

ARTICLES

Presenting Global Warming and Evolution as Public Health Issues to Encourage Acceptance of Scientific Evidence

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Abstract: Although evidence supporting anthropogenic global warming and evolution by natural selection is considerable, the public does not embrace these concepts. The current study explores the hypothesis that individuals will become more receptive to scientific viewpoints if evidence for evolution and implications of global warming are presented as issues of public health. Non-science majors, nursing students, and freshman biology majors from two similar institutions answered pre- and post-test survey questions addressing the autism-vaccine connection, public health issues related to global warming, and public health issues associated with evolution by natural selection. Pretest questions elicited simple yes/no responses, whereas post-test questions were presented with relevant public health-related information and required students to articulate specific rationales. Student responses were categorized as either “evidence-based” or “non-evidence-based.” Only the natural selection question produced post-test responses that were significantly different from pretest responses. There were significantly more post-test “evidence-based” responses to the natural selection question in all three student groups. Results indicate that the presentation of controversial topics, particularly evolution, in the context of public health could be used to encourage public acceptance of scientific viewpoints.

Key words: Global warming, evolution, autism, public health

INTRODUCTION

The Pew Research Center for the People and the Press (PRCPP) is an independent opinion research group that studies attitudes toward the press, politics, and public policy issues. In collaboration with the American Association for the Advancement of Science (AAAS), the PRCPP conducted a phone survey of 2,001 adults from April 28 to May 12, 2009 to assess public perceptions of specific scientific issues. On the issue of global warming, 11% of those surveyed claim there is no evidence that the earth is warming. While 85% acknowledge the warming trend, only 49% agree that the warming is due to human activity. Thirty-six percent of the surveyed adults believe that the warming is part of a natural cycle. Regarding the topic of evolution, 31% of those surveyed reject the concept outright. While 61% acknowledge the evolution of living organisms, only 32% agree that evolution is due to the process of natural selection. Twenty-two percent of the surveyed adults believe that evolution is guided by a “supreme being.” Although public perceptions of certain issues seem incongruent with scientific evidence, the public, in general, seems to respect the scientific process. Eighty-four percent of those surveyed believe that science has produced knowledge that benefits society. When asked for specific examples, 52% cite advances in public health, including the development of vaccines. When

asked directly whether vaccination of children should be required, 69% of those surveyed answer in the affirmative (PRCPP, 2009). Clearly, the public is very supportive of healthcare-related science. Perhaps they would be more likely to accept evidence-based explanations of more controversial scientific issues if those issues were presented in the context of public health.

In the last decade, an anti-vaccine movement has received considerable media attention (Judelsohn, 2007). Included in the movement are those who blame the MMR (mumps-measles-rubella) vaccine for an apparent autism epidemic. Autism is a neurological disorder, typically diagnosed early in life, involving severe deficits in social skills and behavior (Novella, 2007). In the 1990s, the number of autism diagnoses increased from between one and three cases per 10,000 to between 30 and 60 cases per 10,000 (Rutter, 2005). During the same time period, the number of vaccines routinely given to children also increased. This led some to assume causation from correlation (Novella, 2007). A published study by Andrew Wakefield and colleagues (1998) suggested a connection between the MMR vaccine and autism. Although the study was small, it received a great deal of media attention. Subsequent to the Wakefield publication, many follow-up studies have been performed, but none of them have demonstrated a link between the vaccine and the

developmental disorder (Taylor et al., 1999; Dales et al., 2001; Madsen et al., 2002; Honda et al., 2005; Hornig et al., 2008). In 2004, 10 of Wakefield's co-authors on the 1998 paper withdrew their support for its conclusions. Furthermore, the editors of *Lancet*, the medical journal in which the paper was published, also withdrew their endorsement of the paper, citing a conflict of interest for Wakefield. Specifically, at the time of the paper's publication, Wakefield was conducting research for a group of parents of autistic children who were planning to sue MMR vaccine producers for damages (Murch, 2004). Britain's General Medical Council investigated Wakefield and ruled that he acted "dishonestly and irresponsibly" in doing his research, prompting the editors of *Lancet* to issue a full retraction of the 1998 paper (*Lancet*, 2010). According to epidemiologists, the autism "epidemic" of the past 10-15 years is best explained by changes in the way the disorder is diagnosed. It is now referred to as "autism spectrum disorder" and includes milder developmental disorders that had not been previously diagnosed as autism (Taylor, 2006). The issue of autism, and its purported association with certain vaccinations, is obviously a matter of public health.

While there is no shortage of opinion in the debate on whether the earth is warming and, if so, whether that warming is due to human activity, the issue of global warming and the role that humans play in the process is rarely presented as a public health concern. However, since the causes and potential consequences of increased global temperature are scientific issues, conclusions regarding those issues should be based on the best available empirically-collected data. The data, peer-reviewed and published in scientific journals, suggest that global warming is a fact (Dowdeswell, 2006; Overpeck et al., 2006), and the warming is most likely due to human activity (Sarmiento and Wofsy, 1999; Jordan, 2007). Published research indicates that the most likely cause of climate change is an acceleration of the greenhouse effect, with more solar energy being retained than is radiated back into space (Jordan, 2007). The acceleration is almost certainly a result of the increased production of greenhouse gases (primarily carbon dioxide) associated with the burning of fossil fuels (Sarmiento and Gruber, 2002; Epstein, 2004). Potential repercussions of increased global warming have also been addressed in the primary literature. A complete melting of the Greenland ice sheet would result in a sea level rise of approximately 22 feet (Church et al., 2001). Changes in the "oceanic conveyor belt," which governs both surface and deep water currents, could affect major regional climates. Consequently, current temperate areas could become much cooler (Stocker et al., 2001). Finally, climate change may produce profound consequences for public health. Warming trends can expand the geographic distribution of

infectious agents, and extreme weather events can spawn clusters of disease outbreaks. Diseases carried by mosquitoes are particularly sensitive to weather conditions. Warmer temperatures increase the insects' reproductive activity, protect their eggs and larvae from cold stress, and increase the rate at which pathogens mature within them. Extended droughts can devastate populations of insect predators (amphibians, dragonflies), and subsequent floods can contaminate clean water supplies and create new mosquito breeding sites, further encouraging transmission of diseases like malaria, dengue fever, and West Nile virus (Epstein, 2004).

Like global warming, the concept of evolution by natural selection is controversial in the eyes of the public. Furthermore, like global warming, the issue of evolution is rarely addressed as a matter of public health. There are many myths regarding the theory of evolution (i.e. it's just a theory, people come from monkeys, intelligent design is science, etc.). In some cases, the myths are perpetuated because evolution is misinterpreted or misrepresented by high school teachers, religious leaders, and the media (Smith and Sullivan, 2007). The theory of evolution is a fundamental, unifying theme in the sciences. Evidence supporting the theory is robust and widely accepted. There are literally thousands of research studies published over the last century and a half, the conclusions of which support it. The mechanism that drives the evolutionary process is best described by Charles Darwin's theory of evolution by natural selection. The concept of natural selection is based on the idea that individual organisms within populations vary in terms of physical characteristics. Due to the traits they express, some individuals will be better adapted to their local environments. Consequently, better adapted individuals will survive longer and will produce more offspring. The offspring will inherit adaptive traits, and the frequency of those traits will increase in the population. Evolutionary theory provides a framework within which many diverse concepts, including issues of public health, are integrated and explained. Since the 1940s, we have been fighting bacterial infections with antibiotics, toxins that destroy specific components of bacterial cells. Unfortunately, many bacterial strains have become resistant to the antibiotics that were toxic to them in the past. This is a classic example of natural selection. There is variation within any bacterial population. Some individuals will be slightly more resistant to treatment than others. Antibiotics (especially when overused or used inappropriately) will kill most, but not all, individuals in the bacterial population. Consequently, the most resistant bacteria will survive and reproduce, and the "resistance" characteristic will become more prevalent (Ewald, 1994). Effects of natural selection can also be seen in human populations. Sickle-cell disease is a genetic

disorder that affects red blood cells. People suffering from sickle-cell disease have difficulty transporting oxygen through the circulatory system. In the United States, sickle-cell disease is much more common in African Americans than in the general population. Roughly 10% of all African Americans are carriers of the sickle-cell trait. Why? In tropical Africa, where malaria is a major cause of death, it is actually advantageous to be a carrier of the sickle-cell trait. The abnormal red blood cells do not make good hosts for malaria-inducing microorganisms. Therefore, Africans who carry the sickle-cell trait are more likely to survive and reproduce, ensuring that the sickle-cell condition is passed to future generations (Allison, 2004; Harris and Malyango, 2005).

The public, in general, believes that science benefits society, particularly in the arena of healthcare. Even though disproportionate media coverage has been given to the anti-vaccine movement, public support of childhood vaccination continues. However, although the evidence supporting anthropogenic global warming is more than ample, and the evidence supporting evolution by natural selection is overwhelming, the general public has yet to fully embrace these concepts. The current study explores the hypothesis that individuals will become more receptive to scientific viewpoints if the evidence for evolution and the implications of global warming are presented as issues of public health.

METHODS

In accord with official guidelines regarding research and educational practices involving human participants, this study was classified as “exempt from review” by the Institutional Review Boards of Davis & Elkins College (D&E) and Lenoir-Rhyne University (LR).

Student Profile

During the fall semester of 2009 and the spring semester of 2010, a total of 227 students, 69 from D&E and 158 from LR, participated in the study. Both institutions are small, private, liberal arts colleges located in the southeastern United States. Students were enrolled in either Basic Biology for non-science majors (n=87), Microbiology for allied health majors (n=77), or Principles of Biology II for science majors (n=63). At both institutions, Basic Biology has no prerequisites, Microbiology has a two-semester sequence of human anatomy and physiology as a prerequisite, and Principles of Biology II has Principles of Biology I as a prerequisite. Basic Biology students at both institutions were non-science majors, a majority of whom were underclassmen. Microbiology students at both institutions were almost exclusively nursing or pre-nursing majors, while Principles of Biology II students at both institutions were second-semester freshman biology majors. The courses were taught very similarly at the two institutions. Author MLM

developed all three courses at D&E before moving on to LR. Authors LBM and SKS took over teaching the three courses at D&E, using syllabi, PowerPoint slides, and exams from previous semesters to follow the format established by MLM.

Pretest

Each course, at both institutions, incorporated three lecture exams, plus a final exam. Spacing between exams was fairly consistent between courses and institutions. Survey questions used for this study were attached to the exams. Completion of the survey questions was voluntary and had no effect on students' exam grades. As part of their first exam, early in the fall semester of 2009 or the spring semester of 2010, students answered the following Yes/No questions regarding autism, global warming, and natural selection: Do you believe that the MMR (mumps-measles-rubella) vaccine is responsible for the significant increase in diagnosed cases of autism over the last 10-15 years? Do you believe that global climate change, if left unchecked, will have devastating effects on human populations? Do you believe that Charles Darwin's theory of evolution by natural selection adequately explains how living organisms change over time? The autism question served as a positive control, as it obviously deals with an issue of public health. Authors SKS and MLM categorized the student responses from both institutions as either “evidence-based” or “non-evidence-based.” “Evidence-based” answers were deemed consistent with current scientific information. An answer of “No” to the question regarding a potential link between autism and the MMR vaccine was considered “evidence-based.” “Yes” answers to the questions regarding the impact of global warming on human populations and natural selection as an adequate explanation for biological change over time were also considered “evidence-based.”

Post-test

Attached to subsequent exams, the same questions were presented separately to students in the three classes. Autism was addressed in a survey attached to the second exam, global warming was addressed with the third exam, and evolution was addressed at the time of the final. Of the three topics highlighted by the current study, evolution by natural selection was the only one covered (to varying degrees) in each of the three classes. In these later presentations, the survey questions were preceded by paragraphs summarizing relevant scientific data. For the global warming and evolution questions, the presented data were specifically related to public health. Students were asked to justify their Yes/No responses to the questions by answering “Why?” Totals of 214, 216, and 214 students provided complete answers to the autism, global warming, and natural selection questions, respectively. Authors SKS and MLM evaluated the student responses from

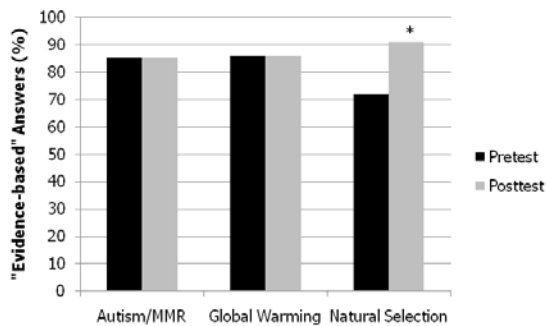


Fig. 1. Percentages of “evidence-based” responses by Basic Biology students (*Significantly different from pretest, $P < 0.05$).

both institutions. As in the pretest, Yes/No responses were categorized as either “evidence-based” or “non-evidence-based.” It is possible that students could provide an “evidence-based” response for the “wrong” reason. For example, an individual might agree that the global climate is changing (an “evidence-based” response), but his/her conclusion might be based solely on the opinion of a popular political candidate (anecdotal evidence). Therefore, “evidence-based” rationales were subcategorized as being based on the evidence presented in the survey, based on evidence that was not presented in the survey, based on anecdote, or based on misinterpretation. Remaining miscellaneous “evidence-based” rationales were subcategorized as “other.” “Non-evidence-based” rationales were subcategorized as being based on anecdote or based on misinterpretation. Remaining miscellaneous “non-evidence-based” rationales were subcategorized as “other.”

Statistics

In an effort to ensure inter-rater reliability, Cohen's Kappa coefficient (κ) was calculated for the categorical evaluation of student rationales. $\kappa > 0.75$ was considered reliable (Portney and Watkins, 2000). Differences between the two institutions (pretest and post-test responses) were determined via analysis of variance (ANOVA). Furthermore, for each of the three classes, differences between pretest and post-test responses to the three survey questions were tested by univariate, repeated measures ANOVA. $P < 0.05$ was considered statistically significant.

RESULTS

Pretest “evidence-based” responses are presented in Figures 1-3. These figures represent combined responses from both institutions. No significant differences were found between the two institutions or among the three classes. In each class, at least three quarters of participating students (75-86%) selected the “evidence-based” responses for the autism and global warming pretest questions, whereas about two thirds of participating students (61-72%) in each class selected the “evidence-based” response for the natural selection pretest question.

There was one significant difference within one of the groups. The Principles of Biology class from D&E had a significantly higher percentage of “evidence-based” responses than the corresponding LR class (87% vs. 63%). The exact reason for this difference is unclear. While both classes consisted of second-semester freshman biology majors, it should be noted that the D&E class ($n=15$) was considerably smaller than the corresponding class at LR ($n=48$).

Post-test “evidence-based” responses are also presented in Figures 1-3. Again, no significant differences were found between the two institutions or between the three classes. In each class, at least 80% of participating students provided “evidence-based” responses for the autism, global warming, and natural selection post-test questions. Only the natural selection question produced post-test responses that were significantly different from pretest responses. There were significantly more post-test “evidence-based” responses to the natural selection question in all three classes.

Student rationales for post-test responses are presented in Tables 1 and 2. The data are presented as a percentages of the total number of students (all three classes combined) providing “evidence-based” (Table 1) and “non-evidence-based” (Table 2) responses to each question. Examples of representative rationales are provided. Inter-rater reliability (κ) was calculated as 0.89, 0.84, and 0.83 for the autism, global warming, and natural selection rationales, respectively. No significant differences were found between the three classes. Academic background and interest in science aside, non-science majors, freshman biology majors, and nursing students provided “evidence-based” responses to the three questions with roughly the same frequency and rationalized their choices in much the same way. Furthermore, each question elicited “evidence-based” responses with about the same frequency and with very similar rationales.

As indicated by Table 1, 60% of participating students justified a post-test “No” to the autism question by citing the evidence that had been presented to them. Another 16% cited evidence that

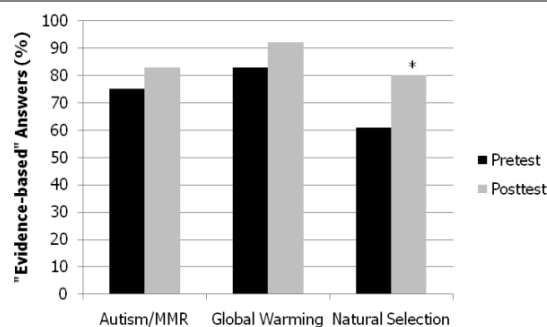


Fig. 2. Percentages of “evidence-based” responses by Microbiology students (*Significantly different from pretest, $P < 0.05$).

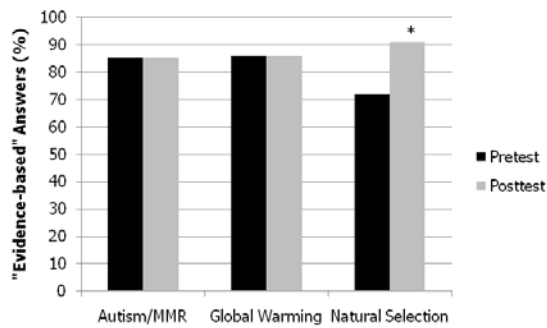


Fig. 3. Percentages of “evidence-based” responses by Principles of Biology students. *Significantly different from pretest ($P < 0.05$).

was not included in the survey as a rationale. Of this other evidence, genetic factors were cited most frequently as likely causes of autism. A few students elected to describe personal experiences, or anecdotes. Others simply misinterpreted the question, providing rationales that directly conflicted with their “No” responses. As indicated by Table 2, a small percentage of participating students misinterpreted the autism question, answering “Yes” while giving a conflicting rationale. Some students justified a “Yes” response by claiming that all vaccines are either unnecessary or harmful, and a few others resorted to anecdote.

As indicated by Table 1, 57% of participating students justified a post-test “Yes” to the global warming question by citing the evidence that had been presented to them. Another 20% cited evidence that had not been included in the survey as a rationale. Of this other evidence, melting ice caps and rising sea levels were cited most frequently as likely consequences of climate change that could devastate human populations. To justify a post-test “No” to the global warming question, some participating students stated that humans will be able to successfully adapt to climate change. Others justified a “No” response by claiming that the current

warming trend is simply part of a natural cycle. A very small percentage of the surveyed students provided anecdotal responses.

As indicated by Table 1, 57% of participating students justified a post-test “Yes” to the natural selection question by citing the evidence that had been presented to them. Another 18% cited evidence that had not been included in the survey as a rationale. Of this other evidence, teleological reasoning was offered most frequently as an explanation for adaptation. To justify a post-test “No” to the natural selection question, some participating students referred to anecdotal evidence, and a few others cited a conflict between Christianity and Darwin’s theory.

DISCUSSION

As stated in the introduction, the current study explores the overall hypothesis that individuals will become more receptive to scientific viewpoints if evidence is presented in the context of public health. The autism question was, essentially, a positive control. Regardless of one’s opinion on the connection between autism and the MMR vaccine, it is clearly a public health issue. A large majority of students (85% of Basic Biology, 75% of Microbiology, and 84% of Principles of Biology) answered “No” to the pretest question regarding autism, indicating they do not believe there is a connection between the MMR vaccine and the developmental disorder. A summary of the Wakefield study and its aftermath preceded the autism question on the post-test. Knowledge of the conflict of interest accusation, the withdrawal of support by Wakefield’s co-authors, and the failure of other studies to replicate his data, did not significantly affect student responses (Figures 1-3). As indicated earlier, the autism question clearly represents a public health issue and requires no “framing” as such.

Table 1. Percentages of “evidence-based” post-test rationales and representative examples.

	Autism/MMR	Global Warming	Natural Selection
Based on evidence presented in survey	60% ; “The original study cannot be supported by subsequent studies.”	57% ; “Warmer temperatures increase the disease-carrying abilities of certain insects.”	57% ; “It explains why individuals with advantageous traits survive and pass the traits on to their offspring.”
Based on evidence not presented in survey	16% ; “The only link between the two is the sudden spike in autism cases occurring after routine vaccinations.”	20% ; “Due to the warmer climate, ice caps are melting, dumping fresh water into our oceans.”	18% ; “There is evidence in the fossil record, embryological structures, and comparative DNA.”
Based on anecdote	2% ; “I had the MMR vaccine, and I didn’t get autism.”	2% ; “Every time I tune in to the Discovery Channel, they seem to be talking about global warming.”	3% ; “Working in forestry, I have witnessed the products of natural selection.”
Based on misinterpretation	2% ; “If the vaccine is supposed to help with autism, then it couldn’t cause autism.”	1% ; “The paragraph addresses a few of the positive effects of climate change. However, the negatives outweigh the positives.”	3% ; “It’s just a theory. Those pathogens probably had the resistant gene from the beginning.”
Other	4%	5%	5%

Table 2. Percentages of “non-evidence-based” post-test rationales and representative examples.

	Autism/MMR	Global Warming	Natural Selection
Based on anecdote	3%; “I have always heard that a vaccine is linked to autism.”	2%; “I listen to information. I just don’t always believe the facts I hear.”	5%; “The fossil record isn’t nearly as complete as scientists would like you to believe.”
Based on misinterpretation	5%; “If they withdrew because of a conflict of interest, red flags go up.”	1%; “Effects from the Earth are going to impact human populations.”	1%; “Bacteria have become resistant to antibiotics because they have been overused.”
Other	8%; “In general, I think that vaccines can be harmful.” “If autism rates went up after vaccines were given, there must be a connection.”	12%; “The current warming trend is just part of the natural climate cycle.” “Humans will be able to adapt to the changing climate.”	8%; “As a Christian, I cannot accept the theory of evolution.” “I believe that factors other than natural selection are more important for adaptation.”

One specific aim of the current study was to explore the hypothesis that individuals will become more receptive to the current scientific consensus on global warming if the implications of climatic changes are presented as issues of public health. Consistent with the PRCPP national poll, roughly 85% of all participating students acknowledge that the earth is warming. Eighty-six percent of Basic Biology, 83% of Microbiology, and 76% of Principles of Biology students answered “Yes” to the pretest question regarding global warming, indicating they do believe that unchecked climate change will have devastating effects on human populations. A summary of potential climate change-related consequences for public health preceded the global warming question on the post-test. Knowledge of an expanded distribution of infectious agents, weather-related disease outbreaks, and contaminated clean water supplies did not significantly affect student responses (Figures 1-3). Apparently, the presentation of global warming as a public health issue is not sufficient to change the perceptions of global warming deniers. It is interesting to note that a small number (roughly 3%) of participating students justified a “No” response to the global warming question by claiming that the current warming trend is simply part of a natural cycle. This is in stark contrast to the 36% of surveyed adults in the national poll who believe that the warming is part of a natural cycle. Deniers of anthropogenic global warming have suggested that solar cycles might be responsible for the warming process. However, published data refute this hypothesis (Ramaswamy et al., 2001; North et al., 2004). There is also speculation that natural cycles of the earth itself might be responsible for the change in global temperature. The El Niño Southern Oscillation might play a role, but there is no convincing evidence to support it (Stocker et al., 2001).

Another specific aim of the current study was to explore the hypothesis that individuals will become more receptive to the current scientific consensus on evolution if the evidence for natural selection is presented as an issue of public health. Sixty-one percent of surveyed adults in the PRCPP national poll acknowledge the evolution of living organisms, while

only 32% agree that evolution is due to the process of natural selection. In the current study, 72% of Basic Biology, 61% of Microbiology, and 69% of Principles of Biology students answered “Yes” to the pretest question regarding natural selection, indicating they do believe that Darwin’s theory adequately explains how living organisms change over time. Public health-related examples of natural selection preceded the natural selection question on the post-test. Knowledge of the evolution of antibiotic resistance and the population genetics of sickle-cell trait expression significantly affected student responses (Figures 1-3). Most students (57%) rationalized a “Yes” response to the natural selection question by citing the public health-related information that had been presented in the survey. Some students (18%) cited other evidence for evolution by natural selection, including the fossil record, homologous anatomical structures, and DNA sequencing. It is interesting to note that teleological reasoning was offered quite frequently as an explanation for biological adaptation. A teleological description of a biological structure or function implies that any benefit derived from the structure or function is a sufficient reason for its existence, negating the impact of variation. Natural selection, to individuals with this perspective, is a process by which nature selects individuals who are in need to become beneficiaries of helpful changes (Greene, 1990). Previous research has demonstrated that even upper level biology majors can fall into a teleological mode of thinking (Stover and Mabry, 2007).

Both global warming and evolution are matters of science, and conclusions regarding these matters must be based on empirical evidence. The intent of our study was to emphasize the aspects of evolution and global warming that are relevant to human health in an attempt to capitalize on the public’s respect for healthcare-related science. On the topic of global warming, it appears that our efforts to emphasize public health did not have an impact on students’ ability or willingness to draw an evidence-based conclusion about this issue. A large majority of the surveyed students were already convinced that global warming is real, that it is a result of human activity, and that, if left unchecked, it will have devastating

consequences on human populations. In terms of evolution, our approach seemed to be much more effective. There were significantly more post-test “evidence-based” responses to the natural selection question in all three classes, even after subtracting responses with “misinterpretation” rationales. While it is possible that other explanations exist for this increase, including coverage of evolutionary topics in each of the three classes, presentation of the issue with a public health perspective is a possible reason for the difference we saw. The majority of “evidence-based” rationales were related to antibiotic resistance and other public health concerns. Thus, these results suggest that, by presenting evidence in the context of public health, it may be possible to convince “antievolutionists” or those who doubt the relevance of natural selection in the evolution of organisms that there is merit in the scientific viewpoint. Given that the public health perspective did not influence the frequency of “evidence-based” post-test responses to the global warming question, however, more research is needed to determine the number and range of issues for which one might successfully use the public health perspective strategy for getting students to see the merit of scientific evidence.

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