The Mismatch Among Students' Views About Nature of Science, Acceptance of Evolution, and Evolutionary Science Understandings

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Abstract

This study explored interrelationships among high school students' views about nature of science (NOS), acceptance of evolution, and conceptual understanding of evolution, and the extent to which these may have shifted from pre- to post-instruction on evolutionary theory. Eighty-one students enrolled in ninth-grade Biology responded to questionnaires measuring views about NOS and acceptance of evolution, and were tested on their conceptual understanding of evolution before and after a month-long instructional unit on evolution. Results revealed that students with more scientifically accurate views of NOS showed greater acceptance of evolutionary theory. Students' conceptual understanding of evolution significantly increased from pre- to post-instruction, but views about NOS and acceptance of evolution did not shift. No correlation was found between students' NOS views or evolution acceptance and their conceptual understanding of evolution. Findings imply that students may increase and refine their understanding of evolutionary theory without showing a change in their views about NOS or acceptance of evolution. (Most of this paper is a summary of Cavallo & McCall, 2008.)

Evolutionary theory has been the core of education and religious debate for well over a century (Brem, Ranney, & Schindel, 2003). This ongoing dispute compromises the very discipline of science, as non-scientists in positions of authority may have the capacity to remove or limit teaching evolutionary theory in our schools (e.g., National Center for Science Education, 2008). Yet the scientific community views evolution as a unifying theory in biology and recognizes that it is based on extensive and comprehensive evidence. The scientific community also asserts that controversial topics are critical to the scientific enterprise (National Research Council, 1996), as long as opposing positions have been subjected to the same show of evidence, rigor, and scrutiny as is the convention in science. Evolution provides, in fact, a classic example of the very nature of the scientific discipline where new evidence in science challenges current views and ways of thinking (Cavallo and McCall, 2008).

Beliefs About the Nature of Science

Though evolution is often headlined in the media, considerable public misinformation exists. Biology teachers find students hold opinions about evolution, yet have little scientific understanding of evolutionary processes. Along with pre-conceptions about evolution, students may not understand that scientific theory is based on substantial evidence and support, yet dynamic in light of new, authenticated findings. Thus, students hold misunderstandings of what defines scientific theory, as in the case of evolutionary theory, which in turn may impact their learning and understanding of scientific topics. Research indicates that promoting more scientifically accurate views of the nature of science (NOS) among students may impact their acceptance of evolutionary theory (Bybee, 2004; Cavallo & McCall, 2008; Dagher & BouJaoude, 1997). Recent research by Winslow, Staver, and Scharmann (2011) supports this approach by posing that if students understand NOS, this understanding "allows them to demarcate the boundaries of, and distinguish between, knowledge claims made by science and religion" (p. 1027). Thus, making the mental separation between what constitutes science and what constitutes faith may help students better understand, and be open to understand, scientific theories such as evolution that are addressed in school.

One way to address students' views of NOS is by means of a "unidimension framework" (Chen, Tsai, & Chai, 2011, p. 967), meaning that their views fall on a continuum with two opposing ends. According to this framework, students' NOS views on one end of the continuum may be characterized as dynamic and tentative, or on the other end, as static and fixed (Cavallo, Rozman, Blickenstaff, & Walker, 2003; Linn & Songer, 1993). Students who view science as dynamic and tentative consider science as constantly changing and understand that scientific conclusions are based on evidence. Students holding this view of NOS perceive science as intelligible, interpretable, and connected with what they already understand about the world (Cavallo & McCall, 2008). At the opposing end of the continuum, students hold the view that science is static and fixed and an assemblage of data and indisputable facts. Students with fixed or static beliefs may see learning science as something to be accomplished through memorization and as divested from their lives (Cavallo et al., 2003). Students who hold a static, fixed view also tend to believe that scientists always arrive, or attempt to arrive, at the "truth" (Linn & Songer, 1993; Saunders, 1998).

Beliefs About Evolution

One of the most influential factors regarding acceptance of evolution may be the students' worldviews. For example, religion may be the central framework in one's views of the world regarding origins of life. However, the scientific bases of evolution may conflict with these views. Dagher and BouJaoude (1997) suggest a strong connection between religious affiliation and personal views regarding the theory of evolution. In one study, beliefs were shown to interfere with students' ability to examine scientific evidence objectively, and the interference was even stronger when learned religious ideas conflicted with the information being taught (Sinclair & Baldwin, 1996). Lawson and Worsnop (1992) found that a substantial portion of students held a belief in creation and related non-scientific beliefs before their study began. These studies highlight the notion that science and religion both serve as ways of knowing about the world, but do so from very different frameworks of understanding (Sinclair & Baldwin, 1996). However, it is yet unclear how incongruous beliefs about evolution and NOS might impact students' acquisition of scientific understanding of evolutionary theory. Therefore, the research questions of this study were:

1. To what extent may views about NOS, acceptance of evolution, and understanding of evolution shift from pre-instruction to post-instruction during an instructional unit on evolution?
2. What are possible relationships among students' pre- and post- instruction (a) views about nature of science, (b) acceptance of evolution, and (c) understandings of evolution topics?
3. What differences may exist in students' achievement of scientific understanding of evolution according to their views of NOS (fixed, tentative) and acceptance of evolution (high, low)?

Method

This study was conducted on a suburban/rural ninth-grade campus located in the Midwestern United States. The students (mean age = 14.5 years) were those enrolled in three biology classes totaling 81 students, with 44 females and 37 males. The ethnicity of the participants was predominantly Caucasian and non-Hispanic, with less than 5% representing other ethnic groups.

Instrumentation and Instruction

The following three instruments were used in this study in a one-sample pre-test/instructional treatment/post-test design.

Science Knowledge Questionnaire (SKQ)

The SKQ measured students' views of NOS on a unidimensional continuum (Cavallo & McCall, 2008; Saunders, 1998). The SKQ used in this study was a 16-item Likert instrument. Students responded to questions about NOS by indicating a choice ranging from *Strongly Agree* to *Strongly Disagree*. The fixed/authoritative views of NOS items on the SKQ were reverse scored so a lower score on the instrument indicated a more fixed view and a higher score indicated a more tentative view of NOS.

Measure of Acceptance of the Theory of Evolution Instrument (MATE)

The MATE was adapted and used to measure students' beliefs about evolution (Rutledge & Warden, 1999). Questions on the MATE determined students' level of acceptance of the theory of evolution. Two additional questions were added to the questionnaire to evaluate overall student perceptions of evolutionary theory (Rutledge & Warden, 1999). The MATE used in this study was a 22-item Likert instrument that provided numerical values for analysis. A high questionnaire score indicated greater acceptance of evolutionary theory, so the scores obtained were termed the students' *acceptance of evolution*.

Understanding Biological Change (UBC)

Students' understanding of evolution was measured by administering the test, Understanding Biological Change (UBC), Version B, designed by Settlage and Jensen (1996). Four additional questions were selected from the questionnaire used by Sinclair and Baldwin (1996). All questions were in a two-tiered format with a question as the first tier and the explanation as the second. The students' response to both the question and the explanation/reasoning for the response were to be correct to receive credit for the item (scored as 1 or 0).

The instruction for the unit on evolution was a combination of active inquiry and discussion to help students gain understanding of the theory of evolution and its supporting evidence. The content of the unit was based on the text *Biology: The Study of Life* by Schraer and Stoltze (1999), with additional resources coming from the website series *Evolution* produced by WGBH/NOVA Science Unit and Clear Blue Sky Productions (2001). The topics for the 4-week instructional unit included the history of evolutionary thought, Darwin, evidence of evolution, and how evolution works through natural selection. Several online and in-class activities were used to help students gain an understanding of the evolutionary topics of this course.

Data Collection Procedures

Analyses on the first two research questions of this study used students' scores on the SKQ, MATE, and UBC to examine possible shifts from pre- to post- instruction, and to explore interrelationships among NOS, acceptance of evolution, and understanding of evolution. Analysis for the third research question used a median split with students placed into low- or high-scoring categories according to responses on the SKQ and MATE. The low-scoring group on the SKQ held more fixed, authoritative views of NOS and the high-scoring group held more tentative, dynamic NOS views. The median split on the MATE provided two groups with either a low or high acceptance of evolution.

Results

Shifts in Student's Views of NOS, Acceptance of Evolution, and Understanding of Evolution

A paired samples *t*-test was used to explore possible shifts in students' views of *NOS*, acceptance of evolution, and evolution understanding from pre- to post-instruction. Results of this test revealed no significant change in students' views of NOS, or acceptance of evolution, from the pre- to post-instruction ($p > .05$). However, there was a significant shift in students' biological understanding of evolution between pre- and post-instruction on evolution ($t = 7.25$, $df = 75$, $p = .000$).

Relationships Among Students' Pre- and Post-Instruction Views About Nature of Science, Acceptance of Evolution, and Understanding of Evolution

Correlation analyses were used to explore the relationships between students' pre- and post-instruction views of NOS, acceptance of evolution, and evolution understanding. Significant positive correlations were found between students' pre-test views of NOS and pre-test acceptance of evolution scores ($p < .05$). This finding indicated that students with a more tentative view of NOS also tended to have a higher acceptance of evolution, and those with a more fixed view of NOS also had lower acceptance of evolution. The correlation between post-test views of NOS and post-test acceptance of evolution scores also tended toward the same positive correlation ($p = .05$). A significant positive correlation was found between students' pre- and post-Evolution Understanding scores ($p < .01$).

Differences in Students' Understanding of Evolution Topics According to Their Views of NOS (Fixed, Tentative) and Evolution Beliefs (High, Low)

Paired samples *t*-tests explored differences in post-test scores on students' evolution understandings with respect to views of NOS grouped as fixed or tentative, and their acceptance of evolution grouped as high or low. No significant differences were found in students' understanding of evolution according to these opposing views of NOS or acceptance of evolution ($p > .05$). Notable, however, was that the difference between tentative and fixed NOS groups approached significance in understanding evolution, favoring students holding more tentative views ($t = 1.89$, $df = 73$, $p = .06$). More research is needed to determine the salience of this finding.

Summary and Discussion

This study explored patterns and interrelationships among students' views of the nature of science, acceptance of the theory of evolution, and their conceptual understandings of evolution. It revealed that students' views of NOS and acceptance of evolution did not shift during the month-long evolution unit, yet students' understanding of the concepts related to evolutionary biology increased. This finding corroborates the literature that reports beliefs as being deeply entrenched in one's persona and unlikely to change in a short period of time (Blackwell, Powell, & Dukes, 2003), yet in the same timeframe students were able to improve their understandings of the scientific concepts.

The results of this study show a positive relationship between students' views of the tentative nature of science knowledge and acceptance of evolution. In both pre- and post-evolution instruction, if students viewed science as a tentative/dynamic process, they were also more likely to accept evolution; the more the students viewed science as fixed and authoritative, the more likely they did not accept evolutionary theory.

For many, science may be considered a subject to be memorized and an authoritative source of knowledge rather than something that is changeable and dynamic. This is clearly not the view of the scientific community, which supports the position that scientific ideas are subject to change, and presumes that "even if there is no way to secure complete and absolute truth, increasingly accurate approximations can be made to account for the world and how it works" (American Association for the Advancement of Science [AAAS], 1990, p. 2). It is important to help students realize that increasingly accurate approximations in science demand evidence, and arguments must be based on logic and reasoning (AAAS, 1990).

Clearly, students enter classrooms with certain worldviews and perspectives that may seem counter to current scientific theory. These worldviews are important for teachers to know prior to instruction, especially when instruction may challenge these views. Matthews (2009) highlighted the perspective of biologist, educator, and Anglican priest Michael Reiss by stating: "Unless science teachers take into account [existing beliefs] school science will fail to enable students to learn much of these areas of science [explanations of biodiversity] at more than a superficial level or to engage students with science" (p. 659). By viewing science as a dynamic process, students may actually be more open to highly charged scientific ideas such as evolution.

The question is not about the teaching of evolution; it is about the manner in which evolution is taught. Too often, the teaching of evolution is conscripted into a philosophical or religious topic, when it should not be; evolution is firmly grounded in the scientific discipline. This study provides no evidence that students' acceptance of evolution relates to their understanding of evolutionary theory: Students will understand the theory even if they do not accept its philosophical or religious implications. Therefore, as scientists and educators, rather than focus on acceptance of evolution, our responsibility should be to promote understanding of scientific processes as well as the body of knowledge accumulated through the processes of science. It is most important that students understand, and are able to practice, the processes of science, experience its tentativeness, and logically analyze evidence gathered today or throughout history so they are prepared to support or refute any scientific theory.

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