MN.

Sloane, J. D., Snyder, J. J., & Wiles, J.R. (2017). The Influence of Peer-Led Team Learning on the Recruitment and Retention of Underrepresented Minority Students in STEM Majors. Presentation at the 2017 International Conference of the National Association for Research in Science Teaching, San Antonio, TX.

Snyder, J. J., **Sloane, J. D.** , & Wiles, J. R. (2017). Peer-Led Team Learning: Improving Achievement, Recruitment, and Retention for Underrepresented Minorities in Post-Secondary Biology. NARST-sponsored research paper selected for presentation at the 2017 National Conference of the National Science Teachers Association, Los Angeles, CA.

Sloane, J. D., Snyder, J. J., Dunk, R. D. P., Winterton, C. I., & Wiles, J. R. (2016.) PLTL Enhances Retention in STEM Majors among Women and First-Generation College Students. Presented at the 2016 Professional Development Conference of the National Association of Biology Teachers, Denver, CO.

Sloane, J. D., Snyder, J. J., Dunk, R. D. P., Winterton, C. I., & Wiles, J. R. (2016.) PLTL Enhances Retention in STEM Majors among Women and First-Generation College Students. Presented at the 2016 Annual Meeting of the Association of College & University Biology Educators, Milwaukee, WI.

Snyder, J. J., **Sloane, J. D.**, & Wiles, J.R. (2016). Peer Led Team Learning: Improving Achievement for Underrepresented Minorities in Post-Secondary Biology. Presented at the 2016 International Conference of the National Association for Research in Science Teaching, Baltimore, MD.

Sloane, J. D., Snyder, J. J., & Wiles, J. R. (2016). Exploring Peer-Led Team Learning in Introductory Biology Toward Recruitment and Retention of Underrepresented Minority Students in STEM Fields. Presented at the 2016 Biology Leadership Conference, New Orleans, LA.

Snyder, J. J., **Sloane, J. D.**, & Wiles, J. R. (2015). Peer Led Team Learning Improves Achievement of Minority Students. Presented at the 59th Annual Meeting of the Association for College and University Biology Educators, St. Joseph's, MO.

Sloane, J. D., Snyder, J. J., & Wiles, J. R. (2015). Exploring Peer-Led Team Learning in Introductory Biology Toward Recruitment and Retention of Underrepresented Minority Students in STEM Fields. Presented at the 59th Annual Meeting of the Association for College and University Biology Educators, St. Joseph's, MO.

Sloane, J. D., Snyder, J. J. & Wiles, J. R.. (2015). Influence of Peer-led Team Learning on Recruitment and Retention in STEM. Presented at the 2015 Professional Development Conference of the National Association of Biology Teachers (NABT). Providence, RI.

Sloane, J. D., Snyder, J. J., & Wiles, J. R. (2015). Influence of Peer-led Team Learning on Recruitment and Retention in STEM. Presented at the 2015 Annual Conference of the Society for the Advancement of Biology Education Research, Minneapolis, MN.

Snyder, J. J., **Sloane, J. D.**, & Wiles, J. R. (2015). Peer-Led Team Learning as Tool for Recruitment and Retention of Underrepresented Minority Students in STEM. Presented at the 2015 Annual Biology Leadership Conference, Austin, TX.

Memberships in Professional Organizations

- Association of College & University Biology Educators (ACUBE)
- National Association of Biology Teachers (NABT)
- National Association for Research in Science Teaching (NARST)