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Students' Attitudes towards Socially--but Not Scientifically--Controversial Subjects: Evaluating Ways in which These Attitudes May Be Shifted

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Abstract

Chapter1: Numerous anti-science bills introduced into state legislatures reference the “strengths and weaknesses” of scientific subjects, but the subjects they target, most commonly evolution and global climate change, are not topics of contention within the scientific community. This brief work provides a researched rebuttal to the notion that evolution and climate change have strengths and weaknesses of the form implied by anti-science legislation while providing examples of actual scientific disagreement about these subjects. The disagreement is not, of course, about whether or not evolution or climate change are factual occurrences, but rather over ideas such as the finer points of evolutionary mechanisms or providing physical evidence that support theoretical ideas produced by mathematical models.

Chapter 2: The HungerU campaign of the Farm Journal Foundation includes a mobile, informal education exhibit centered on raising college students’ awareness of hunger in the US and abroad, as well as the role of modern agriculture in solving hunger-related problems. This study evaluated changes in students’ understandings of hunger as a cause of mortality before and after participating in the HungerU exhibit, as well as concurrent changes in their attitudes toward bioengineered or genetically modified foods. Students showed a significant increase in their understanding of hunger as the leading cause of mortality world-wide as well as a significant increase in their level of concern about hunger. Although there was no explicit instruction on GM foods, there were simultaneous significant increases in these students’ opinions that farmers should be allowed to use bioengineered crops in food production and that GMOs are a good option for solving issues related to world hunger. We posit that becoming more aware of and concerned about issues related to hunger may have allowed students to become more open minded to technologies to which they were previously ideologically opposed.

Chapter 3: Given the high availability of different media sources to students today, it stands to reason that some media sources would be of greater quality than others when communicating particular subjects to students. Previous findings have shown viewers of comedy news shows (the type of news show most frequently watched by younger viewers) to be better informed on some issues than viewers of other news outlets such as Fox News, CNN, or MSNBC. We sought to compare the effects of two different sets of videos, one comedic and one authoritative scientific, on students' knowledge of and attitudes towards climate change as well as how the two sets of videos were received by students. Surprisingly, we found no difference is effects on students' knowledge of or attitudes towards climate change. We did find however, that students generally felt that the authoritative videos were more likely to influence the way someone might vote, and that liberal students felt both videos were slightly more likely to influence voting than conservative students. We then make suggestions for future studies on media related to climate change, and for climate change educators.

Chapter 4: This qualitative study explores the experiences of six students enrolled in a special topics biology class that exclusively used primary literature as course content material. NOS conceptions have been linked to students' attitudes toward scientific subjects, but there has not been research specifically exploring the effects of primary literature use on NOS conceptions. Results, based both upon written responses to an established and validated NOS survey (VNOS-C) taken at the beginning and end of the course and upon reflective essays in which students described in detail their experiences with using primary literature, indicate positive gains in various aspects of NOS conceptions as well as increased confidence with approaching original research. We conclude by suggesting the expanded use of primary literature in biology education.

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Preface

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This dissertation is a compilation of three separate research efforts and therefore comprises chapters that may seem somewhat disparate. Hence, it is necessary to detail the umbrella under which these pieces exist. Broadly, the purpose of this dissertation is to expose why some socially controversial ideas—evolution, global climate change, and genetically modified organisms—are not so controversial within the scientific community and then to evaluate several ways in which this social controversy may be overcome.

The first chapter, recommended by my committee, represents a description of why evolution and climate change are essentially universally considered to be "true" within the scientific community while debated in socio-political contexts based on ideology apart from the scientific consensus. The body of literature supporting these two ideas is truly vast. Indeed, my chapter barely scratches the surface, but the strong consensus behind both evolution and climate change is an important prerequisite for the remaining pieces, for the remaining chapters focus on factors that may affect change in attitudes toward strongly supported science such as evolution and climate change.

The second chapter explores the possible efficacy of an indirect approach to shifting attitudes towards a socially controversial subject (in this case genetically modified foods, the safety of which is strongly supported by the scientific research, yet debated politically) when the subject is not explicitly addressed, but rather framed in terms of solutions to a human health issue (in this case hunger). First, the scientific controversies, such as they are, regarding genetically modified organisms are detailed, along with the myriad studies affirming the safety of those organisms which are available for human consumption. Next, we describe the study in full and our findings, that students did indeed become more open to bioengineered crops over the course of the study.

The third chapter examines whether there might be a difference in two approaches to using video media covering climate change, comedic videos—which are more likely to be viewed by younger individuals such as those involved in our study—and authoritative scientific videos. Our findings, surprisingly, indicate little difference between the two approaches, with one key finding being that the students generally thought the authoritative videos slightly more likely to change how someone might vote than the comedic videos. Liberal and conservative students also differed when answering this question, with liberal students feeling that both videos were slightly more likely to change how someone might vote than their conservative counterparts. Interestingly, though, there were no differences between the two videos when looking only at liberal, or only conservative, students' responses.

Rather than looking at ways to effect change in student attitudes, the fourth chapter examines a possible approach for shifting a key factor identified in previous research as a potentially important contributor to students' views on scientific issues, nature of science (NOS) conceptions. The idea here is that a better understanding of science—its empirical nature, how consensus is reached, etc.—may improve attitudes toward scientific issues. Teaching to improve conceptions about the nature of science, then, may be another sidelong approach to improving student outlooks on all manner of scientific issues including evolution, global climate change, and more. Exposure to science as scientists themselves read and publish it, i.e. primary literature, could be one way to improve NOS conceptions in students. With this in mind, and noting a lack of previous research explicitly linking the use of primary literature in class with NOS conceptions, we developed a qualitative study based upon a course designed to use primary literature as its exclusive source of content material. Students NOS views were surveyed at the beginning and end of the course, and students wrote reflective essays in which they described in detail their experiences with primary literature. Based on our findings, we can conclude that using primary literature improved several aspects of students' NOS conceptions among our students while simultaneously building their confidence in approaching more original research and making science feel like a more accessible human endeavor to them.

Chapter 1:

On the notion of "strengths and weaknesses" of scientific arguments pertaining to evolution and global climate change

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At the time of this writing, and not accounting for legislation barring the adoption of the next generation science standards (NGSS Consortium Of Lead States, 2013), there have been four anti-science bills introduced in the United States in 2015: Oklahoma S. 665, Indiana S. 562, Missouri H.R. 486, and South Dakota S. 114. Bills such as these are commonplace, and modern anti-science legislation almost universally purports to give teachers the power to help their students grapple with the “strengths and weaknesses” of scientific subjects, although the subjects listed as examples are rarely topics of contention within the scientific community. South Dakota's Senate Bill 114 specifically targets “biological evolution, the chemical origins of life, global warming, [and] human cloning” as examples of subjects that are scientifically controversial (*S. 114*, 2015). SB 114 and its ilk have been widely panned by critics. The National Center for Science Education, a group which defends the teaching of evolution and climate science, claims SB 114 would have “allowed public school teachers to miseducate their students about science” (NCSE, 2015). Speaking more broadly about anti-science legislation, Scott (2007) notes that the notion of “teaching the controversy” is rooted in attempts at undermining science.

Critical analysis of scientific arguments is undoubtedly helpful for developing students' understandings of both science content and the nature of science. The key disjunction here seems to be that opponents of such legislation disagree with the assertion that ideas such as evolution and global climate change have strengths and weaknesses. How can it be that these subjects seem to be beyond reproach? In this work, we will focus on the two common scientific ideas which are targeted by anti-science legislation: evolution and global climate change.

“Cornerstone” is not an apt description for evolution's role in biology. Evolution is not merely a basic element or foundational idea within biology. If we are to continue the architectural metaphor, keystone is a more appropriate analogy as evolution is the idea that unites and supports (but is also supported by) all other ideas in biology. Indeed, if evolution were to somehow be disproven, all that we understand, or think we understand, about biology would have to be rebuilt, in a true Kuhnian scientific revolution, the likelihood of which is so minuscule as to be difficult to fathom (Kuhn, 2012).

Evidence for evolution comes from many fields including not only geology and paleontology, but also embryology, biochemistry, and biogeography (J. R Wiles, 2010). Evolution has also been directly observed, for example in long-term experiments with Escherichia coli (Lenski, Rose, Simpson, & Tadler, 1991). Certainly there are examples of scientific disagreement about evolution; an exchange over the importance of kinship selection is such an example. Nowak, Tarnita and Wilson developed a model in which the behavior of returning to the nest and caring for parents' offspring rather than dispersing to reproduce on their own was the result of a single gene, placing the evolution of eusociality in the context of simple selection rather than kinship selection (Nowak, Tarnita, & Wilson, 2010). Herre and Wcislo (among many others) quickly and critically responded to the notion of downplaying inclusive fitness (Herre & Wcislo, 2011), and even now scientists continue to respond, as Liao and colleagues recently varied relatedness in the same model proposed by Nowak et al. and claim their results actually support inclusive fitness (Liao, Rong, & Queller, 2015). Though there may be intellectual disagreements in the field of evolution, there are no modern examples of peer reviewed scientific literature arguing that evolution is not factual in nature. There is no alternative scientific explanation for changes within species or the origin of new species aside from evolution (American Institute of Biological Sciences, 1994).

Part of the confusion over evolution is due to its dual nature. Evolution is both fact *and* theory (Gould, 1981). The fact of evolution is derived from the abundant evidence supporting the idea that organisms change over time. The notion that if we use only one antibiotic to treat a particular bacterial infection then that antibiotic will eventually become ineffective is a notion predicated on the fact of evolution. Evolutionary theory is the body of knowledge related to explaining evolutionary processes. In short, the *what* of evolution is fact while the *how* of evolution is theory. In the above example, a scientific debate arose about evolutionary theory with regards to eusociality, but nowhere to be found in the scientific literature is any debate about the fact that organisms have evolved, are evolving, and will continue to evolve.

Confusion over this duality is what policymakers are seeking to exploit with anti-science legislation. While it is difficult to gauge intent based solely on the verbiage of a bill, one need only look at the groups supporting (and often helping to draft) them to determine whether or not they are anti-science. In the case of the aforementioned bill in South Dakota, a vocal supporter is the Discovery Institute (Discovery Institute, 2015), a group pushing for the inclusion of Intelligent Design (ID)—a pseudoscientific explanation for the diversity of life which arose from creation science (Boudry, Stefaan, Blancke, & Braeckman, 2010)—in public school curricula. Given its base of support and singling-out of evolution as "controversial," we must ask ourselves, was the purpose of this bill to allow teachers to miseducate their students about evolution? The answer seems to be a resounding yes. In a court decision examining the constitutionality of teaching ID in public schools, Judge John Jones III found that ID is not science, promotes religion, and that the school district's decision to take the issue to trial constituted "breathtaking inanity" (*Kitzmiller et al. v. Dover Area School District et al.*, 2005).

The science behind global climate change is decidedly newer than that of evolution. After all, the Industrial Revolution, the impetus for much of the observed climactic change, had only recently occurred when Darwin began publishing his work on natural selection. While it was once contentious among scientists, the vast majority of scientists now agree on many aspects of global climate change (GCC): that the climate is changing, that the changes that we are observing are most likely due to human influence, and that the changing climate may have other effects such as rising sea levels and changes in the nitrogen cycle (IPCC, 2007, 2013; National Research Council, 2010; NGSS Consortium Of Lead States, 2013; Vitousek, 1994). Consensus crosses not only scientific and institutional borders, but political ones as well. The Intergovernmental Panel on Climate Change (IPCC) has produced a number of reports focusing not only on the strength of the science behind GCC, but also on GCC impacts, vulnerability, and mitigation (IPCC, 2007, 2013).

The science continues to advance. In only the first two months of this year, the link between carbon emissions and climate change has been established mathematically (Goodwin, Williams, & Ridgwell, 2015), and the first direct evidence of the influence of carbon dioxide on surface temperature has been published (Feldman et al., 2015). At the same time, climate change deniers appear to be losing steam. One of the few scientists who denies anthropogenic climate change, physicist Willie Soon, has recently come under fire for failing to disclose sizable financial contributions from the fossil fuel industry and those associated with it (Gillis & Schwartz, 2015). Like evolution, GCC does have its share of legitimate professional disagreement, but a survey of climate change papers endorsing a position on whether GCC is human-caused found that upwards of 97% state or assume it to be the case (Cook et al., 2013).

In fact, there seems to be more contention over the best way to communicate climate science to the public than there is about climate science itself. A recent study presents evidence that providing information about the scientific consensus on climate change can shift attitudes towards climate change (van der Linden, Leiserowitz, Feinberg, & Maibach, 2015), but Dan Kahan has presented contrary evidence, that cultural cognition shapes how people receive information on the climate change consensus, so information about the consensus may not be helpful in swaying opinion (Kahan, Jenkins−Smith, & Braman, 2011). He argues that appealing to the authority of the scientific community may be polarizing, tantamount to implying that those who disagree with 97 percent of scientists must be very stupid (Vaidyanathan & ClimateWire, 2014). Controversy over how best to communicate the science, though, is a far cry from controversy over the science itself. Anti-science legislation does not claim that there are controversies with communication, but rather with the science itself. Given the status of climate science today, such claims are most definitely misleading.

Chapter 2:

HungerU: Informal education about hunger-related issues and its potential to change college students' attitudes about modern agriculture and GMOs

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Abstract:

The HungerU campaign of the Farm Journal Foundation includes a mobile, informal education exhibit centered on raising college students' awareness of hunger in the US and abroad, as well as the role of modern agriculture in solving hunger-related problems. This study evaluated changes in students' understandings of hunger as a cause of mortality before and after participating in the HungerU exhibit, as well as concurrent changes in their attitudes toward bioengineered or genetically modified foods. Students showed a significant increase in their understanding of hunger as the leading cause of mortality world-wide as well as a significant increase in their level of concern about hunger. Although there was no explicit instruction on GM foods, there were simultaneous significant increases in these students' opinions that farmers should be allowed to use bioengineered crops in food production and that GMOs are a good option for solving issues related to world hunger. We posit that becoming more aware of and concerned about issues related to hunger may have allowed students to become more open minded to technologies to which they were previously ideologically opposed.

List of abbreviations:

GMOs – genetically modified organisms

GM – genetically modified

SSI – socio-scientific issues

IRB – Institutional Review Board

Core Ideas:

HungerU, a mobile, informal education experience, achieved its educational goals.

Students gained awareness and knowledge about hunger and modern agriculture.

Even without GMO instruction, openness to GMO foods increased with hunger awareness.

Introduction

HungerU is a special project of the Farm Journal Foundation, a non-profit corporation with an aim toward “sustaining agriculture’s ability to serve the vital needs of a growing world population” through education and assistance (HungerU, 2014). It is an extension of the Foundation’s Farmers Feeding the World platform to “rally the agricultural community around the fight against world hunger” (HungerU, 2014). HungerU employs a mobile, informal education exhibit that travels to college campuses across the United States; a series of Food Forums in which university students can engage with experts in agriculture, food sourcing, and other hunger-related areas of research and action; and a website by which information on such issues as well as the exhibit and forums is disseminated to a much wider audience than the tour could otherwise reach. Through the HungerU exhibit, the Food Forums, and the website, the Foundation hopes to educate college students about hunger and the role of modern agriculture in increasing food security locally, nationally, and globally.

The HungerU tour has visited over 70 university campuses in the United States to date, and when we learned that our university would be hosting the mobile exhibit and sponsoring a Food Forum, were immediately interested in its potential effects among our students, particularly with regard to issues related to those that we study around student attitudes toward science. Our primary foci have been on such topics as the acceptance of biological evolution and climate change denial, areas in which many people reject clear and consistent scientific consensus in deference to their own deeply-held ideologies, which at least for these two areas tend to be “conservative” in nature (Carter & Wiles, 2014; J. R Wiles, 2010).

Science denial is not limited to the political right, however. While liberals in the United States often scoff at conservatives' denial of evolution and/or climate change science, they often ignore a growing scientific consensus about the safety of agricultural advances such as genetically modified crops (Haelle, 2014). Little research has been reported on the politicization of student opinions on genetically modified organisms (GMOs), though information based on polls of the general public is available. A recent Pew survey of opinions of scientists and the public on scientific issues failed to break down the political leanings of those Americans who do and do not believe that GM foods are safe to eat, or those of the percentages who check labels to determine if GMOs are present in foods they buy (Funk & Rainie, 2015). A study of factors influencing voting on a GMO moratorium in Switzerland did find "yes" voters to be more likely to support state control as opposed to free market forces, which parallels political liberalism at least fiscally (Schläpfer, 2008). Perhaps more telling is that an extremely large majority of state legislation (over seventy bills) introduced in the U.S. to ban or require labeling of GMOs have been introduced by democrats. By contrast, the board of directors of the American Association for the Advancement of Science has issued a statement discouraging the labeling of such crops because they have been demonstrated to be safe and have been thoroughly tested, so labeling them could potentially mislead and unnecessarily alarm consumers (American Association for the Advancement of Science, 2012).

A recent review of literature on the safety of GMOs analyzed 1,783 separate studies from 2002 to 2012 and found no evidence that they pose any unique threats to the environment or public health (Nicolia, Manzo, Veronesi, & Rosellini, 2014). To date, no human medical issue, toxicological or allergic, has been conclusively tied to the consumption of GM products; the American Medical Association and the World Health Organization have both issued statements affirming this fact (American Medical Association, 2012; World Health Organization, n.d.). Several highly publicized feeding trial studies on other animals have been retracted due to methodological problems. In the meantime, many of the potential benefits of GMOs, increased crop yield, food quality, and diversity of foods that can be grown in an area, are being realized (World Health Organization, 2005). One study found the crop yield benefits to be particularly pronounced in developing countries (Qaim & Zilberman, 2003). Of course, most organizations agree that each GMO should pass strict safety evaluations before becoming available to consumers, but these evaluations already occur (American Association for the Advancement of Science, 2012; American Medical Association, 2012; World Health Organization, 2005).

Some experts claim that opposition to GMOs may come from ideology alone, given their demonstrated benefits and unsubstantiated risks (Trewavas & Leaver, 2001). One study even warns that some recommended risk assessments of GMO safety are recommended based on ideology rather than science (Herman & Raybould, 2013). The clash between science and ideology raises some important questions. What factors affect public attitudes towards GMOs? What types of intervention studies exist that look at GMO attitudes? An important factor identified in the literature as affecting attitudes toward GMOs is direct interest or benefit from the technology (Herring, 2008; Hossain, Onyango, Schilling, Hallman, & Adelaja, 2003), or a positive perception of the benefits of GMOs (Klop & Severiens, 2007), yet intervention studies focusing on GMOs have not been performed. Many organizations suggest transparency and concerted efforts at presenting the science and evidence about GMO benefits and safety to the public (American Association for the Advancement of Science, 2012; American Medical Association, 2012; World Health Organization, 2005), while one study looking at attitudes in younger individuals reminds us to account for differences in our students' attitudes and beliefs (Klop & Severiens, 2007).

The literature on socio-scientific issues may be of some help in considering how attitudes toward GMO's may be shifted. Socio-scientific issues (SSI) are controversial social issues that relate to science (Sadler, Barab, & Scott, 2007). Previous research has shown that content knowledge can be important for decision making on SSI (Sadler & Fowler, 2006; Sadler & Zeidler, 2005b), but also that morality often plays a major role in reaching decisions (Fowler, Zeidler, & Sadler, 2009; Sadler & Zeidler, 2004, 2005a). Further, reasoning has been shown to be influenced by the context of SSI (Topcu, Sadler, & Yilmaz−Tuzun, 2010), and one study in particular found health risks to be particularly important for decision making (Kolst⊘, 2006).

The idea that students might consider health risks to be particularly relevant is central to the hypotheses of Stover, McArthur, and Mabry (2013) whose study explored, and to some extent confirmed, the notion that framing controversial issues in terms of human health could encourage students to be more accepting of scientific information, particularly with regard to evolution. Their findings are consistent with those of Infanti & Wiles (2014) who found that student attitudes toward evolution improved when they became more aware of the relevance of evolutionary science to solving real-world problems, and hunger surely qualifies as one of these.

We are particularly interested in such approaches to teaching about concepts that are socially, but not scientifically, controversial due to an interesting phenomenon known as the backfire effect, specifically, in this case, the "worldview" type of backfire effect as described by Cook & Lewandowsky (2011), whereby "for those who are strongly fixed in their views, being confronted with counter-arguments can cause their views to be strengthened." (p. 4) Considering this type of backfire effect, it is important to note that the neither the HungerU exhibit nor any educational material associated with the HungerU platform expressly mentions GMOs, although references to "modern agriculture", "biotechnology" and even "genomics" are found among the exhibit's interpretive signage and videos aimed at linking modern agriculture to solving the problem of hunger.

With all this in mind, we predicted that students who are presented with meaningful information about an issue that they can easily empathetically understand, namely hunger, might become more open-minded on related issues to which they may have otherwise been ideologically hostile, such as bioengineered crops and other aspects of modern agriculture. HungerU provided us with an informal education intervention, and its aim of increasing awareness about world hunger presented an opportunity to explore whether being more knowledgeable about hunger may lead to shifts in student attitudes about one of its potential solutions, GMOs.

Materials and Methods:

The HungerU mobile exhibit consists of a 40 foot by 40 foot outdoor “classroom” consisting of an impressive trailer decorated with geographical data and statistics related to hunger and several awning-covered learning stations equipped with interactive, large screen displays connected to iPad tablets designed to allow students to explore information about hunger and agriculture in the U. S. and abroad (See Figure 1). The electronic displays provide access to an online food security index and a five-question quiz on hunger dubbed “The HungerU Challenge”. Surrounding the educational exhibit are several attention-getting activities, such as pedal cars modeled after farm tractors; tailgating games, and a prize-wheel, a spin of which determines which of various free gifts students might “win” in appreciation for their participation in the learning experience. A number of trained and knowledgeable facilitators are employed by HungerU both to draw visitors to the exhibit and to interact with visitors, answering questions and engaging in discussions. These facilitators are typically recent graduates in agricultural or food science fields, but close in age to the college students HungerU hopes to reach. Digital education materials like those delivered via the exhibit can be found on the HungerU website (www.hungeru.com), such as the HungerU Challenge, videos (e.g. http://youtu.be/O0zq8YHnSDY), infographics, and other statistical information on hunger and agriculture.

In conjunction with the mobile exhibit, the HungerU staff also organize “Food Forum” events on the campuses they visit in which local experts in various fields, often including food science and bioengineering faculty, hunger activists and organization representatives, or students with their own hunger stories, give brief presentations on their areas of expertise and then engage in an extended question-and-answer session with students.

Both the mobile exhibit and the Food Forum were very well attended on our campus. Many hundreds of students engaged with the informal displays and over one hundred attended the panel discussion. Because we had data collection procedures in place for a particular student population, and under an approved amendment to an existing IRB certificate, we focused our data collection on the students enrolled in a mixed majors/non-majors introductory biology class. We administered surveys electronically through course management software to ascertain student attitudes towards GMOs, hunger, and modern agriculture before and after the mobile exhibit and food forum took place. We separately identified students who attended the food forum only (forum, N = 48), mobile exhibit only (exhibit, N = 150), or both (both, N = 47), as well as those students who attended neither event (neither, N = 415). Within each group, pre- and post-event results were compared using dependent proportions tests. To compare between groups, we used the post-event results from the students who attended neither event as a control, and compared them to forum, exhibit, and both groups using z-tests, t-tests, and paired proportion tests where appropriate. All tests were two-tailed.

Results:

The percentage of students who correctly identified hunger as the number one cause of human mortality worldwide increased significantly for students who participated in the exhibit, by 22% for students who attended the exhibit ($p = 0.00124$, test statistic 3.15) and 27.7% ($p = 0.00676$, test statistic 2.58) for those who attended both the exhibit and the food forum. The rate of increase in correct responses for this question was 12.5% for students who attended the Food Forum only, but this was not a statistically significant improvement. The control group, those who did not attend any HungerU events, differed significantly from those who attended the exhibit with 11.7% fewer correct responses for this question ($p = 0.0128$, Z-score -2.49). In response to the question “How concerned are you about world hunger?” students who attended the HungerU exhibit rated themselves as being significantly more concerned about hunger after attending that they had previously been (two-tailed t-test $t=3.2949$, $p=0.001178$).

Prior to the HungerU events, when asked “Do you think farmers should be allowed to use bioengineered crops for food production?”, students answered 36.2% “yes”, 36.2% “maybe”, and 27.7% “no”. Students who attended the exhibit (N=150) showed a statistically significant increase of 13.3% ($p = 0.0136$, test statistic 2.24) in positive responses to this question (See figure 2). [Insert figure 2 about here] Students who attended both the exhibit and the Food Forum (N=47) returned an 8.5% increase, but although this seems like a substantial gain, it was not statistically significant. Another item asked “GMOs are genetically modified organisms (or food). Do you think GMOs are a good option for solving issues related to world hunger?” For those students who attended both the exhibit and the Food Forum, a significantly higher percentage (91.5%) responded “yes” or “maybe” to the question than those who did not attend any HungerU events (72%). For this comparison, p = 0.00386, and the z-score equals -2.888. (See figure 3.) [Insert Figure 3 about here]

To a lesser extent, (alpha < 0.1) students who attended the exhibit were also significantly more likely after the exhibit to agree that it is very important for small-scale farmers in developing countries have access to modern agricultural techniques. For this group, there was an increase of 9.4% in responses indicating that access to modern agriculture it is very important for small-scale farmers in the developing world (p = 0.0874, test statistic 1.37). There was a similar increase in this type of response among students who attended the Food Forum only (10.4%), but this difference was not statistically significant. Finally, the percentage of students who indicated that it was very important for small-scale farmers in developing countries to have access to modern agricultural techniques was significantly greater for the “exhibit” and “both” groups than the control (40.7% and 44.7%, respectively, compared with 32% for the control). Both groups were significant with an alpha of 0.1; the exhibit group had p = 0.05486 and a z-score of -1.924, and the both group had p = 0.0812 and a -1.751 z-score.

Discussion

In comparing the control group to exhibit-attending groups, these results suggest that the HungerU experience did have effects on its attendees. Differences between students who attended HungerU events and those who did not included increased awareness of hunger as a health issue, level of concern about hunger, openness to GMOs as an option to fight hunger, and feeling that small scale farmers in developing countries should have access to modern agricultural techniques.

Perhaps of broader interest, however, there appears to have been a shift in students' attitudes toward GMOs without any direct, explicit instruction on the issue. These results support our hypothesis that increased awareness of hunger as a human health issue might lead to increased receptiveness to GM technology. This is an important finding, as it implies a successful navigation of the "backfire effect", which has been posited as a concern for teaching about scientifically sound concepts that are nonetheless socially controversial, such as evolution, climate change, vaccines, and GMOs. (Lewandowsky, Ecker, Seifert, Schwarz, & Cook, 2012; Lewandowsky, Gignac, & Oberauer, 2013; Mooney, 2011). This is a key point in teaching about any socially controversial topic, as research indicates that that lack of acceptance of a concept may, in fact, prevent students from developing an understanding of the concept (W. W. Cobern, 1994; Meadows, Doster, & Jackson, 2000; Scharmann, 1990; Smith, 1994). Wiles (2011, 2014) suggests that helping students reach a position of deferred judgement on such topics is paramount in overcoming cognitive barriers rooted in prior rejection.

Conclusions

The science supporting the safety of GM crops is strong (Nicolia et al., 2014), yet they are still often regarded with suspicion by the general public (Funk & Rainie, 2015). In fact, recent work by Blanke and colleagues suggests intuition and emotion play a large role in keeping public support for GM technology low and that anti-GMO activists actively seek to exploit these psychological trends, producing materials that appeal to emotions such as disgust and folk biology ideas about the “essence” of an organism (Blancke, Van Breusegem, De Jaeger, Braeckman, & Van Montagu, 2015). Blanke et al. (2015) suggest that focusing on the benefits of GMOs could induce sympathy regarding GMOs, and studies on socio-scientific issues in science education show a strong moral component to decision making (Fowler et al., 2009; Sadler & Zeidler, 2004), with some studies showing a particular importance of perceived issues related to human health (Kolst⊘, 2006; Topcu et al., 2010).

Our study provides support for the notion that openness to GMOs may increase when it is perceived as a potential solution to a human health issue, in this case hunger. Future research should attempt to further disentangle concomitance from causation, perhaps by sampling from similar but separate institutions, with an intervention such as HungerU taking place at only one, in order to achieve full independence of samples as well as increase generalizability of findings. Further, other possible influences on opinions, such as scientific epistemology, knowledge of biological science, and political views, could be measured and examined to determine their effects on students’ attitudes toward GMOs. This study establishes the effectiveness of an informal education exhibit in its immediate goal, raising awareness of the issue of hunger, but also supports the suggestions of various researchers, that attitudes and decision making may be influenced more strongly when benefits are discussed, especially benefits to human health.

Figure 1: The HungerU Mobile Exhibit (Photo courtesy of The Farm Journal Foundation)

Figure 2: Both group responses regarding farmers' freedom to use bioengineered crops

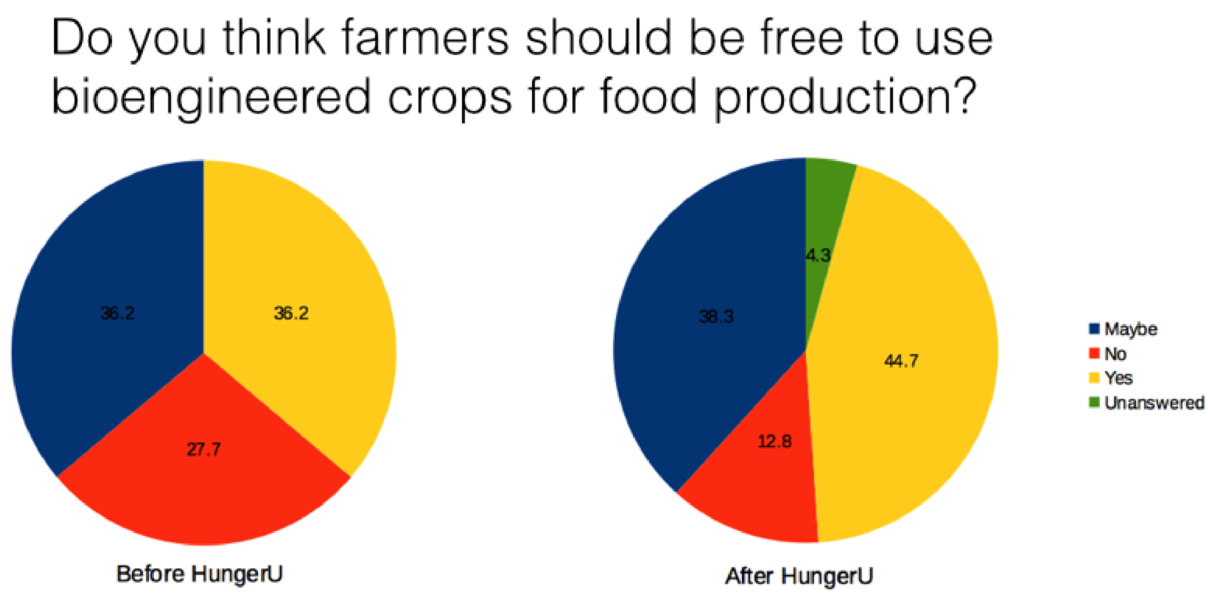
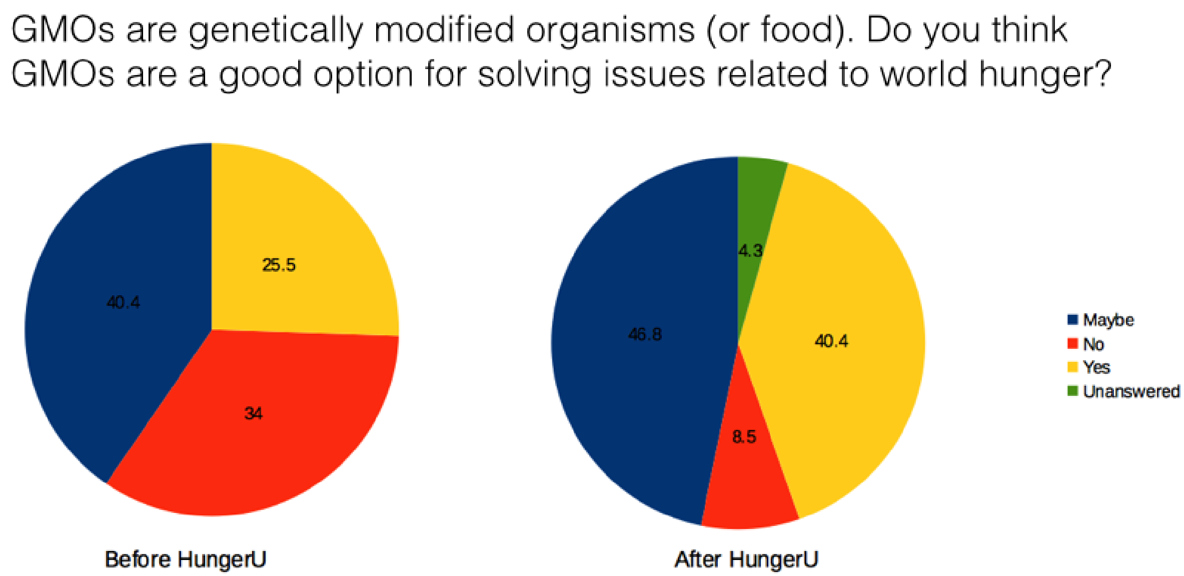


Figure 3: Both group responses on whether GMOs represent a good option to fight hunger



Chapter 3:

Exploring the effects of different climate change video presentations on student knowledge and attitudes about climate change

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Abstract

Given the high availability of different media sources to students today, it stands to reason that some media sources would be of greater quality than others when communicating particular subjects to students. Previous findings have shown viewers of comedy news shows (the type of news show most frequently watched by younger viewers) to be better informed on some issues than viewers of other news outlets such as Fox News, CNN, or MSNBC. We sought to compare the effects of two different sets of videos, one comedic and one authoritative scientific, on students' knowledge of and attitudes towards climate change as well as how the two sets of videos were received by students. Surprisingly, we found no difference is effects on students' knowledge of or attitudes towards climate change. We did find however, that students generally felt that the authoritative videos were more likely to influence the way someone might vote, and that liberal students felt both videos were slightly more likely to influence voting than conservative students. We then make suggestions for future studies on media related to climate change, and for climate change educators.

Introduction:

For some time now it has been apparent that students have access to a greater variety of media sources than ever before (Althaus & Tewksbury, 2000), and the rise of the smart phone and other mobile devices means news is available anytime and anywhere (Chan-Olmsted, Rim, & Zerba, 2013). Prior research has shown that different media sources align more strongly with the views of the scientific community than others. For example, a comparison of climate change news coverage across several countries found that in some countries, including the United States, a false pluralism emerges in the narrative surrounding climate change, implying that there is a debate about its factual nature; in other countries, though, coverage mirrors the views of the scientific community more closely (Dispensa & Brulle, 2003). Media literacy has also been suggested as a possible key factor in shifting attitudes towards global climate change (Cooper, 2011).

A 2012 Pew Research Center report showed that digital news media have surpassed newspapers and magazines, with television still the leading source nationwide. Among younger Americans, though, many do not consume news at all, and the sources most likely to reach them are news comedy programs such as The Daily Show and The Colbert Report (Kohut, Doherty, Dimock, & Keeter, 2012). This fact may seem lamentable if it were not for the curious findings that viewers of such comedy shows have been shown to be better informed on certain issues than viewers of other news outlets. For example, a recent study of public knowledge of proposed Net-neutrality rules found that viewers of The Daily Show, The Colbert Report, and Last Week Tonight with John Oliver were better informed than any other viewership to which they were compared, including Fox News, CNN, and MSNBC (University of Delaware Center for Political

Communication, 2014). It has also been found that The Colbert Report did a better job of communicating about campaign finance than any other outlet, again including Fox News, CNN, and MSNBC (Hardy, Gottfried, Winneg, & Jamieson, 2014). It is important to note that viewers of The Daily Show and The Colbert Report are upwards of 80% moderates and liberals (Kohut et al., 2012), and that conservative viewers of The Colbert Report are likely to view the satire as a sort of double bluff, in which the host is only pretending to joke about the issues (LaMarre, Landreville, & Beam, 2009).

Global climate change (GCC) is a highly politicized scientific issue (McCright, 2010; McCright & Dunlap, 2011b), with conservative white males the most likely group to deny anthropogenic GCC (McCright & Dunlap, 2011a). This trend in politicization has been noted in national surveys in the United States for decades (Leiserowitz, Maibach, Roser-Renouf, & Hmielowski, 2012). Despite the desire of most Americans for news sources lacking a point of view (Kohut et al., 2012), there is still large reliance on partisan media which likely contributes to the widening gap in GCC opinions, a proposed mechanism for which is that conservative media decrease viewers' trust in scientists while liberal media increase trust (Hmielowski, Feldman, Myers, Leiserowitz, & Maibach, 2014). However, whether this difference rests in the media coverage or the viewers themselves is unclear. What is clear is that representing climate science as controversial has measurable effects on reader certainty about GCC (Corbett & Durfee, 2004). In terms of science communication, Kahan advises that climate communication should rely on evidence above all else (Kahan, 2013).

Given Kahan's suggestion that GCC communication should be evidence based (Kahan, 2013), the fact that more young Americans get their news from comedy shows (Kohut et al., 2012), and that viewers of comedy shows have been shown to be better informed about some issues such as net neutrality (University of Delaware Center for Political Communication, 2014) and campaign finance (Hardy et al., 2014), we wondered whether authoritative, nonpartisan, fact-laden educational documentaries on climate change are more effective or are perceived differently than comedic/satirical news stories on climate change in terms of how compelling students find the pieces, whether attitudes shift, and how knowledge of climate change science is influenced.

Methods:

We set out to compare the effects of two different sets of videos concerning climate change by incorporating them into separate sections of a large, mixed-majors introductory biology class in a large, private university in the northeastern United States. One set of videos was comprised of authoritative fact-laden, educational films from the Intergovernmental Panel on Climate Change (IPCC), and the other set included only comedic videos featuring commentary by Jon Stewart, Stephen Colbert, and John Oliver (Comedy). The IPCC-produced videos can be found at <http://www.ipcc.ch/news_and_events/multimedia.shtml> and the specific videos shown were titled “Climate Change 2013: The Physical Science Basis” and “In Harm's Way.” The videos were shown in the order listed above, and the first is a video summary of the Working Group I section of the IPCC's Fifth Assessment Report (AR5, IPCC, 2013). The second is a video summary of the IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX, IPCC, 2012). Both videos include narration by, and interviews with, actual contributors to the respective reports as well as imagery associated with climate change effects and also display text communicating facts about climate change.

The videos were shown in the context of a large lecture class with two separate sections. Students were then asked to respond to questions about their perceptions of the videos' effectiveness using individual response devices (commonly known as “clickers”). Students who did not attend these lecture sections and did not see the videos served as a control group (Control), as long as they reported not having seen the videos at another time. The comedy videos consisted of a segment from The Daily Show with Jon Stewart titled “Burn Noticed” which aired on September 22, 2014 and focused mainly on interactions between presidential science adviser Dr. John Holdren and various members of the US House of Representatives Committee on Science Space and Technology <http://thedailyshow.cc.com/videos/8q3nmm/burn-noticed>, a segment from The Colbert Report called “The Republicans' Inspiring Climate Change Message” which aired on November 6th, 2014 and mainly addressed popular rhetoric by republicans around the time in which they would respond to questions or statements pertaining to climate change with some variant of “I am not a scientist” <http://thecolbertreport.cc.com/videos/sc6mpp/the-republicans--inspiring-climate-change-message>, and a segment from Last Week Tonight with John Oliver in which the host stages a “statistically representative climate change debate” pitting popular science author and former children's science show host Bill Nye (and 96 climate scientists) against three climate change deniers in order to represent the scientific consensus on climate change <https://www.youtube.com/watch?v=cjuGCJJUGsg>. The segments from The Daily Show and The Colbert Report were shown in their edited forms as they appeared on TV, with the exception of skipping directly to the beginning of the segment in the lengthier Daily Show video clip. Volume on the multimedia system was briefly muted during the video from Last Week Tonight in order to censor an expletive.

Outside of class, a measure of knowledge of the science of human-induced climate change (HICCK, Lombardi, Sinatra, & Nussbaum, 2013) was administered before and after the intervention, as were survey questions assessing students' opinions about GCC and recording demographic information (Carter and Wiles, 2014). See Appendix 1 for the full HICCK instrument, and Appendix 2 for additional GCC and demographic questions. For control purposes, additional questions in the post-intervention surveys were asked to ascertain whether students had viewed the videos they watched prior to the intervention. Asking students whether they had previously viewed the videos also allows the exploration of whether these students align with particular demographic or attitudinal categories, and whether these factors may influence those students who had not seen the videos. Each of the two groups (IPCC and Comedy) were compared to the control (Control) in terms of their gains in knowledge about GCC, changing opinions about GCC, thoughts about how scientists view GCC, and how various demographics—especially political leanings—correlate with these results. Pre- and post-viewing numeric responses were compared using paired t-tests, while differences among groups were analyzed using box plots and chi-squared tests for quantitative and categorical variables, respectively. Correlation tests and analysis of variance were used to analyze relationships between quantitative variables from the same time points. The sample consists of a mixed majors introductory biology class grouped as follows: Total N = 650, Comedy N = 288, IPCC N = 250, and Control N = 111.

Results and Discussion

Results were not appreciably different if students who had seen the videos before were excluded from analysis, so they were included in the appropriate experimental groups and the full dataset used for analyses. Despite our expectations about differential effects between IPCC and Comedy videos, little difference was observed. No group was significantly more or less likely to change their opinion about climate change. None of the three groups (IPCC, Comedy, Control) differed significantly pre- to post-treatment in terms of how well they claimed to understand climate change ($p = 0.0639$, mean of differences = -0.0574), and though there was a significant difference in personal importance of climate change ($p = 0.0166$), the average difference was very small between groups.

Confoundingly, we measured a slight but significant decrease in actual understanding of climate change science for each group. For the Control group $p = 0.00116$ and mean of differences = -3.539; the IPCC group had $p < 0.001$, and mean of difference = -3.667, and the Comedy group $p < 0.001$ and mean of differences = -4.69. Pre-post differences were nearly identical when comparing students who identified as liberal versus conservative. Climate science knowledge was significantly lower for both liberals ($p < 0.001$, mean of differences = -3.978) and conservatives ($p < 0.001$, mean of differences = -4.372).

There was a significant difference between the two groups in how students thought the video they were shown might influence the way a person votes, with the authoritative videos from the IPCC perceived to be more influential. A Welch two sample t-test indicates a difference in the means ($t = 3.975$, $p < 0.0001$). This difference is shown in Figure 4. Since this question was asked in class immediately following the video, there are no data to compare with the

Control group. Students perceived both video sets to be equally influential in terms of how they may change people's attitudes or the way people might vote on issues related to GCC. However, liberal students on average thought both video sets would be more influential than their conservative counterparts did. This difference is demonstrated in Figure 5.

A separate interesting outcome of the analysis of these data is that the correlation between pre-intervention, self-reported understanding of climate change and actual measured understanding of climate change science, while positive and significant (R of 0.151, $p < 0.001$), is much weaker than one would expect. This trend is shown in Figure 6. The post-intervention correlation increased ($r = 0.199$, ($p < 0.001$), but was still not at all strong. Results differed somewhat for the IPCC group, in which pre-intervention ($r = 0.167$, $p = 0.0103$) and post-intervention ($r = 0.25$, $p < 0.001$). The correlation between self-reported and measured understandings of climate change were greater post-intervention for the IPCC group than either of the other groups, although only 6.25% of the variance in self-reported understanding is explained by measured understanding.

Conclusions

Although viewers of comedy news shows have been shown to be more knowledgeable about other issues than those who obtain their news from traditional outlets (Hardy et al., 2014; University of Delaware Center for Political Communication, 2014), our results did not support the notion that such comedic news stories are any more informative or more likely to sway opinion than authoritative educational videos focusing on serious communication of facts. Hearteningly, this study also found little evidence for politicization of climate change, despite previous findings of a more general population in the United States (McCright, 2010; McCright & Dunlap, 2011a: McCright & Dunlap, 2011b, Leiserowitz et al., 2012) and findings of a study with a very similar population of students (Carter and Wiles, 2014).

We did find some support for the effectiveness of evidence-based instruction, at least in terms of how influential the content is perceived to be on how someone might vote, lending some evidential support to Kahan (2013). There was no such evidence for Leiserowitz's assertion that focus on the scientific consensus on climate change is an effective strategy (van der Linden et al., 2015), although only a portion of the comedic videos concerned the climate consensus. No data were collected which might support or refute the hypothesis that cultural cognition shapes how people receive information on the climate change consensus such that information about the consensus may not be helpful in swaying opinion (Kahan, Jenkins−Smith, & Braman, 2011).

Future studies should incorporate an overall measure of media literacy in order to explore the role it may play in student knowledge and attitudes, per Cooper (2011), and whether interventions might differentially affect media literacy. Moreover, a study in which students receive more explicit climate change instruction in addition to the video interventions, might have different results both in terms of treatment groups, since adding more background material could lead to increased effectiveness for the more popular comedic videos whereas the authoritative videos may be less effective since students may already have learned much of the presented material. Further, there could be differential effects in terms of political leanings of students, since interaction effects between (self-reported) knowledge of climate change and political leanings have been observed in a previous study (Hamilton, 2011). Additional study is also warranted in order to focus more precisely on the effectiveness of instruction about the scientific consensus on climate change specifically. First, it should be determined whether instruction is more effective when it focuses on the consensus, and in the case that it isn't, it should be determined whether the lack of effectiveness might be due to barriers that result from cultural cognition. Additional studies could also pursue the question of whether liberal and conservative climate change media coverage does indeed affect viewers' trust in the science differently as has been suggested (Hmielowski, Feldman, Myers, Leiserowitz, & Maibach, 2014).

In terms of their opinions about media on GCC that affirm its veracity and anthropogenic causation, and how such media might change people's minds, it is of interest that liberal students viewed both the comedic and the authoritative videos to be potentially more influential than their conservative-leaning cohorts. It may be that pro-GCC media of any stripe amounts to "preaching to the choir" among liberal students while conservative students experience what Cook and Lewandowsky (2011) describe as the backfire effect, whereby "for those who are strongly fixed in their views, being confronted with counter-arguments can cause their views to be strengthened." (p. 4) Perhaps conservative students perceived the both the comedic and the educational films to be unfairly biased against their viewpoint, and in the case of the comedy, even making fun of their ideas. Or, in the case of the clip from the Colbert Report, the conservative students took the host's satirical deadpan at face value. This is the sort of scenario described by LaMarre, Landreville, & Beam (2009) whereby conservatives viewing Colbert's mock-conservative comedy later forget that it was a joke and use what was intended as jest to support their prior thinking. This propensity to "see what you want to see in The Colbert Report" (LaMarre, Landreville, & Beam, 2009, p. 212) makes the use of such complex satire in educational settings particularly difficult.

Instructors may be tempted to use clips from popular comedy shows due to their impressions that students may find them engaging. However, our findings lead us to suggest that educators not devalue authoritative scientific media as too boring or inaccessible to students. Nothing in our experience indicates that the students felt that the authoritative videos were any less interesting or accessible, and unlike the comedic videos, very few had seen the IPCC-produced videos before. Nature of science conceptions have been shown to have positive effects on acceptance of scientific ideas (Carter and Wiles, 2014), and explicit instruction on the nature of science, specifically the role of evidence in supporting ideas, may be a helpful approach for maximizing the effectiveness of evidence-based instruction by helping students to think like scientists. The fact that the correlation between self-reported and measured climate change knowledge increased over time is heartening, and that correlation could perhaps be further strengthened by assessments. If students are afforded more opportunities to disentangle what they actually know from what they think they know about climate change, this correlation is bound to increase.

Figure 4: The relationship between which videos were viewed and response to the question "Do you feel these videos might influence the way someone might vote?" A 3 corresponds to "Maybe," and a 4 corresponds to "Probably."

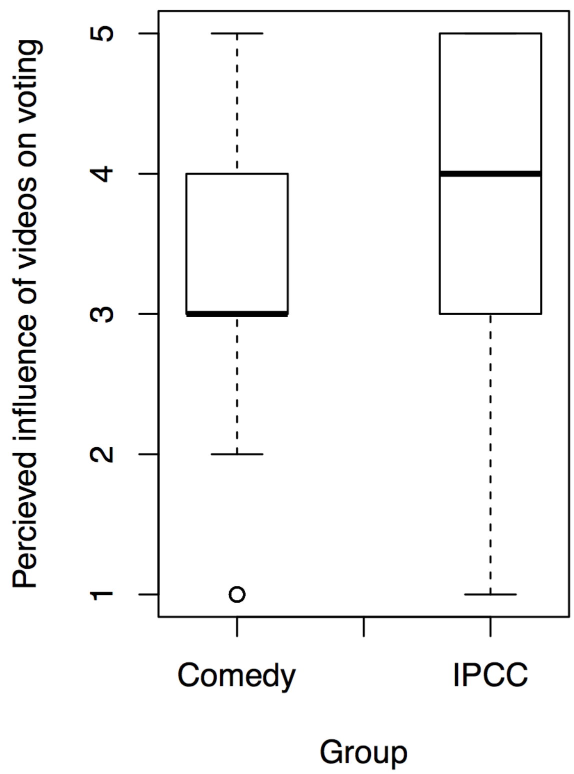


Figure 5: The relationship between which videos were viewed and response to the question "Do you feel these videos might influence the way someone might vote?" broken down by political views held by respondents. A 3 corresponds to "Maybe," and a 4 corresponds to "Probably."

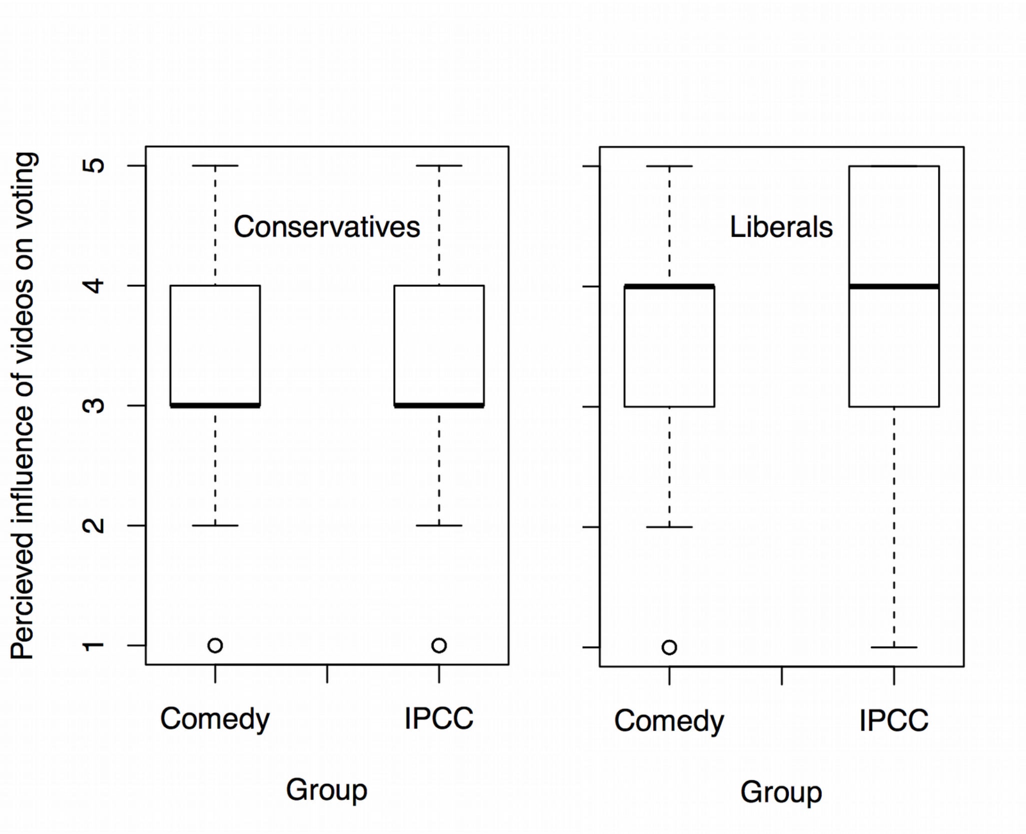
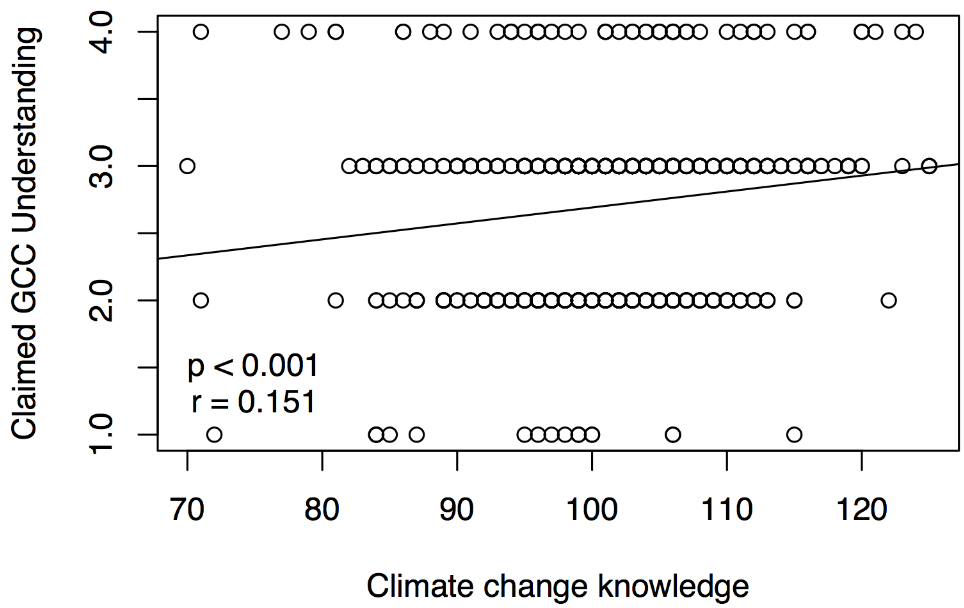


Figure 6: The relationship between climate change knowledge (as measured by individual scores on the HICCK instrument) and claimed climate change understanding (response to the question, "How well would you say you understand climate change?" 1 = Not at all, 2 = A little, 3 = Fairly well, 4 = Very well).



Chapter 4:

A qualitative study examining the exclusive use of primary literature in a special topics biology course: improving conceptions about the nature of science and boosting confidence in approaching original scientific research

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Abstract

This qualitative study explores the experiences of six students enrolled in a special topics biology class that exclusively used primary literature as course material. Nature of science (NOS) conceptions have been linked to students' attitudes toward scientific subjects, but there has been little research specifically exploring the effects of primary literature use on NOS conceptions. Results, based both upon written responses to an established and validated NOS survey taken at the beginning and end of the course and upon reflective essays in which students described in detail their experiences with using primary literature, indicate positive gains in various aspects of NOS conceptions as well as increased confidence with approaching original research. We conclude by suggesting the expanded use of primary literature in biology education.

Introduction

Although scientists do communicate in other ways—personal correspondences, presenting papers and posters at conferences, etc.—the most important, thoroughly vetted, durable, and far-reaching way that scientists communicate is by publishing primary literature. Primary literature is the vehicle by which new research is reported to the scientific community worldwide, where methods, data, analyses, interpretations, and conclusions, are subjected to further scrutiny, perhaps further validated, built upon, critiqued, or replicated by other researchers. Primary research may also inform policy, or inspire new research questions or technologies. Research shared in vetted publications may be viewed as the building blocks for our overall understanding of phenomena.

Primary literature has been used by science instructors in a variety of ways, often to achieve specific educational goals (Muench, 2000). Some instructors have used primary literature "journal clubs" as a sort of gateway to writing reviews and writing up laboratory exercises in the style of scientific articles (DebBurman, 2002) or to build skills in understanding, interpreting, and presenting data (Glazer, 2000). Others use primary literature to demonstrate paradigm shifts in science as a nature of science component to their course (Hoskins, 2008), to demonstrate how research progresses in the real world by focusing on works from a particular laboratory (Hoskins, Stevens, & Nehm, 2007), or to promote active and cooperative learning (Kitazono, 2010). Brill and colleagues suggest journal clubs be used by teachers to stay abreast of advances in science (Brill, Falk, & Yarden, 2003). Whole curricula may even be designed around primary literature (Yarden, Brill, & Falk, 2001). It is clear that educators have many different goals in mind when electing to use primary literature in the classroom, but what has the research shown about outcomes for students?

One of the major desired outcomes of using primary literature is boosting science literacy in students (DebBurman, 2002; Glazer, 2000; Hoskins, Lopatto, & Stevens, 2011; Hoskins et al., 2007; Kozeracki, Carey, Colicelli, & Levis-Fitzgerald, 2006; Muench, 2000; Yarden et al., 2001). In some cases, this outcome was even demonstrated (Glazer, 2000; Kozeracki et al., 2006). Increased critical thinking skills are also a frequently-cited outcome (Hoskins et al., 2011, 2007; Kozeracki et al., 2006; Muench, 2000; Sato et al., 2014). Improved research and data analysis skills have also been reported (DebBurman, 2002; Glazer, 2000; Hoskins et al., 2011; Round & Campbell, 2013). Confidence in approaching and understanding scientific literature is also a reported outcome of primary literature use (Glazer, 2000; Hoskins et al., 2011; Murray, 2014; Round & Campbell, 2013; Sato et al., 2014). Research has also shown that students' epistemological understandings and their conceptions of science as a human endeavor can be improved through exposure to primary science literature (Hoskins et al., 2011). One study even found evidence that teaching using primary literature helped facilitate students' transition to doctoral programs (Kozeracki et al., 2006). Certainly, there are excellent potential benefits to students from using primary literature.

Hence, we used primary literature as our sole source of content material in a special topics biology course, and during this process, we sought to better understand what effects the use of primary literature might have on the students. Because some of the readings focused on shifting understandings of phenomena (Heil et al., 2009; Janzen, 1973), research programs by a particular lab or researcher (http://evolution.berkeley.edu/evolibrary/article/0_0_0/bostwick_01), and also looked broadly at science and society by covering the targeting of some evolutionary biology research that had been branded as “frivolous government spending” by certain political pundits (Brennan, 2013), we hypothesized that students' nature of science views will improve as has been observed by Hoskins (2008). Additionally, as previous research around instruction using primary literature has shown increases in content knowledge in specific areas of biology (DebBurman, 2002; Glazer, 2000; Hoskins, Lopatto, & Stevens, 2011; Hoskins et al., 2007; Kozeracki, Carey, Colicelli, & Levis-Fitzgerald, 2006; Kozeracki et al., 2006; Muench, 2000; Yarden et al., 2001), we wondered if perhaps students' overall biological content knowledge might improve based on the variety of topics covered during the course and the breadth of individual research done by the students in selecting and exploring presentation topics for the course.

Methods

Since little previous research has focused on how the use of primary literature in courses on ecology and evolution might affect students' views on the nature of science, we designed a study to address this paucity in the current research literature. This study was undertaken in the context of a course entitled “Topics in Ecology and Evolution”, which we designed around exploring the relationship between individual research articles and a broader understanding of different phenomena. Students read several primary research literature articles per week and participated in online discussions wherein they posted summaries of and responses to the assigned research papers, explored their thoughts on the papers, and described what types of projects they expected the researchers might pursue next. They were encouraged to read through the works following the CREATE (Consider, Read, Elucidate hypotheses, Assess the methods and data, Think of the next Experiment) approach (Hoskins et al., 2011). Additionally, the online discussion board was set up such that each student would have to submit a response to the assigned article before being able to see any postings from their peers. This arrangement was to ensure that the students would have construct their own responses to the readings rather than draw from the responses of their peers.

After making their own response entries to the online discussion board, students were required to comment on one another's responses online. All readings and online responses were required prior to the in-person class meetings, and the readings were thoroughly dissected through in-class group discussion. After a few class sessions of reading and discussing instructor-selected research articles, the students were asked to choose topics and find appropriate readings (both approved by the instructor), and took over the role of discussion leader for their readings for the rest of the semester.

To ascertain the effects this class may have had on the students' nature of science views and biological content knowledge, we administered previously validated survey tools at the beginning and end of the course including the Biological Concept Inventory (BCI)(Appendix 3, Klymkowsky, Underwood, & Garvin-Doxas, 2010) and the views on the nature of science survey instrument, VNOS-C (Appendix 4, Abd-El-Khalick, 2001; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002), although follow up interviews relating to VNOS responses were not conducted due to constraints related to our IRB authorization for data collection. We also made use of written responses near the end of the course in which students were asked to describe in detail what they found useful about using primary literature, what was challenging, how they felt they progressed in terms of their ability to understand what they were reading, and how they felt about choosing their own topics and leading those discussions. (See Appendix 5 for the writing prompt.) All data were collected under IRB authorized protocols. See Appendix 6 for IRB certification.

Participants in the study were six students, three male and three female, including two biology majors, a forensic science major, one pre-medicine student, one undeclared art major, and one undeclared student in the college of arts and sciences, and ranging in age from 18 to 21 years old. Most were first-year university students. Where students are referred to by name in this work, pseudonyms have been assigned. Use of data for research purposes was voluntary. An additional student was present for much of the class, but was excluded from this study since he did not complete the course. Also, due to technological issues with the online version of the VNOS instrument, responses were not recorded for one student (Lauren) pre-course, or for a different student (Stuart) post-course.

Results and Discussion

Effects of the course on students' views about the nature of science

VNOS-C results, shown in Table 1, were quite positive. There were decreases in “naive” responses and increases in “mixed” and “informed” responses in all but one NOS category. The only NOS aspect without a decrease in naive responses was the theory/law aspect, which was never explicitly addressed in class. Naive responses also persisted fairly strongly with regards to the myth of the singular scientific method, the idea that there is only one way to do science, typically in the familiar, step-wise fashion presented in many primary- and secondary-level textbooks. Sadly, although many of the readings discussed in class were observational rather than experimental studies, the view that all science requires experiments still persisted.

Along with higher VNOS-C scores, some statements made by the students in their reflective written work reflect improving conceptions of NOS as well. Many of the students thought using primary literature provided insight into how science is done “in the real world,” or “in real life.” We take this to mean that the students were able to view science as less of an abstraction, or perhaps that they were better able to focus on the process of science. Ronaldo said, “these articles showed how science is applied in real life,” and Kristin echoed that same sentiment, saying “I also feel that I have a better understanding [of] how research is done in the real world.” Several students made statements that strongly indicate a more informed NOS view. Hilda stated that “scientists work continuously to bring out their discoveries to [the] world and let other people to have more scientific knowledge and attention to science,” indicating that she had thought a lot about how science is communicated. Sam made the statement which perhaps indicated the greatest gains in NOS conceptions when he stated,

> I think that science is done in many ways in the real world, and there are many different types of science. One example of science is going out to a certain area and observe a specific species or working in a laboratory seeing how an animal reacts to something. There are so many different ways science is done today.

It would seem that the myth of a single scientific method has been dispelled for Sam.

Effects of the course on students' biological content knowledge

Students' scores on the biological concept inventory (Klymkowsky et al., 2010) did not differ substantially from the beginning to the end of the course, as the BCI is intended to diagnose common misconceptions across the very broad and interdisciplinary field of biology. Total individual scores have a possible range of zero to thirty points. Scores ranged from 8 to 18 at the beginning of the course and from 12 to 17 at the end. The sum of all students' scores was 77 at the outset of the course, and 76 at the end. While it would have been encouraging if students had been able to overcome some of the general misconceptions they still held, we were not entirely surprised that the students retained some of these often tenaciously persistent naïve conceptions. With regard to more specific content knowledge encountered in this course, there are no extant, previously validated tools with which to objectively measure learning gains, nor could we have anticipated which topics in particular the students would select at the beginning of the course. Hence, we may only provide students' self-reports as evidence of their content-specific learning.

The students' perceptions of how much and what they learned is, however, enlightening and encouraging. Hilda, for example, said,

> My knowledge of science has increased incredibly, not only about specific species that we read about but also about general ecology [and] evolution... Although I am not an environment[al] science major nor was [I] interested in ecology, I feel I have gained a lot of scientific knowledge on other aspects of science.

Sam said, "I do know that my knowledge of science has increased after taking this class." Ronaldo reported that

> This class not only improved my knowledge on science, but improved my literature skills as well. I am very grateful I took this class because I now know my scientific knowledge and writing skills improved tremendously.

Lauren also noted an increased understanding of science, saying,

> this also increased my knowledge and understanding of the world around us and how it is constantly changing to adapt to ever-changing variables. It is easy to understand the processes that go along with evolution, but seeing examples that come from our everyday life was a completely different way of learning and beneficial in the long run.

The students clearly felt confident that they had an improved understanding of biology as a result of their work with primary literature in the course.

Students' self-described experiences with primary literature

The students had much to say about their experiences with primary literature. Most had rarely used primary literature in the past. Stuart stated in a written response, "I read a total of ten or twenty scholarly articles in my entire life before enrolling in this course." The other students had similar made similar statements about their prior use of primary literature. Sam had apparently had the most experience with primary literature, but stated that

> before taking [the course] I had used primary literature for a class first semester. It was different because the other class wasn't a science class so the primary literature was not similar.

Students' statements about how they perceived primary literature at the outset of the course were also very similar amongst the all students. Ronaldo said, "at first these articles were very hard to interpret." Sam echoed the same sentiment when he said, "reading primary literature in the class was difficult because I did not have a lot of experience with science articles so I got confused." Hilda expressed an interesting view, unique among the students in this study, but not likely unique among student readers of primary literature, when she explained of research articles, "although I am a science major, I thought they were for real scientists who are not I." The perception that research articles are only meant for researchers is, of course, completely understandable given the fact that many articles are inaccessible due to factors such as subscription barriers, or, as cited by nearly every student, that scientific articles are perceived as prohibitively challenging due to the complex and specialized language in which they are written. Sam noted that "when reading these articles [the] authors always used words I didn't know, so I had to use a dictionary a lot." Lauren said of reading research articles, "at first, this felt a little overwhelming and it was hard to grasp some of the scientific [jargon]," and Ronaldo also noted that "these journals have an array of vast scientific vocabulary, which was the hardest thing to get used when dissecting these journals." Kristin pointed not to terminology, but to the structure of journal articles as something she struggled with early on. She said,

> when I read journals like the ones we went over in this class, it often took me a much greater amount of time, mainly due to an inability to sit down and read the longer readings word for word all of the way through at once, the way I assumed I should read them. I had no strategy for dissecting the information given to me.

This is an important point, since many readers struggle with the typical structure of research articles. In fact, grasping article structure would prove to be a turning point for several students.

"As I read more and more I really got [used] to them and I started to understand why they were broken up into sections," Sam remarked about reading journal articles. Stuart fleshed this idea out more fully:

> All of the articles we read had general trends in them that made the reading easier to understand. Almost all of the articles had an abstract section in the beginning, which summarized the entire experiment that the article discussed in 1-2 short paragraphs. After [that] an introduction would explain what the point of the experiment was. Following the introduction were normally the methods and results sections which would explain how the experiments were done, and how it ended up working out in the end.

Ronaldo noted,

> at first these articles were very hard to interpret. The scholarly articles had multiple parts to them, which in beginning seemed to be confusing, but proved to make the article more organize and easy to understand.

These statements indicate that our decision to include a guide to examining research articles early in the course was a good one. In one of the first reading sets in the course, we made use of materials from Berkeley's Understanding Evolution website which provided a guide to dissecting a scientific paper about evolutionary biology (http://evolution.berkeley.edu/evolibrary/teach/journal/dissectingapaper.php). These materials provide a reading guide to accompany a study of figs and fig wasps (Dunn et al., 2008), which provides insight into each of the sections of the article. Though the students did not cite these materials explicitly in their written work, these readings and the accompanying class discussion were the foundation of the students' initial guided experience with analyzing scientific articles.

Many students also espoused the benefits of online and class discussions for their understandings of the papers. Ronaldo said,

> I found the most useful part of the class came in the discussions. In this part of the class not only can you demonstrate your perspective of the articles, but other student can chime in and provide information you would not even think about. Thus, giving you a vast knowledge on the topic being discussed in class that day.

Lauren noted that

> eventually it became easier to pick out the key points and summarize after seeing how other students viewed the article and how they interpreted the information. Discussions in class also made it easier to understand the over all goal of the project and sharing thoughts with my peers also opens up the opportunity to discuss possible alternatives to the projects.

Online and class discussions were perhaps most helpful to Hilda, who said,

> There were some articles that I interpreted wrong and realized what the study was actually about during class discussion. If I am in hurry or the article gets confusing, I tend to get lost easily and end up with wrong interpretation of the article.

She also noted that seeing other students' online summaries and discussion of the readings about which she was to lead discussion was helpful in “interpreting the thoughts that [she] had and also [she] understood how others thought about this issue.” Stuart also found discussions helpful in correcting his misinterpretations. He said,

> I feel as though the discussions during class really helped to get the point of the articles across. When reading them sometimes I wouldn’t understand some of what went on, but class discussions really helped to clear up any confusion that I had.

Students universally described changes in how they experienced primary literature. As noted above, Sam became more familiar with the structure of research articles as he read more of them. He also said, “I really don’t know if my abilities have changed from primary literature because I really haven’t used primary literature outside of this class,” but he added, “I have practiced reading these different articles so if I am required to read primary literature for another class I will be able to do it.” Stuart said,

> I feel like my abilities to read primary literature [have] definitely increased since I began taking this class. I feel more confident when reading it because the types of articles we read are all written the same way.

Kristin said, “I feel that my skills in understanding how to interpret primary literature have increased in this course.” Hilda noted, “I can now read faster but still [make] notes and highlights to understand better about the studies." Ronaldo was very specific in how he described his semester-long experience:

> Coming into this class I had no clue how to even dissect these types of scholarly articles... It may have seemed repetitive doing the same thing every week, but with every new week each reply and summary took less time.

Lauren also found repetition helpful, saying "Over the course of this semester, my ability to understand and decipher articles has greatly improved due to the amount of practice we have been doing."

It is clear that more practice with reading original research was helpful for the students, but did the skills they gained in this course carry over to other courses or more broadly to other parts of their lives? Many students thought so. Kristin stated,

> I definitely feel more [confident] in my skills of reading and understanding journal articles, and it is something that has already begun helping me in my current classes that require journal readings. Currently I am in a lab course in which a significant part of my grade was based on reading and understanding a long research paper. At the beginning of the semester I dreaded putting it off, but because of how this course broke down how to summarize and understand a paper I was able to complete the assignment with ease.

Hilda noted, more briefly, "As this course is ending, I feel more prepared to [enter a] science career." Lauren found the methodical way of reading articles that she developed very helpful, as she explained, "I eventually figured out a method that best worked for me when reading through articles to make sure that I do not miss the key points and have gone on to use this in several of my other classes." Ronaldo said,

> With all the lessons and skills I learned from this class I feel more prepared for future science classes, an also my future in my scientific career. I realize that I do not want to pursue a career and research, because of all the writing that comes with it.

Perhaps the last part is disheartening, but the realization that science involves writing is not without merit. Sam said, "I did become more confident in my abilities in science after this class, it's almost like practicing. I think this class has opened my mind up more than prepared me for other classes." Stuart spoke broadly about his gains in confidence, but also predicted that the skills he has gained will lead to success in his chosen field, saying,

> This class has definitely made me more confident in the field of science. I understand how to read journal articles a lot more than I did before, and I feel as though this class has made me able to locate information within journal articles much more quickly than I could before. Since I hope to work with animals one day, I feel as though this class has taught me how to better interpret information when reading scholarly articles.

It is clear that some students felt their experience with original research either was already helping them in other pursuits or would in the future.

One student, Lauren, also confirmed what many science teachers suspect about self-selected topics, that they lead to increased investment and a generally more positive experience for the student. In her words:

> This was one of the more fulfilling projects I have been a part of because not only were you able to research a project that pertained to your interests, you were able to hear what your peers thought of the topic as well as educate them on what can be/has been done which was a major plus for me.

It would seem that self-directed projects using primary literature can be quite positive for students, and may be especially effective when done with a large amount of class discussion.

Conclusions

Though the students did not show gains in a test of biological content aimed at common, broad misconceptions (the BCI), their nearly universal statements claiming increased understanding of specific biology content support our expectation that students' biology knowledge might increase. Further, the students reported increased confidence and facility with reading and understanding research articles, and more confidence in their abilities to understand or engage in science generally. These findings are similar to those of various other studies in which content knowledge (Glazer, 2000; Kozeracki et al., 2006) and confidence (Glazer, 2000; Hoskins et al., 2011; Murray, 2014; Round & Campbell, 2013; Sato et al., 2014) have been shown to increase.

Although previous research has discussed improvements in student outlook on science (Hoskins et al., 2011), this work represents the first research on the effects of using primary literature on NOS conceptions per se. We can conclude, based upon both the students' accounts of how they think about science, and also upon the results of the VNOS-C instrument (Abd-El-Khalick, 2001; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002), that the use of primary literature did lead our students to more informed views on various NOS aspects, especially the empirical, inferential, subjective, and myth of the scientific method aspects. The students' responses also indicate that they now view science as a more human endeavor, a finding shared with Hoskins et al. (2011).

Based on these findings, we concur with our colleagues who recommend expanding the use of primary literature in biology education (Hoskins et al., 2011; Yarden et al., 2001). Many students cited a better understanding of the structure of scientific papers as helpful in improving their overall confidence, so including an explicit primer on how to dissect a scientific research article as we did in this course is a practice we also recommend. The students indicated that repetition was helpful in becoming more confident with reading and understanding research articles, echoing the findings of previous research (Sato et al., 2014). Thus, we recommend spreading the use of primary literature across entire course curricula, with one to several articles being read each week. Group discussions, both online and in person, were also helpful to the students in clearing up confusion, expanding their thinking about research, and generally in building confidence about their experiences. Weekly journal clubs, then, may be a very helpful activity in or alongside formal biology instruction.

There are a number of avenues that future research on this topic could follow. Expanding into a larger sample size has many benefits, especially enhancing the generalizability of findings, although the intensive scoring required in using the VNOS instrument makes it more difficult to use at larger scales. We have used the Thinking about Science Survey Instrument (Cobern, 2000) as a quantitative measure of NOS conceptions in large scale studies (Carter and Wiles, 2014) and found it compare favorably to the VNOS. Another approach to future research could involve a more controlled experiment in which the VNOS is used along with follow up interviews for both pre-course and post-course surveys. In a larger scale study, ideas like the efficacy of online discussions could be more finely explored with differential treatment of different sections of a course, or a “journal club” style component of the course could be compared with a different activity that doesn't involve primary literature.

Overall, these results are quite encouraging, and they suggest that engaging in primary literature is informative to students both in terms of biological content knowledge and nature of science conceptions.

Table 1: VNOS-C results. Numbers represent total number of each type of response as represented by the relevant questions on the VNOS-C instrument, excluding interviews.

NOS aspect	Naive		Mixed		Informed	
	Pre	Post	Pre	Post	Pre	Post
Empirical	5	1	1	5	0	0
Inferential	2	0	3	3	0	1
Theory/Law	2	4	3	1	0	0
Creative	0	1	4	2	2	3
Sociocultural	2	1	2	2	1	1
Myth of SM	7	5	0	1	1	2
Tentative	2	0	2	3	1	2
Subjective	1	0	4	2	1	2

Appendix 1: **Human-Induced Climate Change Knowledge Instrument (HICCK)**

Students should rate the following statements, from 1 (strongly disagree) to 5 (strongly agree) based on what they think climate scientists would say about each statement.

1. The Sun is the main source of energy for Earth's climate.

2. Humans have very little effect on Earth's climate.

3. We cannot know about ancient climate change.

4. Earth's climate has probably changed little in the past.

5. The Sun's brightness is one way to measure solar activity.

6. Sunspot number is related to solar activity.

7. Greenhouse gases make up less than 1% of Earth's atmosphere.

8. Burning of fossil fuels produces greenhouse gases.

9. Humans produce billions of tons of greenhouse gases each year.

10. Humans are reducing the amount of fossil fuels they burn.

11. Greenhouse gas levels are increasing in the atmosphere.

12. Greenhouse gases absorb some of the energy emitted by Earth's surface.

13. Earth's climate is currently changing.

14. Humans are behind the cause of Earth's current climate change.

15. Earth's climate is not currently changing.

16. Current climate change is caused by human activities.

17. Current climate change is caused by an increase in the Sun's energy.

18. Current climate change is caused by the ozone hole.

19. Current climate change is caused by changes in Earth's orbit around the Sun.

20. Current climate change is caused by volcanic eruptions.

21. Current climate change is caused by increasing dust in the atmosphere.

22. Future climate change may be slowed by reducing greenhouse gas emissions.

23. Humans cannot reduce future climate change.

24. Satellites do not provide evidence that humans are changing Earth's climate.

25. Earth's average temperature has increased over the past 100 years. This is evidence of climate change.

26. Average sea level is increasing. This is evidence of climate change.

27. Most of the world's glaciers are decreasing in size. This is evidence of climate change.

Appendix 2: Additional Climate Change and Demographic Questions

GCC questions:

1. Global climate change, also called global warming, refers to the idea that the world's average temperature has been increasing over the past 150 years, may be increasing more in the future, and that the world's climate may change as a result. What do you think? Do you think that global climate change is happening?
   a) Yes
   b) No
   c) Don't know

2. How sure are you that global climate change is or is not occurring, given your previous answer?
   a) Extremely sure
   b) Very sure
   c) Somewhat sure
   d) Not at all sure

3. How well do you feel you understand the issue of global climate change?
   a) Very well
   b) Fairly well
   c) Not very well
   d) Not at all

4. Assuming global climate change is occurring, do you think it is:
   a) Caused mostly by human activities
   b) Caused mostly by natural changes in the environment
   c) None of the above because global climate change isn't happening
   d) Caused by both human activities and natural changes in the environment

5. Which comes closer to your own view?
   a) Most scientists think global climate change is happening.
   b) Most scientists think global climate change is not happening
   c) There is a lot of disagreement among scientists about whether or not global climate change is happening
   d) Don't know enough to say

6. How worried are you about global climate change?
   a) Very worried
   b) Somewhat worried
   c) Not very worried
   d) Not at all worried

7. How much do you think global climate change will harm you personally?
    a) A great deal
    b) A moderate amount
    c) Only a little
    d) Not at all
    e) Don't know

8. How much do you think global climate change will harm your family?
    a) A great deal
    b) A moderate amount
    c) Only a little
    d) Not at all
    e) Don't know

9. How much do you think global climate change will harm people in your community?
    a) A great deal
    b) A moderate amount
    c) Only a little
    d) Not at all
    e) Don't know

10. How much do you think global climate change will harm people in the United States?
    a) A great deal
    b) A moderate amount
    c) Only a little
    d) Not at all
    e) Don't know

11. How much do you think global climate change will harm people in other modern industrialized countries?
    a) A great deal
    b) A moderate amount
    c) Only a little
    d) Not at all
    e) Don't know

12. How much do you think global climate change will harm people in developing countries?
    a) A great deal
    b) A moderate amount

c) Only a little
d) Not at all
e) Don't know

13. How much do you think global climate change will harm future generations of people?
    a) A great deal
    b) A moderate amount
    c) Only a little
    d) Not at all
    e) Don't know

14. How much do you think global climate change will harm plant and animal species?
    a) A great deal
    b) A moderate amount
    c) Only a little
    d) Not at all
    e) Don't know

15. When do you think global climate change will start to harm people in the United States?
    a) They are being harmed now
    b) In 10 years
    c) In 25 years
    d) In 50 years
    e) In 100 years
    f) Never

16. When do you think global climate change will start to harm other people around the world?
    a) They are being harmed now
    b) In 10 years
    c) In 25 years
    d) In 50 years
    e) In 100 years
    f) Never

17. How much had you thought about global climate change before today?
    a) A lot
    b) Some
    c) A little
    d) Not at all

18. Over the past year or two, have you changed your opinion about global climate change?
    a) Yes
    b) No

19. How much do you trust or distrust **television weather reporters** as a source of information about global climate change?
    a) Strongly trust
    b) Somewhat trust
    c) Somewhat distrust
    d) Strongly distrust

20. How much do you trust or distrust **the mainstream news media** as a source of information about global climate change?
    a) Strongly trust
    b) Somewhat trust
    c) Somewhat distrust
    d) Strongly distrust

21. How much do you trust or distrust **climate scientists** as a source of information about global climate change?
    a) Strongly trust
    b) Somewhat trust
    c) Somewhat distrust
    d) Strongly distrust

22. How much do you trust or distrust **other kinds of scientists** as a source of information about global climate change?
    a) Strongly trust
    b) Somewhat trust
    c) Somewhat distrust
    d) Strongly distrust

23. How much do you trust or distrust **President Obama** as a source of information about global climate change?
    a) Strongly trust
    b) Somewhat trust
    c) Somewhat distrust
    d) Strongly distrust

24. How much do you trust or distrust **Mitt Romney** as a source of information about global climate change?
    a) Strongly trust

b) Somewhat trust
c) Somewhat distrust
d) Strongly distrust

25. How important is the issue of global climate change to you personally?
    a) Extremely important
    b) Very important
    c) Somewhat important
    d) Not too important
    e) Not at all important

Demographic questions:

1. Are you male or female?
   a) Male
   b) Female

2. What is your current age?

3. Which of the following best describes you:
   a) American Indian/Native American
   b) Asian
   c) Black/African American
   d) Hispanic/Latino
   e) Caucasian
   f) Non-caucasian white
   g) Pacific Islander
   h) Other

4. If you are from the United States, which state or territory are you from? If not, what country are you from?

5. Which term best describes where you grew up?
   a) Urban
   b) Suburban
   c) Rural

6. Growing up, how often were you exposed to science outside of school (e.g., by visiting museums, science centers, etc.)?
   a) Very often

b) Somewhat often
c) Somewhat rarely
d) Rarely
e) Almost never

7. What is your mother's highest level of education?
   a) Never attended school or only attended kindergarten
   b) Grades 1 through 8 (Elementary)
   c) Grades 9 through 11 (Some high school)
   d) Grade 12 or GED (High school graduate)
   e) College 1 year to 3 years (some college or technical school)
   f) College 4 years (College graduate)
   g) Graduate school (Graduate Degree)
   h) Does not apply

8. What is your father's highest level of education?
   a) Never attended school or only attended kindergarten
   b) Grades 1 through 8 (Elementary)
   c) Grades 9 through 11 (Some high school)
   d) Grade 12 or GED (High school graduate)
   e) College 1 year to 3 years (some college or technical school)
   f) College 4 years (College graduate)
   g) Graduate school (Graduate Degree)
   h) Does not apply

9. What, if any, is your religious affiliation?
   a) Protestant Christian
   b) Evangelical Christian
   c) Catholic Christian
   d) Muslim
   e) Jewish
   f) Hindu
   g) Buddhist
   h) Other ____________ (Write-in response)
   i) No Preference/No religious affiliation

10. If applicable, what is your religious denomination?
    a) ______________ (Write-in response)
    b) Does not apply

11. How active do you consider yourself to be in the practice of your religious preference?
    a) Very active
    b) Somewhat active
    c) Not very active
    d) Not active
    e) Does not apply

12. In general, how would you describe your political views?
    a) Strongly liberal
    b) Somewhat liberal
    c) Somewhat conservative
    d) Strongly conservative

13. Politically, what are your views on most social issues (e.g., immigration, capital punishment, or marriage equality)
    a) Strongly liberal
    b) Somewhat liberal
    c) Somewhat conservative
    d) Strongly conservative

14. Politically, what are your views on most fiscal issues (e.g., government spending, trade regulation, or economic regulation)
    a) Strongly liberal
    b) Somewhat liberal
    c) Somewhat conservative
    d) Strongly conservative

15. Generally speaking, do you consider yourself to be a(n):
    a) Strong Democrat
    b) Not so strong Democrat
    c) Independent-leaning Democrat
    d) Independent
    e) Independent-leaning Republican
    f) Strong Republican
    g) Other _____________ (Write-in response)
    h) Don't know

Appendix 3: Biological Concept Inventory (BCI)

Diffusion and Drift Group

Q1:Many types of house plants droop when they have not been watered and quickly "straighten up" after watering. The reason that they change shape after watering is because...

A. Water reacts with, and stiffens, their cell walls.
B. Water is used to generate energy that moves the plant.
C. Water changes the concentration of salts within the plant.
D. ✔Water enters and expands their cells.

Q5: There exists a population in which there are three distinct versions of the gene A (a1, a2, and a3). Originally, each version was present in equal numbers of individuals. Which version of the gene an individual carries has no measurable effect on its reproductive success. As you follow the population over a number of generations, you find that the frequency of a1 and a3 drop to 0%. What is the most likely explanation?
A. There was an increased rate of mutation in organisms that carry either a1 or a3.
B. Mutations have occurred that changed a1 and a3 into a2.
C. Individuals carrying a1 or a3 were removed by natural selection.
D. ✔Random variations led to a failure to produce individuals carrying a1 or a3.

Q25: Imagine an ADP molecule inside a bacterial cell. Which best describes how it would manage to "find" an ATP synthase so that it could become an ATP molecule?
A. It would follow the hydrogen ion flow.
B. The ATP synthase would grab it.
C. Its electronegativity would attract it to the ATP synthase.
D. It would be actively pumped to the right area.
E. ✔Random movements would bring it to the ATP synthase.

Q29: Sexual reproduction leads to genetic drift because...
A. there is randomness associated with finding a mate.
B. ✔not all alleles are passed from parent to offspring.
C. it is associated with an increase in mutation rate.
D. it produces new combinations of alleles.

Q30: How is genetic drift like molecular diffusion?
A. Both are the result of directed movements.
B. Both involve passing through a barrier.
C. ✔ Both involve random events without regard to ultimate outcome.
D. They are not alike. Genetic drift is random; diffusion typically has a direction.

Energetics and interactions

Q2. In which way are plants and animals different in how they obtain energy?
A. Animals use ATP; plants do not.
B. ✔Plants capture energy from sunlight; animals capture chemical energy.
C. Plants store energy in sugar molecules; animals do not.
D. Animals can synthesize sugars from simpler molecules; plants cannot.

Q3: In which way are plants and animals different in how they use energy?
A. Plants use energy to build molecules; animals cannot.
B. Animals use energy to break down molecules; plants cannot.
C. Animals use energy to move; plants cannot.
D. ✔Plants use energy directly, animals must transform it.

Q17: How does a molecule bind to its correct partner and avoid “incorrect” interactions?
A. The two molecules send signals to each other.
B. The molecules have sensors that check for "incorrect" bindings.
C. ✔Correct binding results in lower energy than incorrect binding.
D. Correctly bound molecules fit perfectly, like puzzle pieces.

Q18: Once two molecules bind to one another, how could they come back apart again?
A. A chemical reaction must change the structure of one of the molecules.
B. ✔Collisions with other molecules could knock them apart.
C. The complex will need to be degraded.
D. They would have to bind to yet another molecule.

Molecular properties and functions group

Q10: What makes DNA a good place to store information?
A. The hydrogen bonds that hold it together are very stable and difficult to break
B. The bases always bind to their correct partner.
C. ✔The sequence of bases does not greatly influence the structure of the molecule.
D. The overall shape of the molecule reflects the information stored in it.

Q11: What is it about nucleic acids that makes copying genetic information straightforward?
A. Hydrogen bonds are easily broken.
B. ✔ The binding of bases to one another is specific.
C. The sequence of bases encodes information.
D. The shape of the molecule is determined by the information it contains.

Q13: When we want to know whether a specific molecule will pass through a biological membrane, we need to consider...

A. the specific types of lipids present in the membrane.
B. ✔the degree to which the molecule is water soluble.
C. whether the molecule is actively repelled by the lipid layer.
D. whether the molecule is harmful to the cell.

Q20: Lipids can form structures like micelles and bilayers because of...
A. their inability to bond with water molecules.
B. their inability to interact with other molecules.
C. their ability to bind specifically to other lipid molecules.
D. ✔ the ability of parts of lipid molecules to interact strongly with water.

Q19: Why is double-stranded DNA not a good catalyst?
A. It is stable and does not bind to other molecules.
B. ✔ It isn't very flexible and can't fold into different shapes.
C. It easily binds to other molecules.
D. It is located in the nucleus.

Q27: Consider a diploid organism that is homozygous for a particular gene. How might the deletion of this gene from one of the two chromosomes produce a phenotype?
A. If the gene encodes a multifunctional protein.
B. ✔If one copy of the gene did not produce enough gene product.
C. If the deleted allele were dominant.
D. If the gene encoded a transcription factor.

Genetic behaviors group

Q7. If two parents display distinct forms of a trait and all their offspring (of which there are hundreds) display the same new form of the trait, you would be justified in concluding that ...
A. both parents were heterozygous for the gene that controls the trait.
B. ✔both parents were homozygous for the gene that controls the trait.
C. one parent was heterozygous, the other was homozygous for the gene that controls the trait.
D. a recombination event has occurred in one or both parents.

Q15: An allele exists that is harmful when either homozygous or heterozygous. Over the course of a few generations the frequency of this allele increases. Which is a possible explanation? The allele...
A. ✔is located close to a favorable allele of another gene.
B. has benefits that cannot be measured in terms of reproductive fitness.
C. is resistant to change by mutation.
D. encodes an essential protein.

Q16: In a diploid organism, what do we mean when we say that a trait is dominant?
A. It is stronger than a recessive form of the trait.
B. It is due to more, or a more active gene product than is the recessive trait.
C. ✔The trait associated with the allele is present whenever the allele is present.
D. The allele associated with the trait inactivates the products of recessive alleles.

Q21: A mutation leads to a dominant trait; what can you conclude about the mutation's effect?
A. It results in an overactive gene product.
B. It results in a normal gene product that accumulates to higher levels than normal.
C. It results in a gene product with a new function.
D. ✔It depends upon the nature of the gene product and the mutation.

Q22: How similar is your genetic information to that of your parents?
A. ✔For each gene, one of your alleles is from one parent and the other is from the other parent.
B. You have a set of genes similar to those your parents inherited from their parents.
C. You contain the same genetic information as each of your parents, just half as much.
D. Depending on how much crossing over happens, you could have a lot of one parent's genetic information and little of the other parent's genetic information.

Q24: A mutation leads to a recessive trait; what can you conclude about the mutation's effect?
A. It results in a non-functional gene product.
B. It results in a normal gene product that accumulates to lower levels than normal.
C. It results in a gene product with a new function.
D. ✔It depends upon the nature of the gene product and the mutation.

Q28: Gene A and gene B are located on the same chromosome. Consider the following cross: AB/ab X ab/ab. Under what conditions would you expect to find 25% of the individuals with an Ab genotype.
A. It cannot happen because the A and B genes are linked.
B. It will always occur, because of independent assortment.
C. ✔It will occur only when the genes are far away from one another.
D. It will occur only when the genes are close enough for recombination to occur between them.

Evolutionary mechanisms group

Q4: How can a catastrophic global event influence evolutionary change?
A. Undesirable versions of genes are removed.
B. New genes are generated.
C. ✔ Only some species may survive the event.
D. There are short term effects that disappear over time.

Q6: Natural selection produces evolutionary change by...
A. ✔changing the frequency of various versions of genes.
B. reducing the number of new mutations.
C. producing genes needed for new environments.
D. reducing the effects of detrimental versions of genes. ...

Q12: It is often the case that a structure (such as a functional eye) is lost during the course of evolution. This is because...
A. It is no longer actively used.
B. Mutations accumulate that disrupt its function.
C. It interferes with other traits and functions.
D. ✔The cost to maintain it is not justified by the benefits it brings.

Q14: How might a mutation be creative?
A. It could not be; all naturally occurring mutations are destructive.
B. If the mutation inactivated a gene that was harmful.
C. ✔If the mutation altered the gene product's activity.
D. If the mutation had no effect on the activity of the gene product.

Q26: You follow the frequency of a particular version of a gene in a population of asexual organisms. Over time, you find that this version of the gene disappears from the population. Its disappearance is presumably due to...
A. genetic drift.
B. ✔ its effects on reproductive success.
C. its mutation.
D. the randomness of survival.

Experimental design cluster

Q8. You are doing experiments to test whether a specific type of acupuncture works. This type of acupuncture holds that specific needle insertion points influence specific parts of the body. As part of your experimental design, you randomize your treatments so that some people get acupuncture needles inserted into the "correct" sites and others into "incorrect" sites. What is the point of inserting needles into incorrect places?

A. ✔It serves as a negative control.
B. It serves as a positive control.
C. It controls for whether the person can feel the needle.
D. It controls for whether needles are necessary.

Q9. As part of your experiments on the scientific validity of this particular type of acupuncture, it would be important to...

A. test only people who believe in acupuncture.
B. test only people without opinions, pro or con, about acupuncture.
C. have the study performed by researchers who believe in this form of acupuncture.
D. ✔determine whether placing needles in different places produces different results.

Appendix 4: VNOS-C Instrument

1.What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?

2. What is an experiment?

3. Does the development of scientific knowledge require experiments? If yes, explain why. Give an example to defend your position. If no, explain why. Give an example to defend your position.

4. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change? If you believe that scientific theories do not change, explain why. Defend your answer with examples. If you believe that scientific theories do change: (a) Explain why theories change; (b) Explain why we bother to learn scientific theories. Defend your answer with examples.

5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

6. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting the nucleus. How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine what an atom looks like?

7. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence do you think scientists used to determine what a species is?

8. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypothesis formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?

9. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced. If you believe that science reflects social and cultural values, explain why. Defend your answer with examples. If you believe that science is universal, explain why. Defend your answer with examples.

10. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations? If yes, then at which stages of the investigations do you believe scientists use their imagination and creativity: planning and design, data collection, after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate. If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

Appendix 5: Reflective Essay Prompt

Please respond, with as much detail as possible, to the following prompt:

In this course, we have made use of primary literature to better understand natural phenomena.

Please begin by describing your experience before this course. How much had you used it? How did you feel while reading journal articles? Think (and write) about how you felt when you first began reading journal articles.

Next, describe your experience with primary literature during this course. Write about how the different articles built upon one another to give more complete pictures of the different phenomena we looked at this semester. What was your experience like during the process of reading several articles, then having a presentation/discussion with me or your classmates? Describe the experience of choosing a topic and finding appropriate readings. How did you decide if a particular reading was appropriate or useful? What was it like to prepare to present?

Finally, describe whether and how you think your skills and abilities have changed as a result of using primary literature. Do you feel your knowledge of science content has increased? How about how science is done in the real world? Did you become more confident in your abilities to read and understand journal articles? Do you feel more prepared to continue in science (classes or career)? Don't just answer yes or no. Write your thoughts in complete paragraphs, with as much detail as possible. The more personal your responses, the better (they will not be shared with your classmates).

I expect your responses to be between one and two single-spaced pages (but feel free to give me more if you have more to say).

Appendix 6: Institutional Review Board certificates

SYRACUSE UNIVERSITY
Institutional Review Board
MEMORANDUM

TO: Jason Wiles
DATE: August 24, 2011
SUBJECT: **Determination of Exemption from Regulations**
IRB #: 11-222
TITLE: *Potential Influence of Introductory Biology Course Components on Standard Measures of Students' Understanding of and Attitudes Toward Science*

The above referenced application, submitted for consideration as exempt from federal regulations as defined in 45 C.F.R. 46, has been evaluated by the Institutional Review Board (IRB) for the following:

1. determination that it falls within the one or more of the five exempt categories allowed by the organization;
2. determination that the research meets the organization's ethical standards.

It has been determined by the IRB this protocol qualifies for exemption and is assigned to category **1**. This authorization will remain active for a period of five years from **August 23, 2011** until **August 22, 2016**.

CHANGES TO PROTOCOL: Proposed changes to this protocol during the period for which IRB authorization has already been given, cannot be initiated without additional IRB review. If there is a change in your research, you should notify the IRB immediately to determine whether your research protocol continues to qualify for exemption or if submission of an expedited or full board IRB protocol is required. Information about the University's human participants protection program can be found at: http://orip.syr.edu/human-research/human-research-irb.html Protocol changes are requested on an amendment application available on the IRB web site; please reference your IRB number and attach any documents that are being amended.

STUDY COMPLETION: The completion of a study must be reported to the IRB within 14 days.

Thank you for your cooperation in our shared efforts to assure that the rights and welfare of people participating in research are protected.

Tracy J. Cromp

Tracy Cromp, M.S.W.
Director

Note to Faculty Advisor: This notice is only mailed to faculty. If a student is conducting this study, please forward this information to the student researcher.
DEPT: Biology, 107 College Place

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121 Bowne Hall Syracuse, New York 13244-1200
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SYRACUSE UNIVERSITY
Institutional Review Board
MEMORANDUM

TO:	Jason Wiles
DATE:	October 9, 2013
SUBJECT:	**Amendment for Exempt Protocol**
AMENDMENT#:	2 - A) Addition of Research Staff (Elijah Carter); B) Change in Questionnaire
IRB #:	11-222
TITLE:	*Potential Influence of Introductory Biology Course Components on Standard Measures of Students' Understanding of and Attitudes Toward Science*

Your current exempt protocol has been re-evaluated by the Institutional Review Board (IRB) with the inclusion of the above referenced amendment. Based on the information you have provided, this amendment is authorized and continues to be assigned to category **1**. This protocol remains in effect from **August 23, 2011** to **August 22, 2016**.

CHANGES TO PROTOCOL: Proposed changes to this protocol during the period for which IRB authorization has already been given, cannot be initiated without additional IRB review. If there is a change in your research, you should notify the IRB immediately to determine whether your research protocol continues to qualify for exemption or if submission of an expedited or full board IRB protocol is required. Information about the University's human participants protection program can be found at: http://orip.syr.edu/human-research/human-research-irb.html Protocol changes are requested on an amendment application available on the IRB web site; please reference your IRB number and attach any documents that are being amended.

STUDY COMPLETION: The completion of a study must be reported to the IRB within 14 days.

Thank you for your cooperation in our shared efforts to assure that the rights and welfare of people participating in research are protected.

Tracy J. Cromp

Tracy Cromp, M.S.W.
Director

Note to Faculty Advisor: This notice is only mailed to faculty. If a student is conducting this study, please forward this information to the student researcher.
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SYRACUSE UNIVERSITY
Institutional Review Board
MEMORANDUM

TO: Jason Wiles
DATE: January 21, 2015
SUBJECT: **Determination of Exemption from Regulations**
IRB #: 15-009
TITLE: *The Effects of Using Primary Literature in a Biology Course on Student Conceptions about Science*

The above referenced application, submitted for consideration as exempt from federal regulations as defined in 45 C.F.R. 46, has been evaluated by the Institutional Review Board (IRB) for the following:

1. determination that it falls within the one or more of the five exempt categories allowed by the organization;
2. determination that the research meets the organization's ethical standards.

It has been determined by the IRB this protocol qualifies for exemption and has been assigned to categories **1** and **2**. This authorization will remain active for a period of five years from **January 16, 2015** until **January 15, 2020**.

CHANGES TO PROTOCOL: Proposed changes to this protocol during the period for which IRB authorization has already been given, cannot be initiated without additional IRB review. If there is a change in your research, you should notify the IRB immediately to determine whether your research protocol continues to qualify for exemption or if submission of an expedited or full board IRB protocol is required. Information about the University's human participants protection program can be found at: http://orip.syr.edu/human-research/human-research-irb.html Protocol changes are requested on an amendment application available on the IRB web site; please reference your IRB number and attach any documents that are being amended.

STUDY COMPLETION: Study completion is when all research activities are complete or when a study is closed to enrollment and only data analysis remains on data that have been de-identified. A Study Closure Form should be completed and submitted to the IRB for review (Study Closure Form).

Thank you for your cooperation in our shared efforts to assure that the rights and welfare of people participating in research are protected.

Tracy J. Cromp

Tracy Cromp, M.S.W.
Director

DEPT: Biology, 107 College Place **STUDENT:** Benjamin Carter

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Vita

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EDUCATION

Aug 2013 - Present

SYRACUSE UNIVERSITY, DEPARTMENT OF SCIENCE TEACHING Syracuse, NY
Ph.D. Candidate in College Science Teaching
- Researching correlations among students' conceptions of the Nature of Science, evolution, global climate change, and demographic factors.
- Design and implementation of educational interventions around these topics in the context of introductory biology courses.

Aug 2012- May 2014

SYRACUSE UNIVERSITY, THE GRADUATE SCHOOL & DEPARTMENT OF BIOLOGY Syracuse, NY
Future Professoriate Program
- Graduate Certificate in University Teaching – Awarded May 2014

Aug 2010 - Dec 2013

SYRACUSE UNIVERSITY, DEPARTMENT OF BIOLOGY Syracuse, NY
Master of Science – Awarded December 2013
- Masters Thesis: "Nature of Science Conceptions, Attitudes towards Evolution and Global Climate Change, and Course Achievement in an Introductory Biology Course"

Aug 2004 - Dec 2008

UNIVERSITY OF GEORGIA Athens, GA
B.S. in Ecology, Odum School of Ecology (Cum Laude)
- Honors Thesis: "Ant-Plant Interactions: Mutualism or Uneasy Balance of Exploitation?"

Music Business Certificate Program
- Participant in highly selective 15 credit-hour program to develop skills in music business, including team projects, student-run record label, and internship experience.

Study Abroad: Redcoat Band Great Wall Tour (May 2006)
- One of about 350 University of Georgia Redcoat (Marching) Band students to tour China by invitation from the Chinese government.
- Performance in soccer stadiums to crowds of up to 30,000 Chinese citizens while experiencing Chinese culture.

EXPERIENCE

January 2015 - Present

SYRACUSE UNIVERSITY, BIOLOGY DEPARTMENT Syracuse, NY
Graduate Instructor
- Design and teach a special topics course in Biology – Biology 200: Topics in Ecology & Evolution

Aug 2010 - Present	**SYRACUSE UNIVERSITY, BIOLOGY DEPARTMENT** Syracuse, NY *Teaching Assistant* • Teach two laboratory sections weekly exercises on diverse topics, ranging from enzyme function to plant and fungal diversity. • Create and grade weekly quizzes, and lead discussion of relevant topics
Jun 2014 - July 2014	**ARKANSAS GOVERNOR'S SCHOOL**Conway, AR *Natural Sciences Faculty* • Teach a natural sciences course at a six-week summer program for gifted and talented rising seniors in Arkansas. • Focused on ecology and evolution, especially how scientists collect data to "tell a story."
Nov 2009 - July 2010	**UNIVERSITY OF GEORGIA COSTA RICA**San Luis de Monteverde, CR *Resident Naturalist* • Guided natural history hikes, bird walks, and night hikes with groups of students (from middle school to college), professors, and tourists • Gave presentations on insect, bird, and plant ID and taxonomy. • Translated tours of sustainable organic farms and coffee processing, as well as cooking classes with local families.
Mar-June 2009	**NATIONAL PARK SERVICE**Prince, WV *Field Technician* • Worked on a long-term monitoring program of songbirds near National Park streams. • Traversed often-treacherous one kilometer transects following streams in two National River areas. • Observed Louisiana Waterthrush and other focal species by sight and sound. • Carried out point counts of all songbird species as well as vegetation cover estimates and hemlock health evaluations at each of five transect points for each of 25 study sites.
March 2009	**UNIVERSITY OF GEORGIA'S GO GREEN ALLIANCE**Athens, GA *Sustainapalooza: Co-organizer* • Worked with the University's Recycling Coordinator to create a free outdoor festival to promote sustainability on campus and in the community beyond. • Booked seven local bands to perform, and found over 50 organizations to table at the event. • Coordinated activities, organizations, and performances at the event itself.
Feb 2009	**UNIVERSITY OF GEORGIA OFFICE OF ACADEMIC SPECIAL PROGRAMS**Athens, GA *Georgia Junior Science and Humanities Symposium: Judge* • Attended audiovisual presentations from outstanding high school student researchers. • Questioned the presenters to determine their depth of understanding and communication ability. • Participated in the process of selecting the students who would continue to the next round of competition.

Nov 2008 - Jan 2009 **UNIVERSITY OF GEORGIA: ODUM SCHOOL OF ECOLOGY** Athens, GA
Sustainability Guidelines Committee

- Sat on a small committee with the purpose of producing a written set of goals to increase the environmental sustainability of the Odum School of Ecology.
- Produced and presented these goals to faculty, staff, and students.

July 2008/9 **UNIVERSITY OF GEORGIA OFFICE OF ACADEMIC SPECIAL PROGRAMS** Athens, GA
AP Environmental Science Training Program: Lab Assistant

- Prepared labs for use by high school teachers seeking to become certified to teach AP environmental science.
- Assisted teachers with lab techniques while maintaining laboratory safety.
- Returned for a second year with the same program.

June-Aug 2008 **UNIVERSITY OF GEORGIA: CENTER FOR UNDERGRADUATE RESEARCH OPPORTUNITIES** Athens, GA
Independent Undergraduate Researcher

- Laid the foundations on a long-term distribution and abundance study of *Aphaenogaster* ants in primary and secondary successional temperate forest.
- Recorded nest locations as determined by the use of protein baits and turning logs.

Jan-Aug 2008 **GEORGIA MUSEUM OF NATURAL HISTORY** Athens, GA
Assistant/Education specialist

- Cleaned, transported, and organized specimens in the invertebrate and ichthyological collections.
- Created presentations on Georgia habitats as a resource for teachers seeking materials for an updated state science curriculum.

May-Aug 2007 **SMITHSONIAN TROPICAL RESEARCH INSTITUTE** Panama City, Panama
Research Assistant

- Lived and worked on Barro Colorado Island through an NSF-funded Research Experience for Undergraduates program.
- Collected data on leaf functional traits of tropical upper-canopy tree species.

Jan-May 2007 **NIMBLESLICK MANAGEMENT AND CONSULTING** Athens, GA
Intern

- Calculated data for purchase of carbon offsets for touring bands.
- Updated official and social networking websites with tour information.

PUBLICATIONS

- **Carter, BE**, Conn, CC, & Wiles, JR. (In Review). HungerU: Impacts of an Informal Education Experience on Student Attitudes toward the Science of Food Sourcing. *Natural Sciences Education.*
- **Carter, BE**, Infanti, L, & Wiles, JR. (2015). Boosting students' attitudes and knowledge about evolution sets them up for college success. *The American Biology Teacher*. *77*(2), 113–116.
- Snyder, JJ, **Carter, BE**, & Wiles, JR. (2015). Implementation of the Peer-Led Team-Learning Instructional Model as a Stopgap Measure Improves Student Achievement for Students Opting Out of Laboratory. *CBE-Life Sciences Education*, *14*(1), ar2.

- **Carter, BE**, & Wiles, JR. (2014). Scientific consensus and social controversy: exploring relationships between students' conceptions of the nature of science, biological evolution, and global climate change. *Evolution: Education and Outreach*, *7*(1), 6.
  - Designated a "Highly accessed" article by SpringerOpen. doi:10.1186/s12052-014-0006-3
- Torrance, D., and Craig, G. (2013; **Carter, BE**, Contributing Author) *Key Connections: Climate Change in the Florida Keys*. iBooks interactive magazine.
- Siefert, A., Ravenscroft, C., Althoff, D., Alvarez-Yépiz, J.C., **Carter, BE**, Glennon, KL, Heberling, M., Jo, I., Pontes, A., Sauer, A., Willis, A., and Fridley, J.D. (2012). Scale dependence of vegetation-environment relationships: a meta-analysis of multivariate data. *Journal of Vegetation Science, 23*(5), 942-951.

PRESENTATIONS

- **Carter, BE**, Infani, L, & Wiles, JR. "Boosting students' attitudes and knowledge about evolution sets them up for college success," Multimedia presentation at the National Association for Research in Science Teaching annual conference, April 2015.
- **Carter, BE**, Conn, CC, & Wiles, JR. "HungerU at Syracuse University: Impacts of an Informal Education Experience on Student Attitudes toward the Science of Food Sourcing," Multimedia presentation at the Association of College and University Biology Educators annual conference, Portland, OR, 16 October, 2014
- **Carter, BE**, & Wiles, JR. "Exploring a potential link between student attitudes towards evolution and global climate change vis-à-vis the nature of science" Multimedia presentation at the 8th annual Summer Symposium at the Paleontological Research Institution, Ithaca, NY, August 2014.
- **Carter, BE**, & Wiles, JR. "Scientific consensus and social controversy: exploring relationships between students' conceptions of the nature of science, biological evolution, and global climate change." Multimedia presentation at the National Association for Research in Science Teaching annual conference, April 2014
- **Carter, BE**, Wiles, JR,. "HungerU at Syracuse University: Impacts of an Informal Education Experience on Student Attitudes toward the Science of Food Sourcing" Poster presentation for the Association of College and University Biology Educators Conference, October 2013
- **Carter, BE**, Wiles, JR,. "Exploring relationships between students' conceptions of the nature of science, evolution and global climate change." Multimedia presentation for the Association of College and University Biology Educators Conference, October 2013
- **Carter, BE**, Wiles, JR,. "Exploring relationships between students' conceptions of the nature of science, evolution and global climate change." Poster presentation for the Association of College and University Biology Educators Conference, October 2013

SKILLS AND ACTIVITIES

- Advanced language skills in Spanish
- Knowledge of Windows and Macintosh systems. Knowledge of Microsoft Office, Apple iLife/iWork, and OpenOffice.org/LibreOffice suites, iBooks Author, and intermediate skills in coding and analysis in R.
- Play various instruments including saxophones, clarinets, guitar, and didgeridoo
- Avid backpacker, cyclist, (indoor) rock climber, kayaker, and bird watcher
- Roller derby referee, Women's Flat Track Derby Association

AWARDS AND HONORS

- 2014 Association of College and University Biology Educators Carlock Award for Graduate Student Research
- Syracuse University Outstanding Teaching Assistant Award
- 2014 Biology Graduate Student Organization Travel Grant
- 2014 Marvin Druger Travel Award
- 2013 Association of College and University Biology Educators Carlock Award for Graduate Student Research
- Honorable Mention, National Science Foundation Graduate Research Fellowship Program
- Sigma Xi Grants in Aid of Research Grant
- Syracuse University Biology Department Travel Grant
- UGA Honors Program participant (graduate with honors)
- Georgia Governor's Scholarship
- HOPE Scholarship
- Robert C. Byrd Honors Scholarship
- UGA Charter Scholarship
- UGA Dean's List (6 semesters)