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Nature of Science Conceptions, Attitudes towards Evolution and Global Climate Change, and Course Achievement in an Introductory Biology Course

Benjamin Elijah Carter

Abstract

Many researchers have studied student attitudes toward and knowledge of evolutionary science, attitudes towards global climate change (GCC), conceptions about the nature of science (NOS), and course success. However, at the time of this writing, no studies explicitly link these topics.

It is overwhelmingly acknowledged by the scientific community that evolution and global climate change (GCC) are undeniably supported by physical evidence. And yet, both topics remain very politically contentious in the United States. Efforts to mitigate the disconnects between the scientific community and the general public on these issues are imperative to science education. Such undertakings need to examine students' conceptions of the nature of science (NOS), how evidence is treated, how theories are constructed, and how scientific consensus is reached, as these may be key factors in acceptance of evolution and GCC. If students have a more thorough understanding of the weight behind scientific consensus and better tools to discern scientific versus non-scientific arguments, they may become more likely to accept strongly supported scientific ideas. Our study explored this hypothesis guided by the following questions: Do changes in NOS conceptions correlate with changes in attitudes towards evolution or GCC? If there are correlations, are they similar for evolution and GCC? What demographic factors affect these correlations? Further, we asked whether attitudes towards evolution before the course began was a significant predictor of achievement in the course.

Previously-developed tools were used to measure students' conceptions of the nature of science and attitudes towards evolution, while national public opinion poll questions were used to measure attitudes towards GCC. Demographic questions were produced to target factors thought to influence attitudes towards evolution or global climate change. Overall sample size was N=620. Principle Components Analysis was used to determine which variables accounted for the most variation, and those variables were analyzed using correlation tests, ANOVA, and ANCOVA to test for significant correlations and interaction effects.

Changes in students' attitudes towards evolution and global climate change were both positively correlated with shifts in conceptions about the nature of science. Attitudes towards evolution were negatively correlated with religiosity. Knowledge of evolutionary science was positively correlated with attitudes towards evolution, but knowledge about GCC was not significantly correlated with attitudes towards GCC. The strongest correlates of GCC attitudes were political leanings.

Findings support the hypothesis that a better understanding of NOS may lead to changes in attitudes towards politically contentious ideas that are not scientifically contentious. Though attitudes towards evolution correlated strongly and significantly with a number of other factors including knowledge of evolutionary science and religiosity, expected non-political correlates with attitudes towards GCC were absent. Giving students a good conception of the modern nature of science may lead to views that are closer to those of the scientific community. This study provides novel evidence of a linkage between student acceptance of evolution and attitudes towards GCC, i.e., NOS conceptions. We also found highly significant, positive relationships between student knowledge of evolution and attitudes toward evolution as well as between introductory biology course achievement and both pre-course acceptance of evolution and pre-course knowledge of evolution among students at Syracuse University, and assert that teachers who scant the teaching of evolution or who do not foster good attitudes toward evolution are not helping their students to prepare for success in science at the college level.

Nature of Science Conceptions, Attitudes towards Evolution and Global Climate Change, and Course Achievement in an Introductory Biology Course

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First and foremost, I owe so much of my success in graduate school to my advisor, Jason Wiles. Without his willingness to take me on as a student, a decision which was politically risky at the time, there really is no telling where I would be today. Jason gave me a chance, and I am so grateful for it.

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Chapter 1- Review of recent literature on evolution and global climate change and how each relates to science education and the nature of science

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Abstract

It is overwhelmingly acknowledged by the scientific community that evolution and global climate change (GCC) are undeniably supported by physical evidence. And yet, both topics remain very politically contentious in the United States. Efforts to mitigate the disconnects between the scientific community and the general public on these issues are imperative to science education. Such undertakings need to examine students' conceptions of the nature of science (NOS), how evidence is treated, how theories are constructed, and how scientific consensus is reached, as these may be key factors in acceptance of evolution and GCC. If students have a more thorough understanding of the evidence required for scientific consensus and better tools to discern scientific versus non-scientific arguments, they may become more likely to accept strongly supported scientific ideas.

The Status of Evolution as a Science

As defined by the textbook that student respondents in this study used, Campbell *Biology* (2011), evolution is "the process of change that has transformed life on Earth from its earliest beginnings to the diversity of organisms living today" (p. 1). Biologists and life science educators have long known that "nothing in biology makes sense except in light of evolution" (Dobzhansky, 1973). Evolution is supported by evidence from many sources, from embryology to geology, and has been directly observed. There exists no alternative scientific explanation for changes within species or the origin of new species (American Institute of Biological Sciences, 1994). Evolution is widely regarded as a central and unifying theme in the biological sciences, and is presented as such in most modern biology texts (Wiles, 2010). Within the scientific community, there is debate over the relative impacts of the known mechanisms by which evolution occurs, but none over whether or not it has occurred or continues to happen.

The Politicization of Evolution

Evolutionary science has been under more or less continuous political attack since Darwin's explanation of evolution by natural selection became widely known in 1859. Early opponents of evolutionary science were mainly clergy (e.g., bishop Samuel Wilberforce), but also included members of the scientific community (e.g., paleontologist Richard Owen) (Moore, 1991). In the 21st century, however, evolution has been overwhelmingly accepted by the scientific community (Wiles, 2010), but it remains a hotly-debated political topic, especially regarding its role in science education (Mooney & Nisbet, 2005). Members of the public are often unable to differentiate between political and scientific controversy, as despite scientific consensus, political leanings have been shown to influence acceptance of evolution (Allmon, 2011; Hawley et al., 2010) which has lead to lower rates of acceptance of evolution in the United States as compared to countries in which the issue is less politicized (Miller et al., 2006). Acceptance of evolution is thought to affect student achievement (Wiles & Alters, 2011), though some may disagree based on the differences among knowing; understanding; and believing (Smith, 2009; Southerland et al., 2001), it is nonetheless important to discuss the status of evolution in education.

The Status of Evolution in Education

Perhaps when school boards are elected just as politicians are, it is inevitable that political controversy will spill over into the classroom. Randy Moore and colleagues have written a very thorough chronology of court cases related to creationism and evolution in the United States in *Chronology of the evolution creationism controversy* (2010). Among the important events in this history were John Scopes' 1923 conviction for teaching evolution, banned in Tennessee by the Butler Act, the subsequent rejection by the U. S. Supreme Court of the banning of evolutionary instruction in *Epperson v. Arkansas* in 1968, the downfall of "balanced treatment" of so-called "creation science" and evolution as the former was declared unscientific in 1982 in *McLean v. Arkansas*, and Louisiana's "Creationism Act," that forbade the teaching of evolution except when accompanied by instruction in "creation science," which was declared unconstitutional by the U.S. Supreme Court in *Edwards v. Aguillard* in 1987.

Evolution has since become regarded as a cornerstone for education in biology, and is incorporated into the US national standards for grade school biology (National Research Council, 1996; Nqss Consortium Of Lead States, 2013(Short & Hawley, 2012)) and has long been considered to be an important part of scientific literacy (American Association for the Advancement of Science, 1990, 1993; National Research Council, 1996). Evolution is also considered to be integral in higher education in the biological sciences (Alters & Nelson, 2002; College Board, 2013).

The controversy continues, however. After the teaching of creation science was declared unconstitutional, creationist opponents to the teaching of evolution began to concoct a more “scientific” sounding alternative to evolution that they called, Intelligent Design (ID). As with creation science, bills encouraging the inclusion of ID in curricula do so to help students “develop critical thinking skills” by “teaching the controversy” (Brumfiel, 2005; Mervis, 2011). ID advocacy groups have celebrated the passage of “teach the controversy” bills in two US states, Louisiana and Tennessee, in the past several years (Thompson, 2012) despite opposition from such groups as the National Center for Science Education.

Factors Affecting Acceptance of Evolution

There are a number of factors that are thought to affect students' acceptance of evolution, which can be grouped into non-religious and religious factors (Alters & Alters, 2001; Wiles & Alters, 2011). Per Wiles and Alters (2011) in which they are discussed in greater depth, they may include the following:

Non-religious factors

- Scientific factors
  - Overall knowledge of evolutionary theory
  - Knowledge of evolutionary evidence
  - Uncertainty about the origin of life
  - Understanding of evolutionary mechanisms and patterns
  - Understanding of the nature of science
- Non-scientific factors
  - Social and emotional factors (e.g., personal relationships, authorities, fear or discomfort with perceived implications of evolution)
  - Critical thinking skills, epistemological views, and cognitive dispositions
  - Demographic factors (e.g., academic standing, political leanings)

Religious factors

- Perception that religious belief and acceptance of evolution are mutually exclusive
- Literal interpretation of scripture
- Creationist convictions
- Labeling of religious doctrine as scientific (e.g., “creation science” and ID)

A number of studies have shown that directly addressing the misconceptions about evolution that can result from these factors (or indeed be intentionally perpetuated by creationist groups) can lead to increased acceptance of evolution (Ingram & Nelson, 2006; Matthews, 2001; McKeachie et al., 2002).

Measuring Acceptance of Evolution

A number of tools exist to measure understanding and/or acceptance of evolution (Hawley et al., 2010; Rutledge & Warden, 1999 Short & Hawley, 2012). A particularly useful tool is the measure of acceptance of the theory of evolution instrument, or MATE (Rutledge & Warden, 1999). The MATE has been validated and implemented in studies involving high school teachers, university students (Rutledge & Sadler, 2007), and high school students (Wiles & Alters, 2011), and has been shown to be reliable and to compare favorably with other instruments.

Evolution and the Nature of Science

It has been suggested in a number of studies that increasing students' understanding of the nature of science (NOS) may enhance their acceptance of evolution (Allmon, 2011; Dagher & BouJaoude, 1997; Rudolph & Stewart, 1998; Sinatra, et al., 2003; Smith, 2009; Southerland et al., 2001). NOS describes the philosophy of science, that is, how scientific knowledge is generated and how science progresses. Key concepts of NOS include the lack of a unified stepwise scientific method, the role of the scientific community in the generation of scientific knowledge, the theory laden nature of observation and experimentation, and the fact that scientific theories are durable yet subject to change upon revelation of enough contrary evidence (Grinnell, 2009). Increasing NOS understanding is important in science education in general, as evidenced by its inclusion in the national science education standards (National Research Council, 1996), but is predicted to increase acceptance of evolution as students learn about how evidence is considered and the role of consensus in the scientific community. Though many authors suggest that NOS understanding plays a role in the acceptance of evolution, we have found no study that has empirically examined correlations between changes in NOS understanding and acceptance of evolution. Further research is required to determine whether a quantifiable correlation exists and whether the relationship is positive as predicted.

The Status of Global Climate Change in Science

While it was once contentious among scientists, the vast majority of scientists now agree on many aspects of global climate change (GCC): that it is occurring, 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 (National Research Council, 2010; Vitousek, 1994; IPCC, 2007; IPCC, 2013; Nqss Consortium Of Lead States, 2013). 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; IPCC, 2013). Consensus across so many scientific, political, and idealogical borders is unprecedented and may speak to the importance of the issues associated with GCC.

The Politicization of Global Climate Change

Like evolution, GCC is a much more contentious issue politically than it is scientifically. In fact, a recent article in EARTH magazine notes that the political groups and organizations touting creationism (as noted above, creationists are the main opponents of evolution education) and climate change denial are often the same (Newton, 2012). GCC has been a common subject in national polls over the last twenty years (Nisbet & Myers, 2007), and these data have been used extensively to document how concern over GCC correlates with different demographic factors, especially whether respondents identify as democrats, republicans, or independents. GCC has been found to be extremely politicized (McCright, 2010a). Studies have shown that the gap in GCC concern between democrats and republicans has increased markedly over the last ten years (Dunlap & McCright, 2008; McCright & Dunlap, 2011a). Conservative white males have been shown to be the most likely demographic to deny GCC (McCright & Dunlap, 2011b). Somewhat surprising is the presence of strong interaction effects between knowledge about climate change and political identification. That is, in democrats GCC concerns increase along with knowledge of GCC, but the same relationship in republicans is weak to negative (Hamilton, 2011). The politicization of GCC is most prevalent in the U.S., with cross-national surveys indicating that in most other industrialized nations the views on GCC are much more closely aligned with those of the scientific community (Dispensa & Brulle, 2003; Kvaloy et al., 2012).

The Status of Global Climate Change in Education

GCC is second only to evolution in topics that educators are unlikely to bring up due to discomfort or fear of controversy (Reardon, 2011). Like evolution, however, GCC has been proposed as a central focus in science education because of the evidence-based scientific consensus behind it coupled with the need for societal action to mitigate its effects (Sharma, 2012). This view is shared by many within the science education community; in 2012 the National Center for Science Education (NCSE), historically a group with the goal of defending the teaching of evolution, added climate change education to its mission. Because attacks on climate change, like those on evolution, rely on misrepresenting the controversy over the issue as scientific rather than political, the NCSE and other groups are concerned that "teach the controversy" bills will affect education on both issues (Mervis, 2011). Strategies for GCC education are still developing, perhaps because it is a much more recent concept than evolution (Cordero, Todd, & Abellera, 2008; Manolas & Filho, 2011; Matkins & Bell, 2007; McNeill & Vaughn, 2012; National Research Council, 2010; Shepardson, Niyogi, Roychoudhury, & Hirsch, 2012; Svihla & Linn, 2012). The fact that many students and members of the public get most of their knowledge about GCC from the media is additionally problematic, because even the media have problems differentiating between scientific and political controversy, and evolution and climate change deniers often actively craft their arguments to appear scientific, thereby encouraging this confusion (Dispensa & Brulle, 2003). Thus, it has been suggested that training in media literacy, specifically how to critically analyze media coverage to determine sources, bias, etc., should be an active pursuit in improving understanding and acceptance of GCC (Cooper, 2011).

Factors Affecting Global Climate Change Acceptance

For GCC, acceptance is not a term that is commonly used in the literature (though denial is frequently used). The data on climate change conceptions are almost entirely from national surveys, which frame their questions as a sliding scale of concern. However, a number of demographic factors have been shown to correlate with views on GCC. These factors include the following (Borick & Rabe, 2012; Hamilton & Keim, 2009; Hamilton, 2011; Marquart-Pyatt et al., 2011; McCright & Dunlap, 2011b, 2011b; McCright, 2010a, 2010b; Nisbet & Myers, 2007):

Scientific factors

- Knowledge about GCC (either measured or self-declared)

Non-scientific factors

- Religiosity
- Demographic factors
    - Political leanings/Party identification
    - Education level
    - Gender (weak but significant correlation)
    - Age
    - Region of residence

The abundance of correlations demonstrates that GCC is a very complex issue, with even regional variation in perceptions (Hamilton & Keim, 2009). One study even found that the presence of healthy vs dead plants in the room in which the survey is administered has a significant effect on GCC concerns (Guéguen, 2012).

Measures of Global Climate Change Acceptance

There is no validated measure for climate change as there is with evolution, but there are many survey questions available to measure variables related to GCC. Important questions include, of course, on whether or not GCC is occurring, the danger it presents, and whether or not it is mainly caused by humans, but also respondents' views on what scientists believe and what groups or individuals (i.e., climate scientists, television meteorologists, presidential candidates) are trusted sources of information on GCC (Borick & Rabe, 2012; Leiserowitz, Maibach, Roser-Renouf, & Hmielowski, 2012). Coupling these questions with self reported knowledge of GCC and questions to evaluate actual knowledge of the science will give an adequate representation of respondents' views.

Climate Change and the Nature of Science

Only one study has directly linked NOS understanding and GCC. The authors found that after receiving explicit instruction in both GCC and NOS, education students showed increased understanding of both. The authors state that explicit NOS instruction had a positive effect on NOS understanding as well as complex issues of GCC (Matkins & Bell, 2007), but given the nature of the study, it is likely impossible to establish NOS instruction as the causal agent of

GCC understanding rather than the extensive GCC study also given to the study subjects. A number of the teaching strategies that have been suggested involve some aspect of NOS, whether it be teaching students the ability to differentiate between scientific and non-scientific items in the media (Cooper, 2011) or teaching about how research programs on GCC are put together including how models are developed (Manolas & Filho, 2011). NOS understanding may play a role in forming students' opinions on GCC, but further research on the topic is clearly warranted.

Measures of Nature of Science Understanding

A number of instruments have been developed to assess NOS understanding in students and educators (Coburn, 2000; Norm G. Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). Unfortunately, the most thoroughly validated among these, the Views on the Nature of Science (VNOS) questionnaire, does not yet have a multiple choice form (Norm G. Lederman et al., 2002), making it difficult to use in any study with a large sample size. The leading multiple choice tool for determining NOS understanding is the Thinking about Science Survey Instrument (TSSI) (Coburn, 2000), which measures the effects of socio-cultural factors on how science is viewed.

Areas of Overlap

Since a number of the factors described in the literature as affecting or potentially affecting attitudes towards both evolution and GCC have to do with how individuals conceive of science itself, it seems likely that positive correlations would exist between a measure of NOS conceptions and measures of student attitudes towards evolution and GCC. Therefore, the following chapter seeks to elucidate whether or not this is the case, and what other important factors may be influence student attitudes. Chapter 3 details a separate important finding, that students' pre-course attitudes towards evolution are significantly correlated with their achievement in the course.

Chapter 2- Scientific consensus and social controversy: exploring relationships between students' conceptions of the nature of science, biological evolution, and global climate change

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Abstract:

It is overwhelmingly acknowledged by the scientific community that evolution and global climate change (GCC) are undeniably supported by physical evidence. And yet, both topics remain politically contentious in the United States. It is thought that students' conceptions of the nature of science (NOS) may be key factors in their attitudes towards evolution and GCC. Our study explored this hypothesis guided by the following questions: Do changes in NOS conceptions correlate with changes in attitudes towards evolution or GCC? If there are correlations, are they similar for evolution and GCC? What demographic factors affect these correlations?

Previously developed tools were used to measure students' conceptions of the nature of science and attitudes towards evolution, while national public opinion poll questions were used to measure attitudes towards GCC. Demographic questions were produced to target factors thought to influence attitudes towards evolution or global climate change. Overall sample size was N=620. Principle Components Analysis was used to determine which variables accounted for the most variation, and those variables were analyzed using correlation tests, ANOVA, and ANCOVA to test for significant correlations and interaction effects.

Changes in students' attitudes towards evolution and global climate change were both positively correlated with shifts in conceptions about the nature of science. Attitudes towards evolution were negatively correlated with religiosity. Knowledge of evolutionary science was positively correlated with attitudes towards evolution, but knowledge about GCC science was not significantly correlated with attitudes towards GCC. The strongest correlates of GCC

attitudes were political leanings.

Findings support the hypothesis that a better understanding of NOS may lead to changes in attitudes towards politically contentious ideas that are not scientifically contentious. Though attitudes towards evolution correlated strongly and significantly with a number of other factors including knowledge of evolutionary science and religiosity, expected non-political correlates with attitudes towards GCC were absent. Giving students a good conception of the modern nature of science may lead to views that are closer to those of the scientific community. This study provides novel evidence of a linkage between student acceptance of evolution and attitudes towards GCC, i.e., NOS conceptions.

Background:

Evolution has been defined, broadly and narrowly, as the fact that the living organisms of today differ from those of the past, the evidence-based inference that the diversity we now see has arisen via descent with modification from an ancient ancestry, and the organic mechanisms though which biological change occurs (Eldredge, 2005; Gould, 1981; Scott, 2004; Wiles & Alters, 2011). As it is defined in the textbook assigned to the student-participants in this study, evolution is "the process of change that has transformed life on Earth from its earliest beginnings to the diversity of organisms living today" (Urry et al., 2011). Biologists and life science educators have long known that "nothing in biology makes sense except in light of evolution" (Dobzhansky, 1973). Evolution is supported by evidence from many sources, from genetics to embryology to geology, and it has been directly observed in numerous species in laboratories and in nature. There are no scientifically supported, evidence-based alternative explanations for changes within species or the origin of new species. Evolution is widely regarded as a central and unifying theme in the biological sciences, and it is presented as such in most modern biology texts (Wiles, 2010). Within the scientific community, there is debate over the relative impacts of the known mechanisms by which evolution occurs, but none over whether or not evolution has occurred or continues to happen.

Although evolution has been overwhelmingly accepted by the scientific community (Wiles, 2010), evolutionary science has been under essentially continuous social attack even since before Darwin's explanation of evolution by natural selection became widely known in 1859 (Moore, 1991). And it remains a hotly-debated political topic, especially regarding its role in science education (Mooney & Nisbet, 2005; Wiles, 2010). Members of the general public are often unable to differentiate between political and scientific controversy, as despite scientific consensus, political leanings have been shown to influence acceptance of evolution (Allmon, 2011; Hawley et al., 2010) which has lead to lower rates of acceptance of evolution in the United States as compared to countries in which the issue is less politicized (Miller et al., 2006). It has been suggested that acceptance of evolution may be linked to student achievement (Wiles and Alters 2011), though some may disagree citing the differences between knowing; understanding; and believing (Smith, 2009; Southerland et al., 2001), but it is nonetheless important to discuss the status of evolution in education.

Randy Moore and colleagues have written a very thorough chronology of court cases related to creationism and evolution in the United States in *Chronology of the Evolution Creationism Controversy* (Moore et al., 2010). Among the important events in this history were John Scopes' conviction for teaching evolution, banned in Tennessee by the Butler Act; the subsequent rejection by the U. S. Supreme Court of the banning of evolutionary instruction *in Epperson v. Arka*nsas; the downfall of “balanced treatment” of so-called “creation science” and evolution; and the federal overturning of Louisiana's “Creationism Act,” which forbade the teaching of evolution except when accompanied by instruction in “creation science,” *in Edwards v. Aguill*ard.

Evolution has since become regarded as a cornerstone for education in biology, and is incorporated into the US national standards for grade school biology (National Research Council, 1996, p. 96; Nqss Consortium Of Lead States, 2013). Evolution has long been considered to be an important part of scientific literacy (American Association for the Advancement of Science, 1990, 1993), and it is also considered to be integral in higher education in the biological sciences (Alters and Nelson, 2002).

The controversy continues, however. After the teaching of creation science was declared unconstitutional, creationist opponents to the teaching of evolution began to concoct a more "scientific" sounding alternative to evolution that they called, Intelligent Design (ID). As with creation science, bills encouraging the inclusion of ID in curricula do so to help students "develop critical thinking skills" by "teaching the controversy" (Brumfiel, 2005; Mervis, 2011). ID advocacy groups have celebrated the passage of "teach the controversy" bills in two US states, Louisiana and Tennessee, in the past several years (Thompson, 2012) despite opposition from such groups as the National Center for Science Education.

The evidence is clear, and the scientific community is unified in its assessment of the fact of evolution. Science educators are resolute in their insistence that evolution be taught as a foundational principle of the life sciences. So why, then, do students emerge from our education system largely unknowing and unaccepting of evolution to the point that the political controversy over the teaching of evolution has continued for generations?

There are a number of factors that are thought to affect students' acceptance of evolution, which can be grouped into non-religious and religious factors (Alters and Alters, 2001; Wiles and Alters, 2011). Per Wiles and Alters (2011) in which they are discussed in greater depth, they may include the following:

Non-religious factors

- Scientific factors
  - Overall knowledge of evolutionary theory
  - Knowledge of evolutionary evidence
  - Uncertainty about the origin of life
  - Understanding of evolutionary mechanisms and patterns
  - Understanding of the nature of science
- Non-scientific factors
  - Social and emotional factors (e.g., personal relationships, authorities, fear or discomfort with perceived implications of evolution)
  - Critical thinking skills, epistemological views, and cognitive dispositions
  - Demographic factors (e.g., academic standing, political leanings)

Religious factors

- Perception that religious belief and acceptance of evolution are mutually exclusive
- Literal interpretation of scripture
- Creationist convictions
- Labeling of religious doctrine as scientific (e.g., “creation science” and ID)

A few studies have shown that presenting students with a direct comparison of the misconceptions about evolution that can result from these factors (or indeed be intentionally perpetuated by creationist groups) can lead to increased acceptance of evolution (Ingram and Nelson, 2006; Matthews, 2001; McKeachie et al., 2002).

Several studies have suggested that increasing students' understanding of the nature of science (NOS) may enhance their acceptance of evolution (Allmon, 2011; Dagher & BouJaoude, 1997; Rudolph & Stewart, 1998; Sinatra et al., 2003; Smith, 2009; Southerland et al., 2001). NOS describes the philosophy of science, that is, how scientific knowledge is generated and how science progresses. Key concepts of NOS include viewing science as more than just the oversimplified, stepwise scientific method presented in many textbooks; the role of the scientific community in the generation of scientific knowledge; the theory laden nature of observation and experimentation; and the fact that scientific theories are durable while science itself is a self-correcting process (Grinnell, 2009). Increasing NOS understanding is important in science education in general, as evidenced by its inclusion in the national science education standards (National Research Council, 1996), but is predicted to increase acceptance of evolution as students learn about how evidence is considered and the role of consensus in the scientific community. Though many authors suggest that NOS understanding plays a role in the acceptance of evolution, the positive link between changes in NOS conceptions and attitudes towards evolution has, until this study, been poorly understood.

Climate Change:

While it was once contentious among scientists, the vast majority of scientists now agree on many aspects of global climate change (GCC): that it is occurring, that the changes 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 (National Research Council, 2010). 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). Consensus across so many scientific, political, and idealogical borders is unprecedented and may speak to the importance of the issues associated with GCC.

Like evolution, GCC is a much more contentious issue politically than it is scientifically. Interestingly, Newton (2012) asserts that the people or groups touting creationism (as noted above, creationists are the main opponents of evolution education) and climate change denial are often the same. GCC has been a common subject in national polls over the last twenty years (Nisbet and Myers, 2007), and these data have been used extensively to document how concern over GCC correlates with different demographic factors, especially whether respondents identify as democrats, republicans, or independents. GCC has been found to be extremely politicized (McCright, 2010a), and studies have shown that the gap in GCC concern between democrats and republicans has increased markedly over the last ten years (Dunlap and McCright, 2008; McCright and Dunlap, 2011b). Conservative white males have been shown to be the most likely demographic to deny GCC (McCright and Dunlap, 2011a). Somewhat surprising is the presence of strong interaction effects between knowledge about climate change and political identification. That is, among democrats, GCC concerns increase along with knowledge of GCC, but the same relationship in republicans is weak to negative (Hamilton, 2011). The politicization of GCC is most prevalent in the U.S., with cross-national surveys indicating that in most other industrialized nations the views on GCC are much more closely aligned with those of the scientific community (Dispensa & Brulle, 2003; Kvaloy et al., 2012).

The political controversies around GCC are surely affecting the teaching of climate science in schools. Like evolution, GCC has been proposed as a central focus in science education because of the scientific consensus behind it coupled with the need for societal action to mitigate its effects (Sharma, 2012). This view is shared by many within the science education community including the National Association of Biology teachers who identify GCC as an environmental concept “particularly relevant to students’ everyday lives” (National Association of Biology Teachers, 2004) and the National Association of Geoscience Teachers who recognize:

(1) that Earth's climate is changing,

(2) that present warming trends are largely the result of human activities, and

(3) that teaching climate change science is a fundamental and integral part of earth science education (National Association of Geoscience Teachers, 2008).

And yet, GCC is second only to evolution in topics that educators are unlikely to bring up due to discomfort or fear of controversy (Reardon, 2011). Recognizing the need for action in defense of climate change education, the National Center for Science Education (NCSE), an organization well-known known for defending the teaching of evolution, added promotion and protection of the teaching of climate science to its mission. Because attacks on climate change, like those on evolution, rely on misrepresenting climate change denial as being scientifically rather than politically motivated, the NCSE and other groups are concerned that "teach the controversy" bills will affect education on both issues (Mervis, 2011). Strategies for GCC education are still developing, perhaps because it is a much more recent concept than evolution (Cordero et al., 2008; Manolas & Filho, 2011; Matkins & Bell, 2007; McNeill & Vaughn, 2012; National Research Council, 2010; Shepardson et al., 2012; Svihla & Linn, 2012). The fact that many students and members of the public get most of their knowledge about GCC from the media is additionally problematic. Reporters often have difficulty differentiating between scientific and political controversy, and both evolution and climate change deniers often actively craft their arguments to appear scientific, thereby encouraging this confusio (Dispensa & Brulle, 2003). Thus, it has been suggested that training in media literacy, specifically how to critically analyze media coverage to determine sources, bias, etc., should be an active pursuit in improving understanding and acceptance of GCC (Cooper, 2011).

For GCC, "acceptance" is not a term that is commonly used in the literature (though denial is frequently used). The data on attitudes towards climate change are almost entirely from national surveys, which frame their questions as a sliding scale of concern. However, a number of demographic factors have been shown to correlate with views on GCC. These factors include;

Scientific factors

- Knowledge about GCC (either measured or self-declared)

Non-scientific factors

- Religiosity
- Demographic factors
  - Political leanings/Party identification
  - Education level
  - Gender (weak but significant correlation)
  - Age
  - Region of residence

(Borick & Rabe, 2012; Hamilton & Keim, 2009; Hamilton, 2011; Marquart-Pyatt et al., 2011; McCright & Dunlap, 2011a, 2011b; McCright, 2010b; Nisbet & Myers, 2007).

The abundance of correlations demonstrates that GCC is a very complex issue, with even regional variation in perceptions (Hamilton & Keim, 2009). Perhaps bizarrely, one study even found that the presence of healthy vs dead plants in the room in which the survey is administered had a significant effect on participants' GCC concerns (Guéguen, 2012).

The only study that we are aware of that explored the link between NOS understanding and GCC revealed that after receiving explicit instruction in both GCC and NOS, education students showed increased understanding of both (Matkins & Bell, 2007). The authors concluded that explicit NOS instruction had a positive effect on NOS understanding as well as complex issues of GCC (Matkins & Bell, 2007), but given the nature of the study, it would be difficult, if not impossible, to establish NOS instruction as the causal agent of GCC understanding rather than the extensive instruction in GCC. A number of the teaching strategies that have been suggested involve some aspect of NOS, whether it be teaching students the ability to differentiate between scientific and non-scientific items in the media (Cooper, 2011) or teaching about how research programs on GCC are put together, including how models are developed (Manolas & Filho, 2011).

NOS understanding may play a role in forming students' opinions on GCC, but further research on the topic is clearly warranted. Herein, we present our exploration of this problem as well as how attitudes toward the topic of evolution compare among a sample of university students in an introductory biology course.

Methods:

Although other extant tools for assessing NOS conceptions provide much more robust measurements (Abd-El-Khalick, 2001; Bell & Lederman, 2003; Norman G. Lederman, 1999), they are decidedly more labor-intensive to score and not easily implemented via the online tools and under the Institutional Review Board guidelines approved for this study. Additionally, these tools do not provide the quantitative output necessary for large-scale statistical comparison. Hence, we chose to measure student conceptions of NOS with the Thinking about Science Survey Instrument (TSSI), (Coburn, 2000). The TSSI provided numeric scores for student agreement with nine aspects of the modern model of science. In our final analyses, the sum total of these scores proved to have the most explanatory value, though the score for the "epistemology" category was a close second. The Measure of Acceptance of the Theory of Evolution (MATE) was employed to assess students attitudes toward evolution, as it has been validated for measuring acceptance of evolution among various populations (Rutledge & Warden, 1999; Rutledge & Sadler, 2007), and it has also been used to measure longitudinal change in students' attitudes toward evolution (Wiles and Alters, 2011). Since a validated tool for measuring attitudes towards GCC did not exist at the time of this study, student attitudes were measured using questions from national opinion polls (Borick & Rabe, 2012; Hamilton & Keim, 2009; Hamilton, 2011; Leiserowitz et al., 2012; Nisbet & Myers, 2007). Demographic questions were generated to measure various factors either shown or suspected to affect attitude towards evolution or GCC. See Appendix 1 for the full list of GCC and demographic questions.

Each survey was administered to a large sample of introductory biology students (N = 620) at a large private university in the northeastern US at the beginning and end of the course (with the exception of demographics, which were administered once near the middle of the semester). Some additional questions were added at the end of the course to determine whether important demographic shifts may have occurred (for example in religious practice or political views) since the previous reporting of these factors. Other variables used in the analysis included a measure of knowledge of evolutionary science (total score on a selection of questions on evolution from the final exam), a measure of knowledge of GCC (total score on a selection of questions on GCC from a quiz produced by NASA, (National Aeronautics and Space Administration, n.d.), and a measure of success in the course (the numeric final grade in the biology course).

In order to account for the fact that those students with high scores on the pre-course surveys would have little room for increase, normalized gain ([posttest-pretest] / [100% - pretest %]) was calculated for a number of items, including TSSI total score and MATE score. Normalized gain is frequently used in pre-test/post-test analyses (Hake, 2002). Using NoS conceptions as independent variables and measures of evolution acceptance and GCC attitudes as dependent variables, Principle Components Analysis (PCA) was used to determine which variables accounted for the majority of variation. Paired t-tests were used to analyze pre-to-post-course differences for individual variables. Finally, ANOVA, along with correlation tests, were used to test for significant correlations, while ANCOVA was used to test for interaction effects with demographic factors.

Student name and ID numbers were removed and replaced with a numeric identifier so that pre- and post-course responses could be paired while maintaining anonymity. The protocols used for this study were approved by the university's Institutional Review Board (IRB).

Results and Discussion:

From the pre-course surveys, it was clear that this population was different from the US general public. Upwards of 60% of respondents scored in the “High” or “Very High” range of evolution acceptance, while most polls indicate that less than half of the US public believe in evolution. For GCC results were similar. Nearly 95% of respondents said they believe GCC is occurring (as compared to 66% of the US public). For this reason, for analysis of attitudes towards GCC, we focused on students’ levels of personal concern regarding GCC rather than acceptance. Responses on this item were considerably more varied, with about 44% of respondents reporting that the issue was “very” or “extremely” important, while about 16% reported that the issue was “not too” or “not at all” important. In the US public, 20% said the issue was “very” or “extremely” important, while 39% rated GCC as “not too” or “not at all” important. It is important to note that while the percentages of students in the low end is low, the overall sample is quite large (N=620), such that the number of students in these lower tiers is actually larger than the entire sample size of many similar studies (e.g., N=205 respondents with acceptance of evolution ranging from “very low” to “moderate”).

Changes in acceptance of evolution are significantly positively correlated with changes in NOS conceptions, with religiosity as the main demographic factor affecting acceptance. As shown in Figure 1, normalized gains of MATE score and total TSSI score had a correlation of 0.35, and were highly significant ($p < 0.100\ 1$). Both pre-course and post-course MATE scores were significantly negatively correlated with religiosity (respondents' Likert-scale responses to the question “how active do you consider yourself to be in the practice of your religious preference?”). The post-course relationship, shown in Figure 2, was more weakly correlated ($r = -0.2$) than the pre-course relationship ($r = -0.32$), but no less significant ($p < 0.0001$). Interestingly, there was a very small and weakly significant *positive* correlation between gains in evolution acceptance and reporting an increase in religious activity during the span of the course ($r = 0.08$, $p = 0.08$). As illustrated by Figure 3, post-course evolution acceptance was also significantly positively correlated with knowledge of evolutionary science ($r = 0.35$, $p <0.0001$), which supports the findings of previous research on this subject (Wiles and Alters 2011).

Changes in GCC attitudes also correlate with changes in NOS conceptions. At an alpha of 0.1, changes in personal importance of the issue of climate change are significantly positively correlated with normalized gains in TSSI total score. This comparison is shown in Figure 4, with $p = 0.065$ and $r = 0.087$. Additionally, respondents' scientific views of GCC (a composite of responses to two questions that measured whether respondents' awareness of the views of the scientific community on GCC) were not significantly correlated with NOS conceptions in the pre-course surveys, but were correlated in post-course surveys, with $r = 0.118$ with $p < 0.01$, which may be linked to NOS conceptions having to do with scientific consensus and the treatment of evidence. Interestingly, knowledge about GCC was not significantly correlated with attitudes towards GCC. A paired t-test indicates a mean difference of just 0.06 between pre- and post-course measurements for importance of GCC, a factor with five levels. The lack of difference is not surprising, given the fact that there is considerably less direct instruction on GCC in the course than there is on evolution.

In both pre- and post-course surveys, personal importance of GCC is most strongly correlated with political leanings, i.e., negatively correlated with conservatism. Interestingly, that correlation was weaker, though still significant, in the second survey as compared to the first; pre-course $r = -0.215$ with $p < 0.0001$ while post-course, $r = -0.171$ with $p < 0.0001$. The trend is also present when examining political party affiliations. As shown in Figure 5, identifying as a democrat is positively correlated with GCC importance ($r = 0.113$, $p < 0.01$), while identifying as a republican is negatively correlated with GCC importance ($r = -0.11$, $p < 0.05$).

Conclusions:

In this study, changes in evolution acceptance and changes in attitudes towards GCC do correlate positively with changes in NOS conceptions. These findings support the hypothesis that a better understanding of the modern model of science may lead to changes in attitudes towards politically contentious ideas that are not scientifically contentious. However, the data indicate that correlations differ between evolution and climate change. Of all the measured variables in this study, measures of political views were most highly correlated with attitudes towards GCC. More conservative political views, especially fiscal conservatism, correlated negatively with personal importance of the issue of climate change. Broken down among party lines, correlations between party identification and importance of GCC were almost exactly opposite (for republicans, $r = -0.11$ while for democrats $r = +0.13$). Interestingly, party leanings do NOT significantly correlate with *changes* in GCC attitudes, which could indicate a lack of large enough changes in GCC attitudes to measure.

GCC importance and concern were most strongly correlated with political views, and of the GCC deniers in our sample, over two-thirds identified politically as fiscal conservatives. Unsurprisingly, evolution rejection was most strongly correlated with religious factors. However, GCC deniers in this study tended not to be highly religious or affiliated with conservative denominations. These results are consistent with data from a Pew Foundation (2009) poll which found that the strongest predictor of climate change denial is political affiliation, with political conservatives being more likely to deny GCC than other groups. The same poll also found that religious conservatism, whether measured by denominational affiliation or degree of religiosity, was the strongest correlate of evolution denial. Religious conservatism does not map perfectly onto political conservatism, but there is certainly an area of overlap known as the “religious right”. Similarly, rejection of evolution does not always predict rejection of GCC. Figure 6 illustrates this, as the “zone of denial” shifts from religious to political conservatism as it moves from rejection of evolution to rejection of GCC.

The lack of correlation between *changes* in evolution acceptance and changes in religious activity counters the idea that belief in evolution and religion are mutually exclusive, one of the "pillars of evolution denial" according to the National Center for Science Education (National Center for Science Education, 2008a). That is to say, becoming more accepting of evolution does not necessarily mean becoming less religiously active, or vice versa. Actually, a very slight positive relationship between the two was measured among this population.

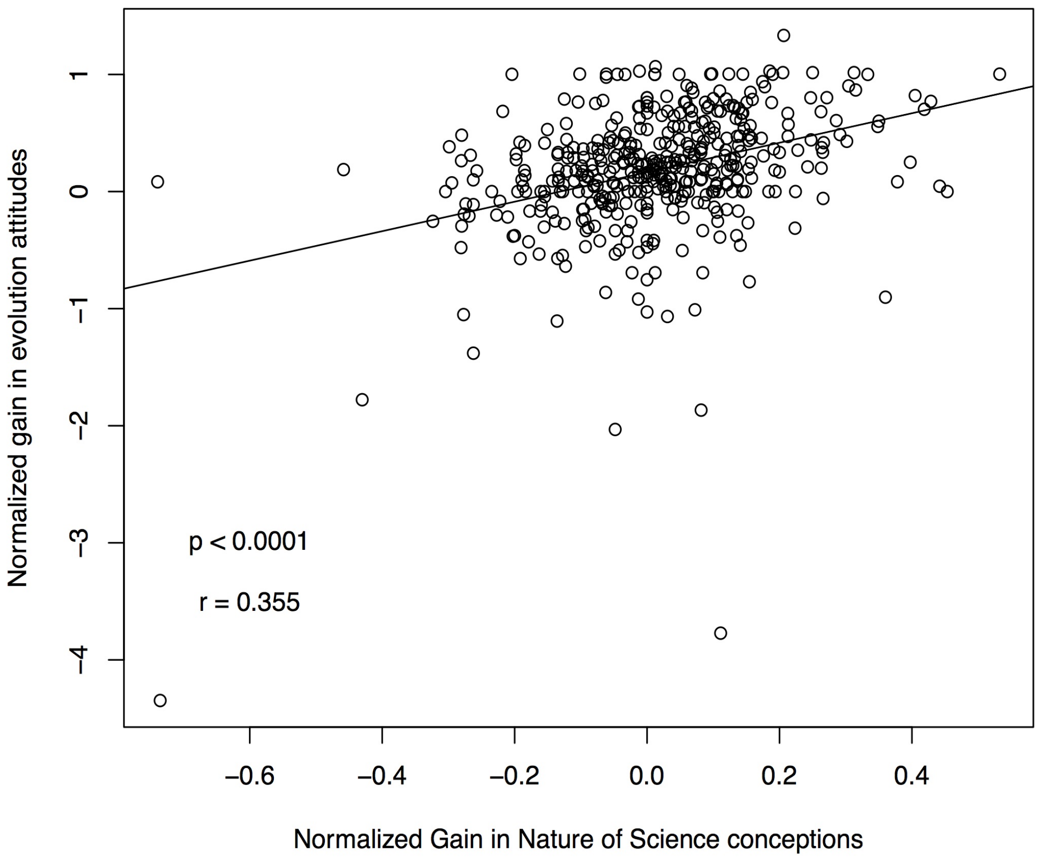
This study has various important implications. First, giving students a good conception of the modern nature of science may lead to views that are more in line with those of the scientific community. Of course, further research is required to establish the direction of causation, but it is difficult to imagine how becoming more concerned about climate change could cause a more scientific epistemology or a better understanding of scientific methodology. Second, while evolution is thought of as a politically contentious topic, as is the case currently in Louisiana, attitudes towards GCC are much more related to political views in this study population. The fact that these correlations do decrease over the span of the course, however, is heartening. A greater emphasis on GCC (and NOS) in the may even lead to the disappearance of this correlation entirely. Finally, this study represents the first concrete evidence of a linkage between acceptance of evolution and attitudes towards GCC, i.e., NOS conceptions.

Future research on this topic should involve multiple institutions, comparing universities of different types, sizes, and geographic locations. More robust measures of NOS conceptions should be employed where possible, and qualitative methods such as interviews could be used to help determine the direction of causation for the various correlations discovered in this study. Students with large gains in evolution acceptance should be interviewed to determine how those changes came about.

Acknowledgements:

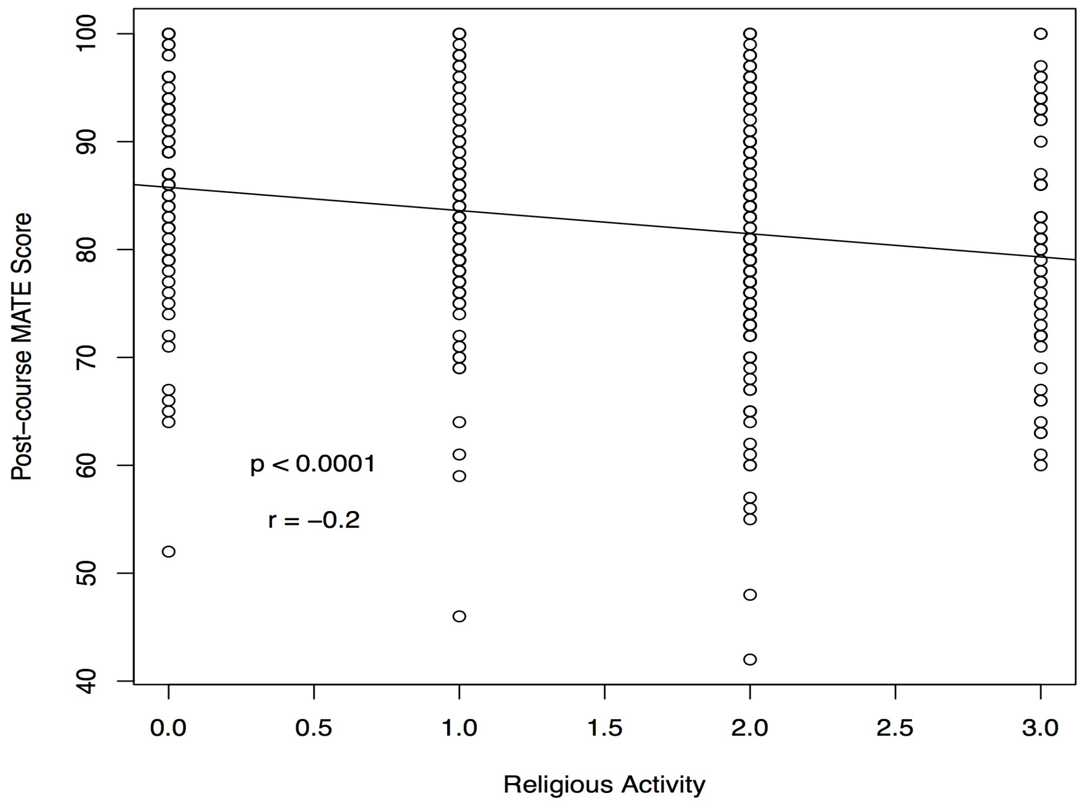
The authors offer sincere thanks to Bev Werner for her help with the logistics of electronic administration of surveys as well as anonymizing them. BEC thanks Caitlin Conn for her feedback on drafts of the manuscript. The authors also thank Eugenie Scott for her original conception of the shifting zone of science denial amongst conservatives, and Josh Rosenau for help with data processing and key information from public opinion polls.

Figure 1: The relationship between changes in students' nature of science conceptions and evolutionary attitudes



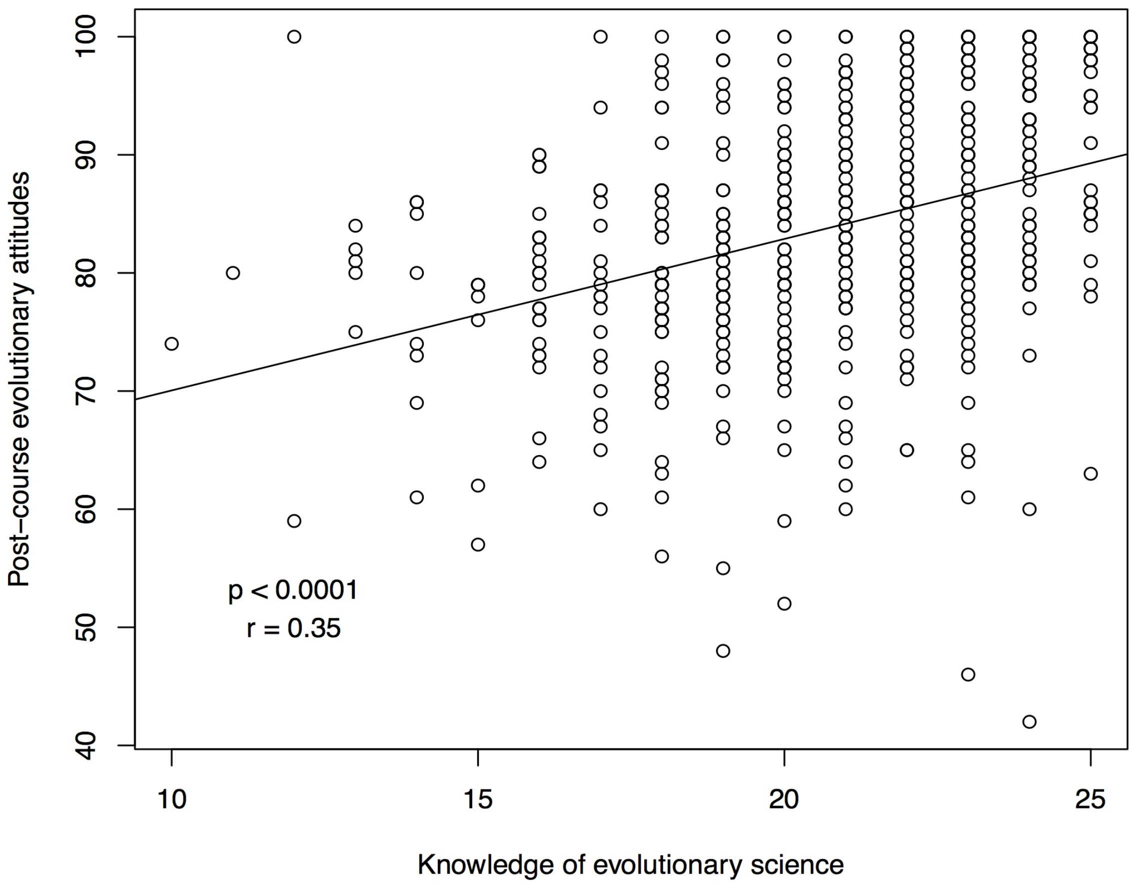
Changes in nature of science conceptions, as measured by the normalized gains of total scores on the Thinking about Science Survey Instrument, are significantly positively correlated with changes in attitudes towards evolution, measured by normalized gains of total scores on the Measure of Acceptance of the Theory of Evolution tool. The value of r indicated in the figure (0.355), is Pearson's correlation coefficient for the two variables.

Figure 2: The relationship between students' post-course evolutionary attitudes and religiosity



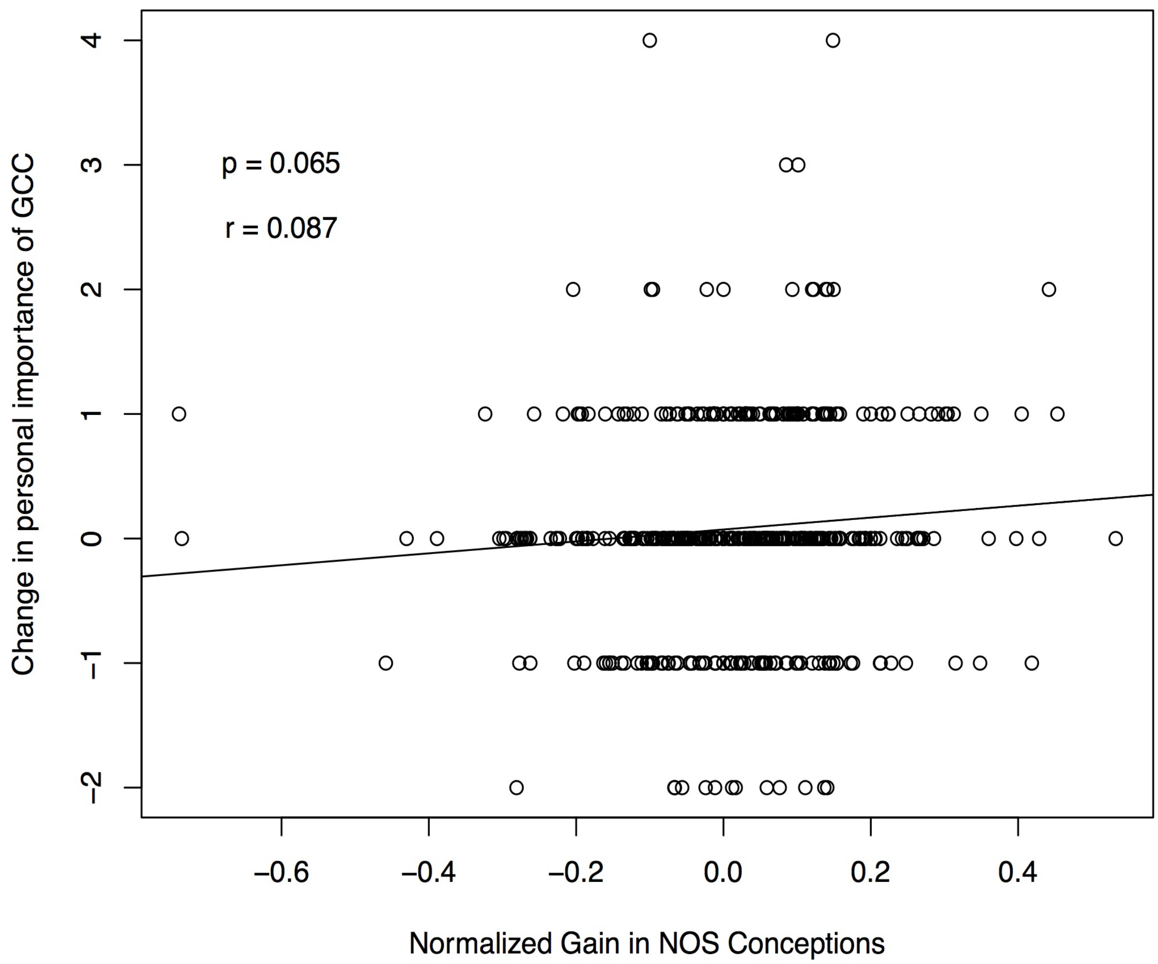
Student attitudes towards evolution, as measured by their post-course total score on the Measure of Acceptance of the Theory of Evolution tool, are negatively correlated with religiosity, here a Likert-scale response to the question “how active would you say you are in the practice of your religious preference?” This factor has four levels, ranging from zero (not active) to three (very active). The value of r indicated in the figure (-0.2), is Pearson's correlation coefficient for the two variables.

Figure 3: The relationship between students' post-course evolutionary attitudes and knowledge of evolutionary science



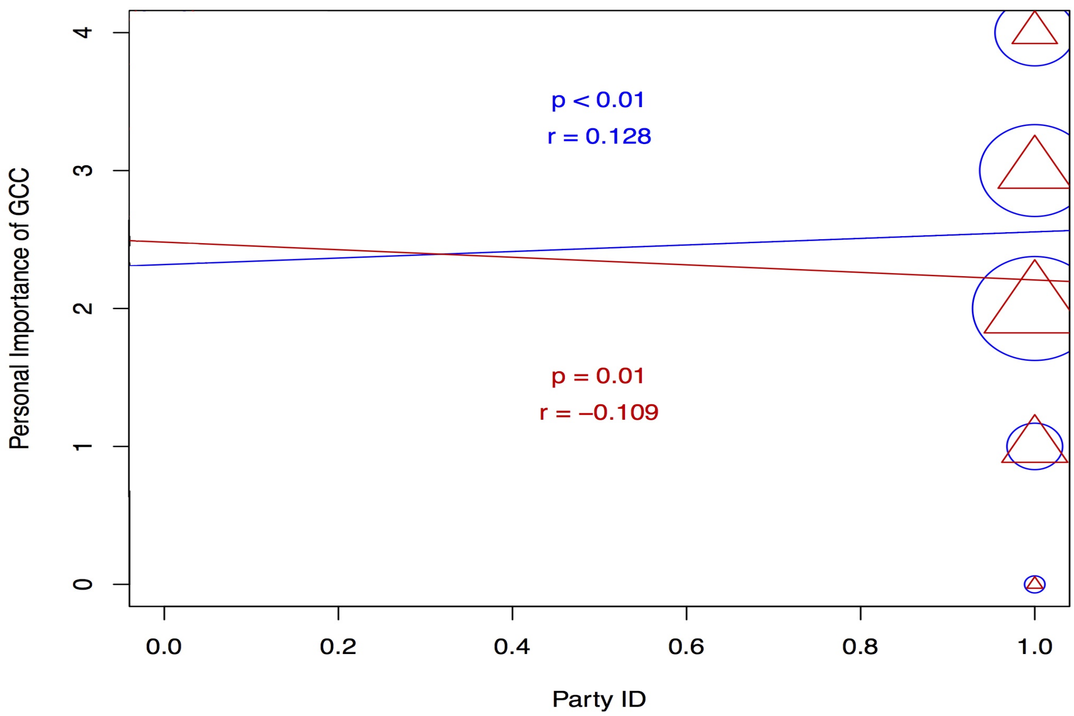
Student attitudes towards evolution, as measured by their post-course total score on the Measure of Acceptance of the Theory of Evolution tool, are positively correlated with knowledge of evolutionary science. The latter was measured using a subset of questions from the course final exam which pertained directly to the science of evolution. The value of r indicated in the figure (0.35), is Pearson's correlation coefficient for the two variables.

Figure 4: Relationship between changes in students' attitudes towards GCC and conceptions about the nature of science



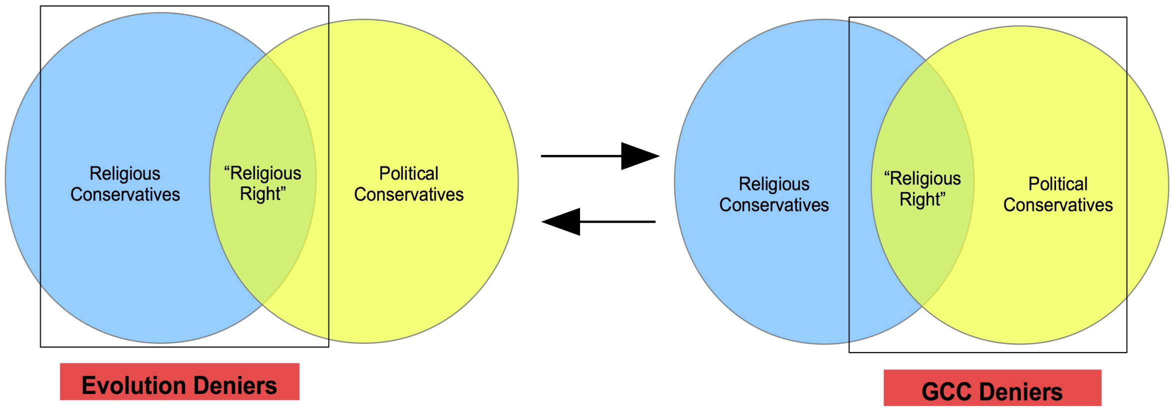
At an alpha of 0.1, changes in how important the issue of global climate change was to students had a weak positive correlation with changes in nature of science conceptions, measured by the normalized gains of total scores on the Thinking about Science Survey Instrument. The value of r indicated in the figure (0.087), is Pearson's correlation coefficient for the two variables.

Figure 5: The relationship between students' political party identification and personal importance of climate change



In this figure, blue circles and the blue positive trend line represent the relationship between post-course personal importance of global climate change and identification as a democrat. Red triangles and the red negative trend line represent the relationship between post-course personal importance of global climate change and identification as a republican. The sizes of the symbols increase with increasing number of overlapping data points so that their distribution can be more easily visualized. Here the trends are essentially opposite for students identifying with the two parties, with a positive Pearson's correlation coefficient (0.128) for democrats, and a negative one (-0.109) for republicans. It is important to note, however, that the two variables were more weakly correlated, for both democrats and republicans, when comparing post-course attitudes towards climate change rather than pre-course attitudes.

Figure 6: The shifting zone of science denial



Political conservatives and religious conservatives are represented separately in this Venn diagram, with the overlap between them identified as the "religious right." The zone of denial shifts from being driven primarily by religious ideology with regard to evolution to being predominately influenced by political ideology for climate change.

Chapter 3- Boosting students' attitudes and knowledge about evolution sets them up for college success

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Abstract:

Students who enter college with a solid grounding in and positive attitudes toward evolutionary science are better prepared for and achieve at higher levels in university-level biology courses. Consistent with assertions in the NSTA position statement on the teaching of evolution, we found highly significant, positive relationships between student knowledge of evolution and attitudes toward evolution as well as between introductory biology course achievement and both pre-course acceptance of evolution and pre-course knowledge of evolution among students at Syracuse University. Teachers who scant the teaching of evolution or who do not foster good attitudes toward evolution hinder students' success in science at the college level.

Forty years ago, Theodosius Dobzhansky (1973) famously explained in his missive to teachers that "nothing in biology makes sense except in the light of evolution." And since that time, his apt assertion has been cited by numerous scientific societies, education organizations, and scholars, in hundreds upon hundreds of research articles, position statements, and other documents, overwhelmingly ratifying the notion that evolution is the most fundamental concept in all of the life sciences and serves as a powerful scaffold around which a comprehensive and integrative understanding of biology and related fields can be built.

It would seem to follow, then, that students who understand evolution ought to have higher levels of achievement in biology and related science subjects than those who do not. But while evolution is overwhelmingly accepted in the scientific community and informs essentially all biological research, large proportions of the general public, including many students, reject the solid scientific consensus (Miller et al., 2006; Wiles, 2010). This is important to teachers for many reasons, including that a number of researchers have found that lack of acceptance of a concept may in fact prevent students from developing an understanding of the concept (Coburn, 199; Meadows, Doster, & Jackson, 2000; Scharmann, 1990; Smith, 2009b).

Students' prior knowledge of and attitudes toward evolution have been of major concern to science education researchers, but the relationship of these constructs to achievement in post-secondary science has been a matter of particular contention with legal ramifications in recent years. For example, the University of California system was sued by a group of Christian high schools over a policy of rejecting certain secondary courses from religious schools that do not treat evolution in a manner consistent with the consensus of the scientific community on the grounds that such courses do not adequately prepare students for college-level study in the biological sciences (National Center for Science Education, 2008b). This policy, which has been upheld by the courts, is predicated upon the notion that achievement in post-secondary courses in the life sciences is related to students' prior knowledge of evolution. The National Science Teachers Association (2013) agrees with this assessment, explaining that "...if evolution is not taught, students will not achieve the level of scientific literacy needed to be well informed citizens and prepared for college and STEM careers."

Results from Berkman and Plutzer (2011) indicate that on a local scale, biology teaching tends to reinforce the sentiment of the local community. This suggests that the teaching of evolution is more likely to be compromised in those areas with the largest disconnects between public understandings and scientific consensus. This has implications for students from such communities and their potential to excel in science. Consistent with this notion are results from Belin and Kisida (2012), who found a clear and consistent relationship between the acceptance of evolution among the populations of U. S. states and the levels of science achievement of the students of those states.

While teachers in some communities may feel it is necessary to introduce the topic of evolution gently as students are presented with scientific information which they may perceive to conflict with their personal beliefs (Long, 2012), our data indicate that it is nonetheless essential for college preparation to give students opportunities to develop positive attitudes toward, and a solid understanding of, evolution.

In a semester-long study of students in a large introductory biology course at Syracuse

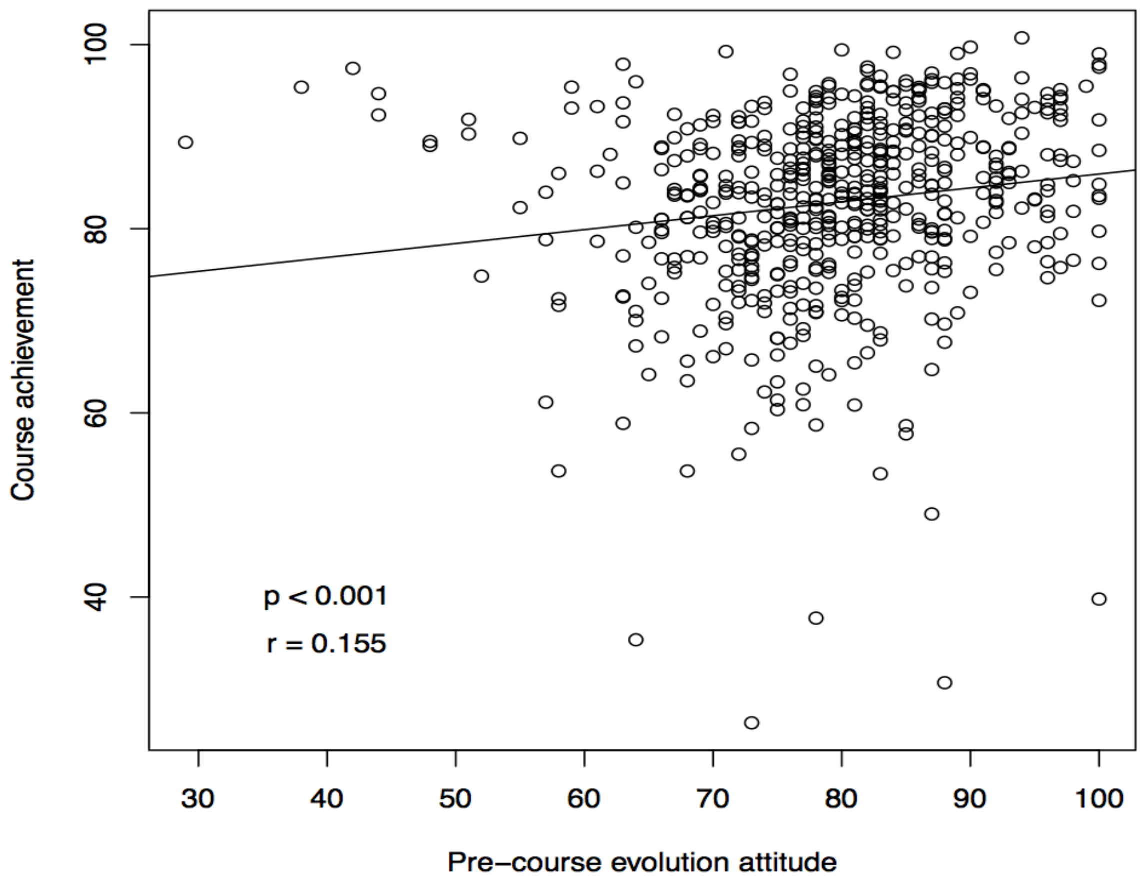
University, we found a highly significant correlation between students' attitudes towards evolution at the beginning of the course and their final achievement in the course ($r = 0.155$, $p < 0.001$, $N = 620$, see Figure 7). In other words, their attitudes towards evolution before setting foot in the classroom are predictive of their final course grade. It is important to note that the assessment of student attitudes we used, the Measure of the Acceptance of the Theory of Evolution instrument (MATE), was not designed to test students' knowledge about evolutionary science, but simply their attitudes toward it (Rutledge & Warden, 1999; Rutledge & Sadler, 2007).

The distinction between knowledge and acceptance of evolution is an important one, given the observation that students are sometimes able to separate their acceptance of evolution from learning about evolutionary science (Southerland et al., 2001). Also, acceptance is only one aspect of overall attitudes toward evolution, which can also include, among other factors, students' conceptions of the relevance of evolution to ongoing scientific research or to their daily lives (Hawley, et al., 2010). And it appears that knowledge of evolution and overall attitudes toward evolution are very much related to each other among our students, and both constructs influence how well students fare in the life sciences at the college level. In a smaller ($N = 116$) but more detailed investigation of undergraduates in an introductory biology course at the same university, we used the Evolutionary Attitudes and Literacy Survey (EALS, Hawley et al., 2010) to explore students' understandings of a wide range of attitudes toward evolution, and found highly significant relationships between both constructs and course achievement as well as a strong relationship between attitudes and knowledge. (See Figure 8.)

Ingram and Nelson (2006) suggest that student attitudes be addressed directly and respectfully, and posit that acknowledgement of students' attitudes may lead to decreased effects of attitudes towards evolution on course achievement. And, citing his findings that some students may experience stress when they perceive affronts to their religions, Long (2012) reminds us to be sensitive to our students' beliefs. However, we would caution teachers against treating evolution as less important or less scientifically sound in an attempt to assuage students' (or parents', or administrators') concerns. Construing evolution as "*only* a theory" or framing it in terms of the "tentative" nature of science with the intent or effect of suggesting that evolution is somehow in doubt, or that its status as the most powerful explanatory principle in biology is at all likely to change, are not helpful practices. Evolution is as well-evidenced as any core concept in science, and it should be presented as such. Our understanding of evolution is based on abundant and consistent knowledge generated over decades of interdisciplinary study, and there is no scientific explanation for the diversity of life apart from evolution (American Institute of Biological Sciences, 1994; National Science Teachers Association, 2013).

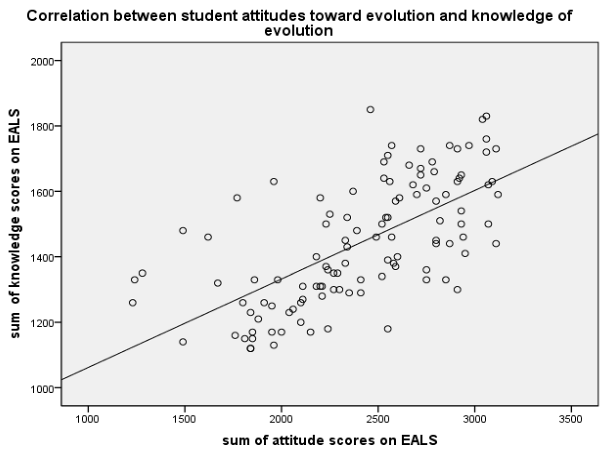
Teachers who perceive pressure from students, parents of students, or school administrators ought not to feel that they must navigate this territory alone. National benchmarks, state standards, professional societies, and textbooks all prescribe and present evolution as a fundamental component of modern science education, and teachers can confidently lean on the established curriculum. Wiles and Alters (2011) offer more advice on such matters, and resources have never been more widely available. (See Table 1 for a few suggestions.) Scanting instruction in evolution, or teaching it in a fashion that casts or fosters doubt regarding the veracity of evolution or its centrality to modern biology, does students a great disservice. At the very least, it misrepresents a foundational principle in the life sciences, but it also diminishes students' chances of success in higher education and science-based careers.

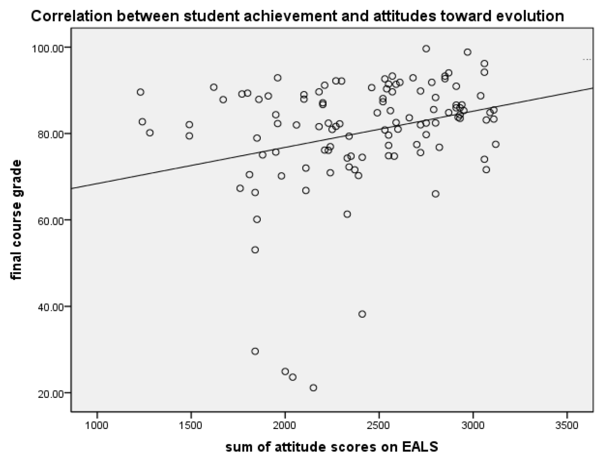
Figure 7: Correlation between pre-course evolution attitudes and course achievement



In this figure, the x-axis represents students' numeric scores on the Measure of Acceptance of the Theory of Evolution (MATE) instrument from before the course began. The y-axis represents course achievement, in terms of students' final numeric scores in the course. In this figure, r (0.155) represents Pearson's correlation coefficient. Results were highly significant, with $p < 0.001$.

Figure 8: Relationships between pre-course attitudes and pre-course knowledge of evolution, between achievement and pre-course attitudes toward evolution, and between achievement and pre-course knowledge of evolution.

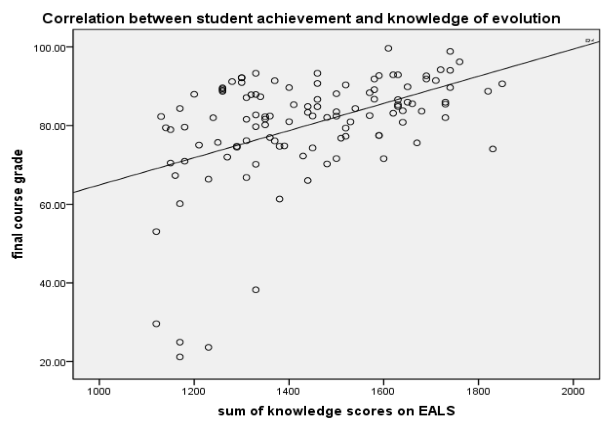




Correlations from pre-survey data

Measure	Knowledge score	Final course grade
Attitude score	.653**	.270**
Knowledge score		.461**

**p < 0.01



Clockwise from upper left, a strong, positive relationship was found between pre-course attitudes toward evolution and pre-course knowledge of evolution ($r = 0.653$, $p < 0.001$); a smaller, positive relationship was found between pre-course attitudes toward evolution and achievement in the course ($r = 0.270$, $p < 0.004$); and a strong, positive relationship was found between pre-course knowledge of evolution and course achievement among students in an introductory-level university biology course ($r = 0.461$, $p < 0.001$).

Table 1: resources for evolution instruction

Type of resource	Resource	Location
Lesson plans, background information for teachers, and helpful tips for teaching evolution	Understanding Evolution website Evolution and the Nature of Science Institutes (ENSI)	http://evolution.berkeley.edu/ http://www.indiana.edu/~ensiweb/
Where to go if you have community/political issues	National Center for Science Education	http://www.ncse.com
National Standards on Evolution Teaching	National Science Education Standards Next Generation Science Standards	http://www.nap.edu/catalog.php?record_id=4962 http://www.nextgenscience.org/hsls-nse-natural-selection-evolution
Compendium of Position Statements in Support of Teaching Evolution	Voices for Evolution	http://ncse.com/voices
Help from NSTA	Position statement and concise guidelines for common issues	http://www.nsta.org/about/positions/evolution.aspx

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 or Alaska Native
    b) Asian
    c) Black or African American
    d) Hispanic or Latino
    e) White
    f) Native Hawaiian or other Pacific Islander
    g) Other (write-in)

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
    h) Don't know

(GCC questions compiled from Borick & Rabe, 2012; Hamilton, 2011; Hamilton & Keim, 2009; Leiserowitz et al., 2012; Nisbet & Myers, 2007. The term "global warming" has been changed to "global climate change." Many scientists prefer the term global climate change because though global warming correctly references rising average global temperature, it can be misleading for individuals in those geographic areas predicted by climate models to experience decreasing temperatures, changes in precipitation without changing temperature, etc. Further, many problems accompany rising temperature as part of climate change including receding sea ice and frequent intense weather events. Demographic questions are of my own design.)

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