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ORIGINAL PAPER

Changing minds or rhetoric? How students use their many natures of science to talk about evolution

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Abstract

Recommendations for teaching the nature of science (NOS) are grounded in a deficit view of students and/or the public—wherein people accept pseudoscientific claims, particularly about evolution, because they do not adequately understand what counts as being "scientific." Under the deficit view, correct views of science are defined by the normative claims of particular authorities, and public views are evaluated based on similarity to those authoritative claims. Such normative accounts have come under increasing criticism among researchers attentive to cultural dimensions of science education. Ethnographic fieldwork in eastern Tennessee, where evolution remains a highly salient topic, in churches and public spaces, gave me further reason to doubt the deficit account. In order to clarify the relationship between views on the NOS and beliefs about evolution, I interviewed students at a public high school in rural Tennessee and asked them to complete two surveys—on "Nature of Science" and "Beliefs about Origins"—which I developed in light of my earlier ethnographic fieldwork. In order to avoid the aforementioned deficit approach, I analyzed their responses using a cultural consensus analysis, which generates multiple "answer keys" based on participant agreement. I then interpreted the results of the cultural consensus analysis in the light of the student interviews. Drawing on Malinowski's insights on studying myth, I paid attention not only to the content of statements with which students agreed, but also how such statements are used by students. I conclude that, irrespective of their position on evolution, the students draw on both cynical and celebratory ideas about science. However, they deploy those ideas differently, in ways that support their position on scientific assertions. These findings speak to a growing literature in NOS research that frames views about the NOS as argumentative resources. Students assign value to scientific claims through exchanges with other people. Ideas about science are recruited in these exchanges to support claims about which claims have scientific merit. Science educators should be aware of how ideas about science are deployed by students before figuring out how they should be taught.

Keywords Evolution · Creationism · Rural school · Nature of science · Tennessee

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An anthropologist working in science education straddles two disciplines that differ in method and purpose. Science education is centrally concerned with changing students so that they understand and value scientific knowledge. According to the National Research Council's Committee on Science Learning:

> The eventual goal of science education is to produce individuals capable of understanding and evaluating information that is, or purports to be, scientific in nature and of making decisions that incorporate that information appropriately, and, furthermore, to produce a sufficient number and diversity of skilled and motivated future scientists, engineers, and other science-based professionals. (NRC 2007, p. 34)

In contrast, anthropology is centrally concerned with understanding how other people, including teachers, students, policy-makers, and researchers, make sense of their world and act within it. Whereas science education research studies the effects of science education with the ultimate purpose of improving instruction, an anthropology of science education studies "the role which science education research, and science itself, plays in the lives of teachers, students and communities which it affects" (Hammond and Brandt 2004, p. 1). Furthermore, by recognizing science education and science education research as inescapably cultural, an anthropologist working on these issues is well poised to consider questions of "who teaches science, how it is taught, and what ends it serves" (2004, p. 2).

These questions are especially relevant with regard to research on understandings of the nature of science (NOS), particularly as they relate to evolution education. Perhaps the best known scholar on the nature of science, Norman Lederman, has defined NOS as "the values and assumptions inherent to the development of scientific knowledge" (e.g. Lederman 1992). While these specific "values and assumptions" have shifted over time for Lederman, his more recent work (2007) specifies that they include the recognition that scientific knowledge is tentative, subjective, influenced by a cultural milieu, empirically-based, and generated through a process that relies on creativity and imagination. This view of NOS is based on a constructivist epistemology of science, with parallels to constructivist models of learning, though also notably embraced by critics of scientific claims (Matthews 1998).

Work on how students and others understand the nature of science and scientific knowledge goes back nearly a century and has already been reviewed extensively by scholars, including Lederman (2007) and more recently by Feng Deng, Der-Thanq Chen, Chin-Chung Tsai and Ching Sing Chai (2011). Throughout the history of the construct, scholars have reported that students and other people have "inadequate" understandings of science that fall short of the views of experts (Lederman 2007). These results have been consistent despite the fact that expert views of NOS have shifted substantially during the twentieth century, making measurements of NOS a moving target (Deng, Chen, Tsai and Chai 2011). The consistency in results in spite of shifting measures would be surprising were it not so trite—why would we not expect experts to understand their subject matter better than lay persons?

Then again, perhaps reporting such findings and repeating them can be more profitably understood in terms of the symbolic function it serves. The act of defining the characteristics of scientific knowledge while also asserting the asymmetrical understandings of NOS between scientific experts and others is effectively boundary-work (Gieryn 1983). Thomas Gieryn notes the value of such activities for scientists as ways to "enlarge the material and symbolic resources of scientists or to defend professional autonomy" (1983, p. 781). Science educators and science education researchers have an interest in engaging in boundary-work on behalf of scientists, since their own authority is contingent on the authority of their subject matter.

Crucially, as boundary-work enlarges the symbolic resources of scientists, it also can diminish their critics, such as people who reject evolution. For example, boundary-work has been critical in the court battles over teaching evolution, such as McLean v. Arkansas, where the separation of science from non-science served as a linchpin in legal arguments against including “creation science” in public schools (Gieryn, Bevins, and Zehr 1985). Likewise, linking rejection of evolution to inadequate understandings of NOS has the effect of explaining away and discrediting the views of students and teachers who call themselves creationist, by casting them as ignorant of science. In doing so, research on NOS and evolution acceptance echoes (whether intentionally or not) long-running stereotypes of creationists, stretching back to H. L. Mencken’s descriptions of the Scopes Trial of 1925 and the “so-called minds of these fundamentalists of upland Tennessee” (Mencken 2006).

While discussing culture and boundaries, it is relevant to mention how I employed the culture concept throughout this study. Lisa Borgerding has employed a metaphor of the science classroom as constituting a cultural border crossing in her study, which like mine concerned evolution instruction in a rural setting. Borgerding found the metaphor helpful in accounting for differential learning outcomes among various students, arguing that they were able to marshal different levels of competence in crossing from the culture of everyday life, which they mostly share, and the culture of science, which is foreign to them. She advocates for science teachers in similar settings to act as “tour guides,” helping students make the “hazardous” crossings (Borgerding 2017). Gale Seiler (2013) has already pointed out serious problems with the border crossing metaphor—noting that anthropologists have rejected the idea of clear cultural boundaries in favor of the view that apparent borders are always shifting and porous. While Borgerding acknowledges Seiler’s critique, she does not really address it in her paper.

More to the point, Borgerding’s analysis leaves open and under-theorized what precisely comprises these “cultures” on either side of this supposed border. Anthropologists who have not yet abandoned the concept would define culture as some mixture of values, beliefs, practices and artifacts, learned from and more-or-less shared by people who interact. Surely though Borgerding is not suggesting that students are encountering the “culture” of professional scientists, such as how they work, interact, and respond to the vagaries of “doing science” on a quotidian basis. If students encounter any aspect of scientific “culture” in the classroom, it would mostly be related to scientific claims and models of reality (Taber 2013), with some portion dedicated to “labs” that intend to convey something about scientific method (usually limited to making systematic observations of specific things or changes).

It would, of course, be possible to imagine that NOS, comprising “the values and assumptions inherent to the development of scientific knowledge,” is a stand-in for that narrow aspect of scientific culture many educators hope to impart through instruction. Certainly students bring to the classroom different affiliations and identities vis-à-vis evolution and human origins, and they will disagree with one another with respect to particular claims relating to those topics. However, I am not convinced that describing such disagreements in terms of cultural differences adds anything to the analysis, as opposed to merely exchanging one construct (NOS) with another (culture). Moreover, such an account would restate in fresh terms the findings of decades of NOS research—people understand the nature of scientific knowledge differently than the scholars who study science.

In the interest of clarity then, my analysis and discussion is “cultural” in so much as it focuses on the values, beliefs or practices relating to claims about the nature of scientific knowledge or the reality of evolution. As will be seen, in spite of their disagreements over the reality of evolution, the students share a great many ideas about the nature of scientific knowledge, a fact which should not be surprising. After all, the students have been interacting and talking about a great many claims, including scientific ones, for many years, both in the context of school and elsewhere in their community. We could very well say that they share "cultural" ideas about science, but I will attempt nonetheless to be a bit more specific about what ideas are shared and, even more importantly, how they are employed in situ.

While these topics are related to questions of religion and science, discussions of those issues are beyond the scope of this article. This article primarily aims to explore how students use ideas about the nature of science in relation to evolution. Along the way, it also considers how methods and assumptions used in most science education research on NOS render invisible the complicated ways in which the rhetoric of science intersects with positions on evolution. Drawing on Bronislaw Malinowski's insights on studying myth, I consider not only the statements about science to which students will assent, but also how those tenets are used—their sociological function. I describe research in rural Tennessee that explored ideas about evolution in the context of conservative Christianity and its insistence on a biblical creation narrative construed to conflict with evolution (Kohut 2016). I discuss evidence collected through semi-structured interviews and questionnaires, which shows how students employ claims about the nature of science contextually to advance particular positions in socio-scientific controversies. Finally, I discuss the implications of these findings for NOS research, reiterating criticisms that have framed NOS in terms of argumentative resources rather than knowledge or understandings per se.

Creationism as problem in science education

In order to fully appreciate the cultural work performed vis-à-vis science education research, it is helpful to situate this study in its larger societal and historical context. Creationism, as it exists in the U.S., refers to the position that humans and the world originated through the creative acts of a Judeo-Christian God. It emerged in opposition to accounts of origins coming from the naturalistic sciences, particularly the biological theory of evolution, but also the theory of the Big Bang, among others. Its most staunch adherents claim that the world and all life was created through direct acts of God as described in the first three chapters of *Genesis*, the first "book" of what Christians call the *Old Testament*. The position was developed in the early twentieth Century in the United States through the formation of publications and organizations dedicated to defending creationism and criticizing evolution (Numbers 2006). As a movement, creationism has been successful, gaining greater acceptance over time, such that nearly half of the U.S. population endorses it in recent polls (Newport 2014). The critiques of evolution associated with creationism have also been exported during the last several decades to other Anglophone countries (Numbers and Stenhouse 2000), elsewhere through Christian evangelical missionaries, and into many predominantly Muslim countries.

The persistence of creationism, especially among students and teachers in public schools, has been identified as a problem by science educators (A. Moore 2008), evolution education advocates (Miller, Scott, and Okamoto 2006), philosophers (Forrest and Gross 2007), and anthropologists (Seaford 1990). As examples of how the "problem" manifests, they observe that efforts to educate students about evolution are undermined by creationist lawmakers and teachers (R. Moore and Kraemer 2005). Furthermore, scholars have observed that, even when evolution can be taught well, students' creationist beliefs may be obstacles to better understanding the theory (Sinatra, Southerland, McConaughy, and Demastes 2003).

As research on teaching and learning evolution emerged in the 1990s, science education researchers sought explanations for students' rejection of evolution by hunting for missing knowledge or skills that they might be able to correct. Scholars working on public understandings of science refer to this framing as the "deficit model" of the public (Simis, Madden, Cacciatore, and Yeo 2016). Three possible deficiencies in creationist students were quickly identified: they either were not good reasoners, they did not understand evolution, or they did not understand science.

First, some of the earliest studies of evolution education cited cognitive deficiencies to explain why students and teachers reject evolution. For example, Anton Lawson and John Weser (1990) found that students who rejected evolution had poorer "reflective reasoning skills" than those who accepted it. More recently a study asserted that students who engage in "analytic thinking" are more likely to endorse evolution (Gervais 2015), prompting an article for NPR titled "Don't believe in evolution? Try thinking harder" (Lombrozo 2015).

Second, other studies investigated the possibility that creationists suffer from a deficit of knowledge about evolution and the evidence that supports it. For decades studies sought evidence for a connection between understanding evolution and accepting it, but findings were inconsistent (Smith 2009). Sherry Demastes and her colleagues reported examples of students who rejected evolution despite good understandings, and others who accepted it despite misconceptions (1995). Despite inconsistent findings (Lombrozo, Shtulman, and Weisberg 2006), science educators have continued to recommend more evolution teaching as a solution to the problem of creation belief (Leonard 2009). Ultimately, focus on the connection between acceptance and understanding only complicated the issue of teaching evolution more. Students cannot learn evolution because they reject it, but they cannot accept it until they understand it better.

The third hypothesized deficiency of creationists was their understanding of the "nature of science" (e.g. Scharmann and Harris 1992). This explanation is immediately buoyed by the fact that creationist literature and discourse sometimes presents a vision of science that is incongruent with modern scientific thought. For example, biologist and philosopher Massimo Pigliucci has argued forcefully that creationists misunderstand key aspects of the nature of science, but places the blame on science educators for not teaching more realistic views of the nature of scientific knowledge (Pigliucci 2002). Biology teachers have also observed that many students object that evolution is "only a theory," suggesting erroneously that theories and laws are related hierarchically in terms of support.

Christopher Toumey, who conducted ethnography with a small scientific creationism group in North Carolina, characterized his subjects as displaying a Protestant model of science, in which nature is studied in order to see God's handiwork. The Protestant model was dominant in the US up through the nineteenth century when it was gradually supplanted by the secular model, which seeks naturalistic explanations of natural phenomena (Toumey 1994). Thus, from the perspective of contemporary science education researchers, who accept the secular model as a given, creationist efforts to advance (or revert to) the Protestant model of science appear as misconceptions about the nature of science.

The logic of NOS as a deficiency in creationists was apparently so compelling that it was supported and recommended for years despite a lack of evidence. In one of the earliest published studies examining the relationship between NOS and evolution understanding, Lawrence Scharmann and William Harris found "minimal evidence" that incorporating nature of science into the teaching of evolution was effective at improving outcomes of understanding or acceptance. Yet despite negative results, Scharmann and Harris concluded with a recommendation for teaching evolution and the nature of science together (1992). Soon after, Martin Nickels, Craig Nelson and Jean Beard received support from the National Science Foundation to develop an intervention to teach evolution alongside the nature of science (1996). Two years later, the National Academies Press published *Teaching about Evolution and the Nature of Science* (NAS 1998), which further emphasized the importance of understanding science for understanding and accepting evolution.

However, even in the midst of its popularity among science educators, there is substantial cause to question the idea that teaching about NOS would actually increase acceptance of evolution. Indeed Lederman and his colleagues specifically tested the hypothesis that understanding NOS influences decision-making about scientific claims, and found no effect (Bell and Lederman 2003). Since reporting those findings, they have downplayed and denied claims that understanding NOS would allow students to better evaluate scientific claims (Lederman 2007) more than once (Schwartz, Lederman, and Abd-El-Khalick 2012).

The inefficacy of NOS to engender acceptance of scientific claims is hardly surprising given that the characteristics of NOS were never developed to defend the reliability of scientific knowledge, nor to convince anyone to accept scientific claims. The characteristics of NOS are based on the work of historians and philosophers of science interested in how science is practiced, with all of its warts. To illustrate this point, the nature of science literature recognizes the following as characteristics of scientific knowledge (paraphrased from Lederman 2007):

1. Scientific knowledge is tentative, which means that it is never conclusively proven, but always subject to change based on new evidence.
2. Facts do not speak for themselves, but must be interpreted.
3. While scientific knowledge is at least partially derived from observations, it is also constructed through human imagination and creativity.
4. Scientific knowledge is subjective. Scientists are affected by their training, theories, beliefs and expectations, which shape what they observe and the questions they ask.
5. Scientists exist in a larger cultural milieu, and they are influenced by what is going on in the societies of which they are a part.
6. Theories and laws are not hierarchically related, with laws being more reliable than theories. Instead, they are two different kinds of knowledge. Laws describe relationships among observable phenomena, while theories explain observable phenomena.

In summary, science is tentative, unproven, interpreted, imagined, subjective and biased. Rather than make a case for accepting scientific knowledge, these tenets of NOS insinuate limitations and qualifications in scientific claims by alluding to its tentative and subjective nature. Of all the characteristics of NOS, only the sixth, which distinguishes theories from laws, seems to give anything like a rebuttal to a creationist argument—that evolution is "only" a theory. The other characteristics only seem to reinforce criticisms of evolutionary science.

In fact, I frequently encountered many of these same claims about the nature of scientific knowledge during ethnographic fieldwork in eastern Tennessee. In churches committed to creationism, I heard many conversations and sermons that pointedly contrasted the tentativity of scientific knowledge with the certainty promised by God's Word. Creationist literature abounds with examples of reasons to doubt the supposed "scientific fact" of evolution, and much of it emphasizes these limitations. The Creation Museum in Petersburg, Kentucky, begins with an exhibit that emphasizes that scientific evidence must be interpreted, that scientists use their imagination to infer what happened in the past, and that they are affected by their beliefs and expectations (Long 2010). The exhibit further claims that another scientist with different assumptions and beliefs (e.g. a young earth, global flood, and biblical account of origins) could interpret the same facts differently and derive evidence for creation. This same argument was well-represented at my site in eastern Tennessee. For example, I encountered it almost verbatim at a conservative evangelical private school where students were "armed" to defend their faith against ideas like evolution.

Given these issues, the more surprising finding ought to be when research appears that actually seems to support the possibility that understanding NOS is helpful in accepting evolution. The clearest example of a positive correlation between measures of understanding the nature of science and acceptance of evolution comes from work by Tania Lombrozo, Anastasia Thanukos and Michael Weisberg (2008). They had 96 college students complete a questionnaire with Likert-style responses on five themes: nature of science, the limits of science, attitudes toward science, evolution acceptance, and religious belief. The NOS score was based on responses to 60 items covering 4 broad aspects of science: theories and hypotheses, the tentativity of scientific knowledge, the creative nature of doing science, and the embeddedness of science in culture and society. The themes were scored by averaging responses across items, and then compared. The authors report significant correlations between NOS scores and acceptance of evolution. This correlation remained significant even when the researchers controlled for attitude toward science and number of college-level science courses taken. They report that "the most plausible interpretation is that understanding the nature of science makes an independent contribution toward accepting evolution" (Lombrozo, Thanukos and Weisberg 2008). However, in their conclusion, the authors note that correlation does not mean causation and allow that the factors may be working in the opposite direction. This alternative hypothesis will be discussed later in this paper.

The aforementioned parallels between tenets of NOS and creationist critiques of evolutionary science present a puzzle: why would creation-affirming students have scored lower on NOS assessments than their evolution-accepting peers? If anything, one might have predicted the opposite pattern—students who doubt the veracity of evolution as a scientific claim would be more likely to agree with statements that mitigate scientific claims. Clearly, we are lacking a complete account.

Understanding the nature of nature of science understanding

In his influential essay "Myth in primitive psychology," Malinowski criticized his religion scholar contemporaries for focusing too closely on the text of myths while ignoring the contexts in which they are told. Malinowski argued instead for the importance of investigating how myths are told, the nature of the performance and even the interaction between story-tellers and their audiences in order to understand the sociological import of the stories (1948). Though Malinowski was speaking of myths and "natives" rather than surveys and students, his insights may be helpful if we are to understand the nature of ideas about science. Rather than treat myth as an abstract intellectual exercise, he recognized it as a cultural force, “active in discussion and squabbles in reference to the relative superiority of the various clans…” (90). Through ethnography, Malinowski documented the ways that Trobrianders invoked myths and other stories for various purposes in different contexts—“to glorify a certain group, or to justify an anomalous status” (1948: 102). Statements about science and scientists may not be myths in the sense intended by Malinowski, and yet they too are produced and invoked in particular contexts and for particular purposes.

I spent 6 months in a community in Appalachian Tennessee in order to better understand contestations over teaching evolution in public schools. I attended churches, talked to people in parks and bars, and met with religious leaders in order to hear their perspectives, particularly how they regarded the scientificity of evolution in relation to their faith. I learned that, contrary to supposition that creationists are “anti-science,” basically everyone I met expressed deep appreciation for science. I observed many examples of people celebrating scientific evidence that they believed confirmed the truth of events described in the Bible, and people were adept at seeking out and sharing arguments (often in the form of webpages and paper tracts) that denied the science of evolution. As Toumey observed, the modern creation science movement is not religion colonizing science, but rather the exact opposite. Science’s mantle of authority is too powerful in the modern world to simply dismiss, and so it becomes necessary to seek out scientific authority in favor of creationism (Toumey 1994).

With regard to the notion that NOS can act as a guide in evaluating scientific claims, I never encountered anyone at my field site referring to their views on the nature of science as a guide for whether scientific claims such as evolutionary origins ought to be believed. In fact, their claims about science seemed to shift depending on the circumstance. At various times scientists were described as capable, duplicitous or confused. Scientific knowledge sometimes was presented as incontrovertible and other times as tentative and untrustworthy. If these people had a particular view of NOS, then it was far more complicated than most of the NOS literature would seem to indicate.

In their review of NOS research, Deng and colleagues identify three “theoretical frameworks” that have guided various methods and analyses of students’ views of NOS. The first of these is what they call the “Unidimension Framework,” which is characterized by measuring lay understandings directly against “correct” understandings, producing a score that places participants on a scale between naïve on one end and constructivist on the other (Deng, Chen, Tsai and Chai 2011). In other words, the framework is based on the assumption that there exists *a* correct or normative “nature of science,” the characterization of which can be derived from expert views, and that students and teachers have “adequate” or “sophisticated” understandings of the nature of science only to the extent that they express those expert understandings (Schwartz, Lederman, and Abd-El-Khalick 2012). While science education researchers have debated over whether experts—namely, historians and philosophers of science, not to mention scientists themselves—actually agree over the precise characteristics of scientific knowledge (cf. Hipkins, Barker, and Bolstad 2005), the assumption has remained that the benchmark(s) ought to be expert views. Within such a comparison, of course, people’s understandings of the nature of science can only be defined as a deficiency, and the methods of assessment only serve to reify that view.

Rather than use a single scale, Deng and colleagues use the term “Multidimension Framework” to describe approaches that break NOS into two or more aspects that can be compared or analyzed separately. For example, views on the role of creativity in science could be measured separately from views on the empirical nature of science. One advantage of this framework is that it can isolate particular aspects of NOS that are more clearly associated with positive science learning outcomes. However, it maintains a focus on a normative view of NOS, based largely on constructivist epistemologies. Though NOS is broken down into multiple dimensions, each dimension remains a scale between naïve and constructivist (Deng, Chen, Tsai and Chai 2011).

An example of the Multidimension Framework is Ester Aflalo's study, published in 2013 in *Cultural Studies of Science Education*. Aflalo sought to explore "the connection between the degree of religiosity and the perception of the NOS" among student teachers in Israel. She used a questionnaire designed to explore attitudes about science, performing a factor analysis on the resulting data in order to create four dimensions: tentativeness and freedom of inquiry, cultural and social superiority of science, practicality of science, and idealization and appreciation of science (Aflalo 2013). She then compared participants' scores on each dimension with other attributes, such as "nationality" (Arab vs. Jewish) and "religiosity" (secular, traditional or religious), and found being "religious" was associated with less support for the first dimension and more support for the second dimension (Aflalo 2013).

Aflalo's study is somewhat typical among work coming from either of the above-mentioned frameworks, in that it effectively treats participants' views of NOS as something like an entity or mental object that individuals are presumed to have or "possess" (Deng, Chen, Tsai and Chai 2011). As Keith Taber (2013) has pointed out, however, human thought is manifold and often in flux, such that espousing one set of ideas does not preclude entertaining their alternatives. Consequently, if assessments of students and teachers are merely designed to detect whether and to what degree particular understandings are present, they are unable to explore what other ideas are lurking in the minds of participants. Neither is it clear what these understandings are doing in people's minds and how they interact with one another or the world around them.

On a related note, according to Deng and colleagues, both the Unidimension and Multidimension Frameworks tend to ignore context when examining views on NOS, focusing on what views students "profess" in the presumably sterile environment of questionnaires. They contrast these frameworks with the Argumentative Resource (AR) Framework, which takes context seriously by studying how students' views are enacted through discourse and behavior. Deng and colleagues note that such research relies strongly on qualitative methods, such as classroom observations, analyzed through content and discourse analysis. At the time of their review, Deng and colleagues identified only 9 studies that employed the AR framework, though that number has doubtlessly grown since 2011.

The research described in the following section does not clearly fit the frameworks Deng and colleagues described in their review. In a sense, it forms a kind of bridge. Like the Unidimension and Multidimension Frameworks, it used a survey tool with statements about science. However, it diverges from previous research in several respects. First, the survey tool was not designed to measure views of NOS in relation to the constructivist NOS favored by most NOS scholars. Instead, I designed it to identify the range of views to which students would assent. Rather than use experts as a benchmark for "adequate" understandings, I sought to characterize students' understandings only in relation to themselves and peers. Second, rather than treat students' views of NOS as static and consistent, this study used a mode of analysis that permitted students to agree with different, overlapping ideas about science. Finally, I remained attentive to how context was likely to shape students' responses. Thus, it found many points of agreement with the AR framework.

This methodological mismatch deserves consideration. It is suggested by Deng and colleagues that quantitative analysis and survey-style tools intrinsically ignore context. Their supposition may reflect the aims of psychologists using such tools that they are controlled, i.e. decontextualized, thus allowing the possibility of generalizable conclusions beyond the confines of their WEIRD study populations (sensu Henrich, Heine, and Norenzayan 2010). It ignores, however, the fact that survey tools are always themselves encountered and answered in particular contexts. Students are not magically teleported into a sterile and abstract extra-dimensional space when their eyes meet a questionnaire. We ought to give students some credit and recognize their capacity to realize that there are people behind the questionnaires who will be reading their responses. Granting this, we ought to allow that responses on a survey, like responses in an interview, are not simply mental objects expelled into a social scientist's database, but rather efforts at communication in a social environment. With this fact in mind, my approach is focused on understanding what ideas students may express about science in particular contexts, and what those expressions reveal.

Behavioral snapshots in a scholastic context

I draw on data I collected as part of a larger research project that included ethnography and spanned several school districts in Tennessee in 2009 and 2010 as part of my doctoral research (Kohut 2016). The data presented here come from face-to-face interviews and two short surveys I conducted with students attending the same rural high school. Thirty-four students were recruited from a year-long Biology I course. I am focusing on this particular group of high school students for this analysis because they represent the largest sample in my study from a single teacher, ensuring comparable classroom presentations of science. Informal conversations with the teacher, his responses in the interview, and observations from the students together established that he both taught evolution and regarded it as scientific and true.

The students lived in and attended high school in a rural county in middle Tennessee. Many families in the school district make a living farming. Rates of poverty are higher than the state average and the majority of adults have a high school education or less. As Borgerding noted, rural adolescents in the US tend to be more religious than their non-rural peers (Borgerding 2017). The religious identities of the students who participated reflected that of the surrounding community. Nearly all (94%) identified as Christian or with a Christian denomination, and the remaining identified as non-religious or agnostic. All but one who identified as Christian attended a church in the area—either United Methodist, Southern Baptist, any of several Pentecostal denominations, or Roman Catholic. Though the United Methodist Church and Roman Catholic Church have officially stated that evolution is compatible with Christian faith, there was no significant difference between students who attended such churches and their peers from more conservative denominations with regard to acceptance of evolution.

The interviews and surveys at the high school were conducted over a two-day period in May 2011, between the completion of the state-mandated end-of-course test and the end of the school year. All students attending Biology I were invited to participate, and most chose to do so, contingent on parental consent. They were informed that they would not be identified with their answers, nor would their answers be shared with their teachers, parents or classmates. Instructions on the surveys and verbal instructions from the survey administrator emphasized that these were not tests that would be graded as right or wrong, and that students should answer according to what they believe to be true. They were also told not to write their full names on the surveys, but instead only their initials, which were later converted into unique numerical identifiers for the purpose of comparing responses between surveys and interviews while preserving the anonymity of respondents.

Participating students completed the Beliefs about Origins Survey (BOS) and the Nature of Science Survey (NOSS), each of which I developed based on ethnographic observations at my field site in eastern Tennessee. They also participated in interviews, in which they told my fellow interviewers and me about their views of science, religion, and evolution, including their experiences learning about evolution in the biology course. For the purpose of brevity, I will limit my discussion to the results of a subset of that interview, which was most directly concerned with their views on science. This portion typically took between 5 and 10 min to complete. It came near the beginning of the interview, before the topic of evolution had been introduced. In it, students answered questions about what makes something scientific, about the differences between scientific laws, theories and facts, and about the limits of science. These interviews help to better understand the results of the two surveys.

The BOS comprised four multiple choice and one open-ended question concerning the age of the earth, the origins of humans and the origins of life more generally. Each of the multiple choice questions included an option to write-in a response. It was developed as a heuristic to group students according to their self-ascribed positions on questions relevant to the evolution-creation debate, and it was validated through internal consistency in response patterns and comparisons to interview statements (Kohut 2016). Rather than a simple dichotomy (e.g. accept vs. reject evolution), responses permitted identification along a continuum of positions, including naturalistic evolutionism, theistic evolutionism, theistic evolutionism with special human creation, old-earth creationism and young-earth creationism. These were positions identified in the course of 2 years of ethnographic research and previous studies of the debate (cf. Scott 1997).

Based on responses to the BOS, the distribution of positions on origins is presented in Fig. 1. As can be seen, only a minority of students took the "extreme" positions of young-earth creationism or of naturalistic evolutionism. While the BOS is able to make more fine-grained distinctions among positions, I sought to improve statistical power by combining the positions in order to make three categories—*naturalistic evolutionists* accept scientific accounts of evolutionary origins, *creationists* reject those scientific accounts in favor of biblical accounts, and *theistic evolutionists* combine scientific and biblical accounts. Dotted lines on the graph illustrate the borders of these categories.

I hypothesized early in my project that the students who accepted evolution would have different ideas about science than those who rejected it. I had no reason to expect that either group of students was thinking about science in a way that would satisfy experts so I needed a way to differentiate various ideas about what science is and how it works. Doing so required not merely developing a new instrument, but also analyzing it in a very different way. The NOSS was designed to characterize students' views of science quickly, without assuming a priori what those views would be. In it, students were presented a list of 24 diverse statements about science and scientists. Responses could be analyzed according to patterns of response agreement among students through a variant of cultural consensus analysis.

The statements were based on claims about science heard during ethnographic fieldwork, representing four broad views of science. Six of the statements, which I call "Creationist," reflected ideas about science based on creationist criticisms of the scientificity of evolution, except that explicit references to evolution were removed. For example, many self-identified creationists related to me stories about how some scientists had actually found evidence that disproved evolution, but that other scientists were discriminating

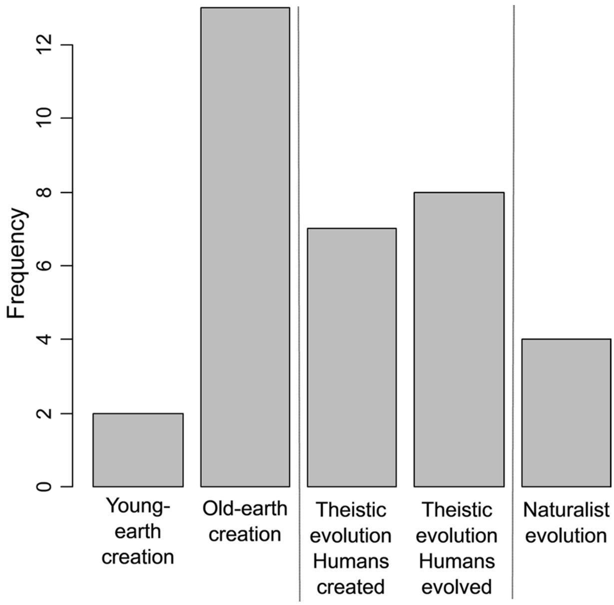

Fig. 1 Distribution of positions taken by students on the beliefs about origins survey

against them—e.g. by not letting them publish their research, getting them fired from their faculty positions, etc. The following statement on the NOSS reflects this claim:

> If a scientist finds evidence that challenges established theories, other scientists will attempt to hide that evidence and punish the scientist.

Another six of the statements, which I call "Evolutionist," were based on counter-claims to each of the creationist critiques. Regarding the Creationist statement presented above, the corresponding Evolutionist statement appears as follows:

> Most scientists want to tell the public about evidence they find, regardless of whether it supports or disproves established scientific theories.

The remaining statements were divided into six that reflected views of science that I will call "Relativist" and six that reflected what I will call "Absolutist." Relativist statements claim that scientific knowledge is relative, in that it changes over time and depends on a scientist's perspective or prior beliefs in making observations and interpreting them. They present scientists as fallible and subject to practical concerns of "normal science" (Kuhn 1962). Many of these statements are basically aligned with the characteristics of scientific knowledge given in the NOS literature, albeit with emphasis on their least flattering aspects. The Absolutist statements are counterpoints to the Relativist statements. They reflect a confidence that science is based on evidence and hypothesis-testing with the goal of discovering the true nature of things. In these statements, scientists behave as impartial seekers of truth.

Students were instructed to agree or disagree with each of the statements and then to rate the strength of that agreement or disagreement on a scale of 1–3, producing a set of ordinal-level data points for each student. Consistent with the purpose of the NOSS, the four sets of statements were not distinguished from one another on the survey and were distributed evenly throughout it. All four sets included shorter and longer statements, all of which were written at an 8th grade reading level. Statements were worded carefully to avoid the impression that statements written as counterpoints were contradictory. No statement was positioned adjacent to its counterpoint, as this may have led students to conclude that they could only agree with one or the other. Furthermore, there were two versions of the NOSS, presenting the statements in opposite sequence, so that any effect of order could be detected by comparing responses from each version. In short, it is reasonable to expect that any patterns in the responses reflect something about students and are not simply artifacts of the instrument itself.

Multiple, conflicting natures of science

Unlike previous researchers working on NOS, I could not begin with an answer key against which to score students. Instead, I analyzed the set of responses from each student using cultural consensus analysis (CCA), which Kimball Romney, Susan Weller and William Batchelder (1986) originally developed to identify "key informants" in the field and also to determine whether a group of respondents agreed sufficiently with one another to be considered to have achieved "cultural consensus." As I was not specifically concerned with these uses of cultural consensus theory, I was able to use the informal version of the analysis, which includes fewer assumptions and works with the ordinal-level data produced by the NOSS (Weller 2007). The informal cultural consensus analysis is basically a principal components analysis (a kind of factor analysis) with the data transposed to compare patterns of agreement among the responses of individuals.

Because the CCA is so rarely used among education researchers, it is important to recognize how this analysis differs from a factor analysis, which was, for example, used by Aflalo in her study of attitudes toward science and religiosity in Israel (2013). A factor analysis compares factors or responses to survey items, in order to compound the responses that tend to covary. Doing so allows the researcher to reduce a host of responses to several scores without simply summing or averaging them. By contrast, the CCA compares individual students based on the extent to which they agreed on their responses (Ross 2004). In this way, it is ideal for identifying ideas and values that are shared across a group or within sub-groups.

The CCA produces answer keys based on the responses on which the participants agreed. The primary answer key, which I will call Model 1 for simplicity, is produced based on agreement among students in the sample, where answers of individuals that agree more with their classmates are weighted more than those who do not. The primary key is a hypothetical set of responses that correlates positively with the responses of most of the participants. In other words, if someone gave those answers on the NOSS, their answers would agree more with all the other students than any other possible set of answers. Each individual receives a score based on the strength of correlation of their responses with this key.

After the CCA calculates agreement with Model 1, it performs the same calculations based on agreement among individuals not explained or captured in Model 1. The analysis repeats this process reiteratively, creating more and more "models," each with diminishing returns in terms of the agreement. Notably, this approach does not assume that any of these models entirely captures the understandings of any given student, nor does it assume that each student has *an* NOS. In fact the responses of seven of the students were significantly

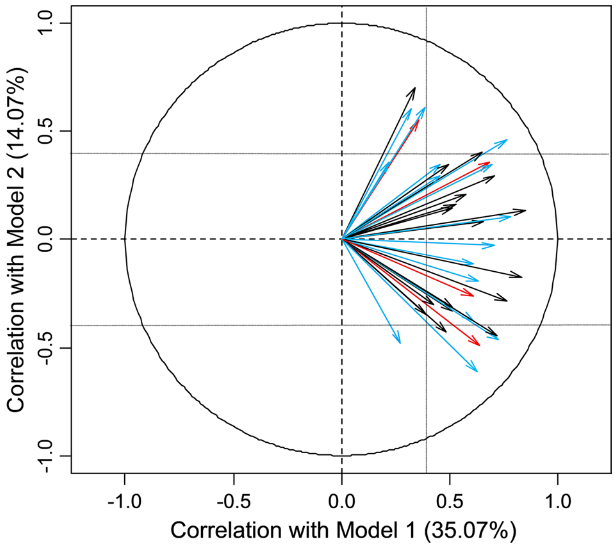

Fig. 2 Agreement with models for each student. Red arrows are students positioned as naturalistic evolutionists. Blue arrows are students positioned as creationists. Black arrows are students taking hybrid positions

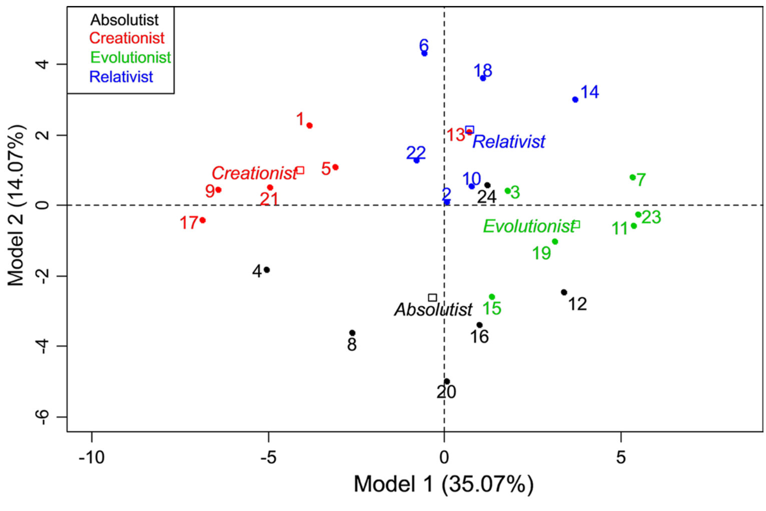

Fig. 3 Answer keys for the first two models produced by the informal cultural consensus analysis. Positive scores indicate agreement; negative scores indicate disagreement

correlated with more than one model. I ran the principal components analysis using the FactoMineR package in R. The results are presented graphically in Figs. 2 and 3.

Whereas the formal cultural consensus model focuses entirely on Model 1, more recent applications have analyzed informant agreement with secondary keys to characterize subgroup differences within a larger group that agrees overall (Handwerker 2002). For example, Norbert Ross examined intergenerational differences in environmental knowledge among Lacandon men (2002). Jeff Shenton and colleagues compared plant knowledge between Tzotzil children in a town and a neighboring hamlet in southern Mexico based on these secondary keys (Shenton, Ross, Kohut, and Waxman 2011). As I was interested specifically in differences in ideas about science among students, I chose to include both Models 1 and 2, which together account for half of the variance in responses.

Figure 2 visualizes the extent to which the responses from each student match the first two answer keys. Students are represented as arrows beginning at the center and stretching along both axes to show how each student's answers correlated with the primary key (horizontal axis) and the secondary key (vertical axis). The further to the right they stretch, the higher the correlation between their set of responses and the primary key. The pattern visualized in Fig. 2, wherein the arrows all point more or less in the same direction (to the right), suggests that most of the students drew, to some extent, on this same set of ideas about science. Indeed, for 83% of the students, Pearson's correlation with Model 1 was greater than 0.404, considered to be significant at a 95% confidence level (Howell 2008). They were more divided regarding Model 2, as indicated by the vertical axis. Of the 36 students who completed the NOSS, the responses of six of them were significantly positively correlated with Model 2 ($r > 0.404$, $p < 0.05$). At the same time, another six were significantly negatively correlated with it.

In summary, the cultural consensus analysis of the NOSS responses indicates that, in the context of the survey, students were willing to agree with certain ideas about science—Model 1. At the same time, they were divided with regard to another set of ideas referred to as Model 2. The fact that some students had positive correlations with Model 2 whereas others had negative correlations means that their responses were the opposites of one another. In this sense, it is necessary to characterize three models represented across responses—Model 1, Model 2, and Model-2.

Recall that each of these models is effectively an answer key, with ideal responses to each of the statements on the NOSS. To characterize these Models, it is necessary to examine these keys, which are visually represented through Fig. 3. Each of the points is a statement on the NOS survey. The position of the points along the horizontal axis corresponds to the ideal response with regard to Model 1. Points to the left of zero indicate disagreement, while points to the right indicate agreement. Likewise, position along the vertical axis indicates the ideal responses for Model 2.

The points are color-coded to indicate to which set of ideas about science they were conceived to belong. As can be seen, statements conceived to represent particular views of science tend to cluster together on the plot. This pattern offers validity to the instrument since it indicates that students tended to answer statements from each set in similar ways. While it is possible to describe the models based on the original sets of views upon which the statements were based (e.g. Model 1 distinguishes between Evolutionist and Creationist statements, whereas Model 2 distinguishes between Relativist and Absolutist statements), doing so would risk occluding students' models behind those of the research instrument. Instead, I examine the statements falling on the extremes of the plot, corresponding to the strongest levels of agreement or disagreement.

For Model 1 the statements that fall on the far right of Fig. 3 are most agreeable, and those on the far left are most disagreeable. Looking first at the statements on the right side, what emerges is an overall positive view of science as universal, farreaching and self-correcting: Ambiguities in scientific results can be eliminated through further scientific study, and erroneous scientific theories will be eliminated. Scientific claims lie outside of morality, though a scientist's observations may be colored by his beliefs.

In summary, Model 1 views the process of science as transparent and scientists as accountable and basically honest. Just as these students agreed with statements that view science as a positive force, they also tended to disagree with characterizations of scientists as duplicitous or responsible for evil. The majority of the statements with which students disagreed were based on Creationist criticisms of evolutionary science. The fact that the students, most of whom identified themselves with a creationist position on human origins in the Beliefs about Origins survey, tended to disagree with those statements when applied to science more generally suggests that creationist critiques are not generalized to all of science. Such accusations about scientists are only uttered in the context of evolution.

Recall that whereas all the students basically agreed with the primary key, they were divided over the second, with one group strongly disagreeing with the other. Because of this, the secondary key can be said to present two sets of ideas about science, one of which is the inverse of the other. Those students whose arrows point up on Fig. 2 agree with the statements plotted on the upper half of Fig. 3, and disagree with those on the bottom half. In order to characterize Model 2, I focused on the statements plotted at the highest positions and those at the bottom-most positions. I found that this pattern of responses is more critical of scientists, particularly regarding their objectivity. Model 2 emphasizes that scientists are influenced by their beliefs, which are assumed to be irreligious. The universality of scientific claims is doubted, and there is even the suggestion that scientists may act unethically in certain circumstances. These ideas cast doubt on the validity of science, due not necessarily to malevolence or duplicity on the part of scientists, but rather due to their human foibles. Thus Model 2 represents science as subjective and tentative. By contrast, the inverse of Model 2, or Model -2 emphasizes the objectivity of scientists and their good faith effort to find truth. Accusations of bias on the part of scientists are dismissed. Not only is scientific knowledge universally applicable, but science itself, as an approach to truth, is wholly reliable.

Thus the results of the CCA suggest the existence of multiple, conflicting ideas about science, which were evinced to varying degrees by the student participants. While taking the survey, most students endorsed a generally positive view of science as accountable and honest, and rejected the notion that scientists would purposefully hide evidence. At the same time there was a sizable subset that was ready to employ a view of scientific knowledge as less than fully reliable. These students did not agree with the generalized creationist claims about science, but they did agree with many of the relativistic statements, and disagreed with some of the more idealistic views on science. Another subset endorsed an extremely positive view of science, with idealized scientists that are always objective, and emphasized the reliability of Science.

Based on previous studies, I expected to see some relationship between students' ideas about science and their positions on origins. Perhaps creationist students would agree more with negative statements about science than their evolutionist peers. Alternatively, since Model -2 is most closely aligned with the "inadequate" understandings of NOS discussed in that literature, perhaps creationist responses would correlate more highly with it. To test this hypothesis, I compared students' orientations to evolution and creation based on the BOS with their agreement with the Models. In Fig. 2, blue arrows indicate students who responded as creationists, red arrows indicate students whose responses were consistent with naturalistic evolution, and black arrows indicate hybrid positions. As can be seen, both evolutionist and creationist students answered according to the positive view of science, and there were evolutionists and creationists who answered according to the negative view. Statistical analysis of means of individual agreement with Models 1 and 2 revealed no reliable difference between evolutionists and creationists. How should these results be understood, particularly in light of previous studies? To help answer this question, it is necessary to consider what students told us in interviews.

Using versus having ideas about science

The Nature of Science interview took place near the beginning of an hour long interview that included topics related to evolution. Evolution itself was not introduced as a topic by the interviewer until much later, so most students were not primed to think about anything but science more generally when responding to NOS questions. This portion of the interview took about 10 min to complete, and included most of the important themes noted in the NOS literature, such as differences between theories and laws.

Looking first at the interview transcripts of students whose survey responses best matched the answer key for Model 1, we encounter a view of science that is quite optimistic, as might be predicted. In this view, the power of science comes from the importance of proving its claims, and the use of terms like “proof,” “proving” and “proven” are frequent. For many of these students, the reason that religious ideas are not a part of science is because they cannot be “proven.” Scientific laws are proven to be true and never change, suggesting that science is capable of telling us what is true.

At the same time, practically all of the 31 participating students said that scientific theories were decidedly not proven. As an example, one student gave the following responses:

> *What’s a scientific fact?* Something that has been proven by scientists
> *What’s a scientific theory?* A bunch of scientists think that it’s possible, but they haven’t been able to really prove it.
> *What’s a scientific law?* It always happens, no matter what you do with it.
> *What’s the difference between facts, theories and laws?* If you have facts, you can use those to come up with different theories, and eventually, once you have a theory, and you can prove that it happens every time, you can make it into a law.

As mentioned earlier, skeptics of evolution often object that evolution as “only a theory,” emphasizing that it is not the final truth and may later change. On its face, this claim is accurate, and one could say that this is an attitude that a science educator ought to want from students, as it clearly recognizes the tentative nature of scientific claims (Taber 2017). However, situated within the hierarchical view of theories and laws described above, the “only a theory” challenge is meant to suggest that evolutionary theory is especially tentative. This view is also consistent with the idea that science is about proving things to be true (positivism), wherein theories and laws exist on a hierarchy of credibility. Against that backdrop, distinguishing theories and laws based on other criteria (involvement of an equation, explanation vs. description of observed facts) can be used to point out that even laws are tentative and incomplete. Nevertheless, only one of the students characterized scientific theories adequately in terms of NOS, as explanations that have not yet been disproven.

If we look specifically at the students whose survey responses agree more with Model 2, then we reliably see a dismissive attitude toward science and scientific claims like evolution. When one such student was asked whether scientists make assumptions, she answered, “They assume that we’re all from monkeys and everything.” Asked about why scientists don’t consider supernatural explanations, she said, “They don’t think the supernatural exists. They want to believe that we’re from apes or we’re from bubbles.” Asked about how beliefs affect scientists, she asserted, “Whatever you think that belief is, you’re going to try to prove in your study that your belief is right.” This cynical view of atheistic scientists as interested in confirming their own beliefs and unwilling to test their assumptions is exactly what one might expect to hear based on her survey responses and their close match to Model 2.

However, strong agreement with the second answer key can apparently reflect a very different attitude, as it did for another student. When asked why scientists rule out supernatural explanations, he answered, “Because it would go against a lot of their theories, like the theory of evolution, and the big bang theory would go against it.” He seems to be saying that scientists avoid supernatural explanations because they do not want to disprove their theories. He goes on to tell us that beliefs have a definite effect on scientists, because what a scientist believes “could change the way they look at it. Like if they’re a Christian they could look at something completely different than if this other person was an atheist. They could have a totally different view of it.” Clearly the student recognizes that scientists can be biased and even self-interested. All of this would seem to fit well with the highly cynical views of science noted above, except that he is also the only student who defines a scientific theory as, “something that cannot be disproven as of right now. It’s been fought against, but it’s come out as the top. Like the Big Bang Theory. We can’t really disprove that right at this moment, but with further information we could, possibly,” a definition that emphasizes both the tentativity and reliability of science. Elsewhere in the interview, he confirms that he regards the Big Bang theory and evolutionary theory as well-supported by evidence that he finds convincing. In this light, his answers take on a new meaning. Why are supernatural explanations dismissed by scientists? Because they already have better answers to those questions. And while an atheist and Christian may approach science through different lens, this clearly does not mean that their interpretations are equally valid.

What this tells us is that statements about the nature of science can all be spun in different ways. Two students could agree that scientists’ beliefs matter, that theories are tentative, and that scientists frequently make assumptions, and yet reach opposite conclusions about the reliability of scientific knowledge. The fact that multiple meanings hide in these statements helps to explain the fact that evolutionist and creationist students did not systematically differ in their responses on the NOSS. For example, both may say that scientists exclude the supernatural because they do not believe in it, but creationists are critical of this tendency and evolutionists praise it.

Not only did students demonstrate how the same set of answers could imply contradictory things, but they also demonstrated a capacity to invoke different, contradictory ideas depending on context. For example, one student whose survey was strongly correlated with Model 1 ($r=0.78$), actually shifted during the course of her interview between two attitudes about science. In the first part of her interview, she describes laws and facts as being proven and unchanging, similar to other students with strong agreement to Model 1. However, when asked whether scientists ever make assumptions, she says that they do, and then elaborates, “I think it goes back to evolution. I don’t really believe in that. That is something that I just think somebody came up with that’s not necessarily true.” After this point in the interview, the student speaks of scientists in sharply critical terms. Asked whether a scientist’s beliefs can affect his observations, she strongly agrees, and then states, “It’s really based on their opinion against the other person’s opinion.” Asked whether there are questions that science can never answer, she says, “Evolution questions and stuff like that. People are going to all believe something different. Everybody’s going to believe something different.” It is as though her understanding of the nature of science has completely changed. Whereas her survey and initial answers in the interview indicated that science was all about doing research and testing claims, she suddenly speaks about science as mere opinion.

Her answers on the NOSS may have been different had she been primed to think about evolution beforehand. Students were not told by the researchers that the interviews or surveys were part of a project on evolution until later. However, it was clear that evolution was already salient for many of the students, who brought up the topic themselves as an example of a scientific theory in the interview. There is some evidence to suggest that this salience of evolution influenced the way that students answered the NOSS. On average, students who brought up evolution on their own had significantly lower correlations ($x = 0.455$) with Model 1 than those who did not ($x = 0.592$; Welch Two Sample t test, $t = 2.1868$, $df = 14.163$, p value $= 0.04602$). These results suggest that many students characterize science more cynically when they are thinking about evolution, but more charitably when they are not. As an example of this, one student disagreed on the survey (as did virtually all of her peers) with the statement that scientists are unable to study the past, yet she later stated in her interview that evolutionist claims about the past are not scientific because no one was there to directly observe what happened.

One final section of the interview over the nature of science is relevant to mention at this point. As noted, recommendations that NOS be taught alongside evolution implicitly assume that students and teachers have a single, coherent mental model of the nature of scientific knowledge that is used to understand and evaluate whether certain claims are scientific. During interviews, participants were asked how they know whether something is scientific. In their responses, students talked mostly about looking for the symbols they associate with science. Such symbols included phrases such as “studies show,” “hypotheses,” or “research.” For some it was sufficient that the material in question include “big words” and “science-y stuff.” Others based their judgement on whether it concerned topics associated with science such as the human body or nature. Contrary to common assumptions, the students in my study did not invoke any set of characteristics of scientific knowledge, neither their own nor that of the experts.

Regardless of how students may have described their criteria for deciding whether something is scientific, they also drew on the conflicting ideas, anecdotes, and associations having to do with “science” that are available in their environment, in order to justify their positions. Students navigated claims about evolution (and likely other topics) by referencing a set of shared ideas about the nature of science such as the role of scientists’ beliefs and the tentativeness of scientific knowledge. However, students qualified those claims in different ways, and even deployed contradictory claims in different contexts, as needed. The same statements about science are used by a creationist student to argue against evolution as scientific, and by an evolutionist student to argue against creation as scientific. But they are also internally negotiating these ideas, such that the same student may disparage science at one point, only to celebrate it later.

The rhetorical efficacy of NOS

Earlier in this paper, I asked why creationists, who are steeped in claims about science that are consistent with most characteristics of NOS, would score lower than evolutionists in the Lombrozo study. One possibility is that the correlation was driven by responses to statements about theories, hypotheses, and testing. As noted before, creationists do tend to mischaracterize the relationship between theories and laws, by NOS standards. Given that these statements make up one-fourth of the NOS score in Lombrozo and colleague’s study

(2008), it may be worth investigating further, though doing so would require examining finer levels of data than were published.

Another possibility is suggested by Lombrozo, Thanukos and Weisberg themselves. In their discussion, they consider that the correlation between understandings of NOS and acceptance of evolution may be due to a rhetorical rather than cognitive efficacy. They express doubt that teaching accurate views of NOS would convince students who have already rejected evolution in favor of creationism to rethink their positions. Instead, they suggest that understanding NOS may help students who are undecided or leaning toward accepting evolution by giving them *rhetorical tools* to refute antievolution messages (Lombrozo, Thanukos and Weisberg 2008), a phrase that echoes Deng, Chen, Tsai and Chai's *argumentative resources* (2011). Indeed, though seemingly an afterthought of Lombrozo's team, these parallel lines of thought serve as convenient reminders of the long-held hope of science educators that teaching NOS will aid in confronting the problem of creationism.

However, as I noted earlier, the key characteristics of NOS—subjectivity, tentativity, imagination, interpretation—are among the characterizations of science most common in creationist discourse, which suggests that basic knowledge of NOS alone could just as easily be recruited to attack evolutionary science as to defend it. In fact, scholars aligned with the argumentative resources framework have advocated for a fundamental shift in how NOS ought to be defined and measured, focused not on normative NOS content knowledge, but instead specifically on whether students are capable of identifying and rejecting pseudoscientific claims (Allchin 2011). Nevertheless, Lombrozo and colleagues found their effect despite measuring something closer to the normative NOS model.

We may escape this conundrum by tweaking their claim slightly to recognize that *something* about NOS allows it to function as an apologetics of science, providing tools to defend against detractors. Though characteristics of NOS listed by Lederman and others undermine idealistic notions of science as objective or absolutist, they are not obviously intended to demean scientific knowledge or problematize its authority. In fact, when the characteristics of NOS are discussed together, they are often part of an implicit argument. When Lederman presents statements that characterize NOS, his elaborations on them both recognize a potential problem for science and then transform that problem into a strength. For example, though science is always tentative, this is because claims stand or fall based on the evidence. As a consequence, accepted theories are borne by a great deal of evidence and are therefore reliable. Thus, like any apologetics, an apologetics derived from NOS transforms seeming contradictions into distinctions and opportunities for more sophisticated understandings. If a student were under the impression that science is absolute, but then were to learn that a scientific claim has been refuted, that student may learn to distrust other scientific claims. Yet if the student had a correct understanding of NOS, she would see the refutation of a scientific claim as evidence of its reliability, rendering many creationist attacks on the science of evolution as rhetorically ineffective.

Of course an apologetics is not merely a list of statements about a matter, but rather a set of arguments. Thus when NOS is taught or assessed, it is necessary to be aware of whether the arguments are included or implied. Failure to remember this issue during research could, for example, lead to situations in which participants interpret a statement as synecdoche for the argument while researchers interpret it based on its text (or vice versa). This possibility would help to explain why a creationist would be less likely to agree with the NOS statements in the Lombrozo study—they may agree that science is tentative, but are less willing to agree with implications that seem favorable to evolution. It may be possible as well that these implications are more apparent when the topic of evolution has been introduced, as discussed earlier.

Four implications for NOS research

To summarize the findings of this article, students refer to a wide range of ideas about science, both cynical and celebratory, regardless of their beliefs about evolution. Rather than conceive of students to be individually engaging with claims about scientific knowledge in light of a more-or-less impoverished understanding of the true NOS, it is more accurate to recognize that any given student thinks and interacts within a community of both peers and adults, and that engagement with scientific knowledge or claims about the world (such as evolution) occurs vis-à-vis the many, oftentimes conflicting, ideas and claims about "science" that are voiced within that community. Students draw on these ideas situationally in their interactions with peers to support or undermine scientific claims. While peers who interact in a community are likely to agree on most of these claims, they will employ them differently, depending on the positions they wish to assert or defend.

These findings have several implications for science education research related to NOS. First, it is crucial that NOS researchers and advocates consider carefully what NOS is and what they expect it to be doing. Past research has operated on the assumption that students "have" an understanding of science, which more or less approximates NOS, and which they use to evaluate scientific claims. Under that paradigm, students simply need to be surveyed or interviewed about science, and the resulting model can be deposited in the database: this is so-and-so's understanding of the nature of science. However, these results suggest that understandings of NOS are not as stable and consistent as much of the NOS research implicitly assumes (cf. Taber 2013).

Second, researchers must keep in mind that participants are situated in social and cultural contexts, which is relevant for understanding their responses. If students selectively draw on a range of ideas about the nature of science depending on their purposes, then researchers must ask themselves what purposes a participant may have in mind while they answer a questionnaire. If she wants to justify her position on evolution, she may answer differently than if she wants to justify her appreciation for science as a body of knowledge, and she may answer differently again if she wants to communicate a more realistic or more idealized view of science. Students interact within a community of both peers and adults, and their engagement with scientific knowledge or claims about the world (such as evolution) occurs vis-à- vis the many, oftentimes conflicting, ideas and claims about "science" that are voiced within that community.

Third, it is impossible to discover the myriad ways that students think about science by asking questions about only one specific way of thinking. While Deng and colleagues (2011) have suggested that qualitative methodologies are necessary in this regard, this article demonstrates a way that even quantitative tools can play a key role. If we want to access the rich sets of ideas around science, researchers need to include alternative ideas on survey tools. Single-dimension metrics for characterizing student understandings are inherently incapable of capturing the complexity of thinking and talking about science. Researchers ought to seek out and develop tools capable of capturing multiple dimensions and allowing for students to have contradictory ideas.

Finally, this research supports the point that students are capable of referring to a whole range of ideas about the nature of scientific knowledge and deploying them differently in different situations. This ability extends even to the canonical characteristics of NOS, such as the subjectivity, tentativity and creativity inherent in science. The NOS literature claims relevance through the possibility that understanding NOS helps students to better understand, evaluate and (most importantly) *accept* scientific knowledge. However, there seems to be a difference between NOS as a list of characteristics and NOS as an apologetics (cf. Allchin 2011). Failing to recognize this difference opens the possibility that they could be co-opted by creationists and other science deniers to find ways to dismiss the evidence for an unwanted explanation. If it is not NOS itself but rather something implied in its presentation that supports acceptance of legitimate scientific claims, then we ought to figure out what that "something" is. After all, it may be the necessary component in the goal of convincing people to recognize the authority of science to tell us what is, for now, true.

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