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Student Teachers' Understanding and Acceptance of Evolution and Nature of Science Subject.

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ABSTRACT

The results of studies of the nature of science (NOS) as a factor that enhances students' understanding of evolution have been inconclusive. Therefore, the main purpose of this study was to test the role of NOS instruction in enhancing students' learning about evolution. We used a quasi-experimental design with pre- and post-tests to investigate the impact of teaching evolution with and without NOS in two classes with 15–16-year-old students, who were randomly assigned to these two classes. To measure their understanding of NOS and their acceptance and understanding of evolution, we used three different instruments that have been shown to generate reliable and valid inferences in comparable populations. The main results of this study were that, in the class in which the teaching of evolution included NOS instruction, the students' understanding of NOS and their acceptance of evolution significantly improved. However, irrespective of the use of NOS instruction, both classes increased their understanding of evolution. These results support the claim that NOS instruction may influence students' acceptance of evolution but not their understanding of evolution and natural selection.

KEYWORDS: SCIENCE, EVOLUTION, UNDERSTANDING

INTRODUCTION

Most Science teachers would agree that biological evolution represents a unifying theory and a common thread within the biological sciences and how the methodology of science is practiced. Unfortunately, the available evolution education literature provides little practical guidance on how to effectively blend evolution content with science process. As a result, the topic of evolution along with its various mechanisms such as mutation, gene flow, genetic drift, and natural selection, can assist students and teachers of science alike make sense of complex and diverse biological concepts, while at the same time providing students with an opportunity to engage in the scientific processes found within the boundaries of the nature of science (NOS) (Smith, et. al. 1995). What is biological evolution? How does it work? What types of questions does evolution try to answer? What processes do scientists use to try and explain the variety of life on earth? These and numerous other questions regarding the (NOS) can serve as an ideal tool for students and teachers alike within courses such as biology, chemistry, physics, and the earth sciences. It is human nature to be curious and to ask questions about the world around us in order to better understand it. Biological evolution, along with its historical development, and the nature in which scientists collect and analyze empirical evidence can help students make sense of diverse concepts, such as mutation and genetic variation, Mendelian population genetics, selection and mutation, migration, genetic drift, non random mating/inbreeding, and quantitative genetics.One way of knowing or understanding our world is through the biological sciences. The biological sciences developed around a specific form of rationality which we know as inductive thought. Scientists were able to describe and explain the general principles or mechanisms involved in everyday observed natural phenomena through observation, experimentation, and collection of empirical evidence. As a result these nature of science principles formed the foundation of organized knowledge across the scientific disciplines such as biology, chemistry, physics, and earth science. As a result, the aforementioned scientific methodologies such as observation, hypothesis generation, experimentation, gathering of empirical evidence, and data analysis should also be associated with learning within the science classroom.

Science as a Way of Knowing

The National Academy of Sciences (2008) defines science as “the use of evidence to construct testable explanations and predictions of natural phenomena, as well as the knowledge generated through this process” . Science involves particular ways of knowing about the world (Moore, 1999). Scientific ways of knowing include: proposing a testable framework of questions and ideas based on observations; providing predictions and explanations about the natural world based on empirical evidence; and gathering information and knowledge by conducting experiments and/or through analyzing data (CDE, 1990). Recent studies have indicated that accepting and comprehending evolution is related to understanding the nature of science (Lombrozo, et al. 2008). Numerous research articles and books have been published during the past decade concerning the curricular and pedagogical aspects of the NOS. Given the vast amount of research conducted by science educators during the past 20 years a consensus has emerged highlighting the fact that students tend not to learn science content meaningfully (Osborne, et al. 2003). As a result of the research, several core NOS ideas have emerged as well .

Acceptance and understanding of evolution among students

Acceptance of evolution. About 70% of the students who completed the voluntary survey identified evolution as an established scientific fact supported by overwhelming evidence (figure 1). A further 16% indicated that they recognize that evolution is accepted by the scientific community at large, but that they themselves remain “partially convinced.” About 11%

responded that there is evidence in support of evolution but that it "remains just a theory." Only 7 students (< 4%) felt that evolution is "purely speculative" and unsupported by evidence (four in OVC, one each in the other colleges). There were no significant differences in the overall level of acceptance among colleges (ANOVA, $p > 0.13$).Acceptance of evolution was not significantly correlated with the time since taking a formal course in evolution (table 1). Almost half (48%) of the students had never taken a formal course in evolution, but 68% of these students nonetheless rated evolution as an established fact, and another 14% were partially convinced. The level of acceptance was positively correlated with the self-assessed level of understanding, Darwin index score, and theory index score, but not with the other indices (table 1). Not surprisingly, students who accepted evolution as fact were more likely to consider it important for the scientific goal of understanding the natural world. Nearly 87% of all surveyed students considered evolution to be relevant or very relevant to the broader goals of science. As might be expected, students in the CPES were less likely than those in the three life science—oriented colleges to consider evolution directly relevant to their day-to-day research and interpretation of data (figure 2; ANOVA, $p < 0.0001$; differences between the other colleges were not significant). Students'opinions regarding the relevance of evolution were positively correlated with the Darwin index score but were independent of the time since taking an evolution course. Self-assessment of understanding. Students were asked to estimate the level of understanding of evolution for themselves, their peers, and the general public. The most common rating students gave to themselves and their peers was "good" (about 60% of responses in both cases). However, students were twice as likely to rate their own understanding as "very good" (25%) than they were to give that rating to their peers (13%). Students who had taken a course in evolution were more likely to rate their own understanding highly (very good: 32%; good: 57%) than were students who had not taken an evolution course (very good: 19%; good: 66%). On average, students in all four colleges were equally confident in their own understanding (ANOVA, $p > 0.8$). Students' assessments of their own understanding correlated positively with Darwin index scores and negatively with scores on both the intuitive index and the orthogenesis index . Fewer than 8% of the students ranked the public's understanding of evolution as good (none said very good), and about 65% considered it to be poor or very poor.

Interpretation of major findings

This passage highlights the major patterns found among graduate students in terms of acceptance, conceptions, and misconceptions of evolution.Acceptance and relevance of evolution. Roughly 70% of the students who volunteered to complete the survey selected the description of evolution as an established fact supported by overwhelming evidence, and more than 85% at least agreed that evolution is "supported by sufficient evidence to be convincing to the scientific community." Only a very small percentage of students (approximately 4%) indicated that they reject evolution outright.Similarly, a large majority (87%) of the students consider evolution to be important to understanding the natural world, even if it is not directly relevant for their own day-to-day research. This suggests that graduate students in a variety of scientific disciplines have developed an appreciation of the standing of evolution as the unifying principle in biology.

Of course, the voluntary nature of the survey may have resulted in some self-selection bias. However, the results of this study accord well with recent polls regarding the acceptance of evolution in Canada (insofar as polls using differently formatted questions can be compared). Two surveys conducted in 2007 (Angus Reid Global Monitor 2007, Canadian Press and Decima Research 2007) indicated that 58% to 63% of the Canadian public accepts evolution (vs. approximately 40% in the United States; Miller et al. 2006, Gallup 2009a). However, it must be noted that more than half of these are theistic evolutionists. Only about 22% to 26% of Canadians surveyed indicated the view that humans were created in their present form within the last 10,000 years (vs. approximately 45% in the United States; Gallup 2009b). For Canadians with at least one university degree, the level of acceptance of evolution is about 70%, outnumbering creationists five to one. About half the students surveyed in our study had not taken an undergraduate evolutionary biology course, so it is not surprising that their level of acceptance is about the same as other members of the public with a baccalaureate degree. (In the United States, about 53% of college graduates and 74% of individuals with postgraduate degrees indicate that they accept evolution; Gallup 2009a). The highest level of strong acceptance was found in the CBS (78%), and the lowest level in the OVC (58%); however, prior undergraduate training had no effect on acceptance.

In this study, there was a positive correlation between acceptance of evolution and general understanding as indicated by Darwin index scores. Interestingly, similar correlations have been reported among preservice teachers (Vlaardingerbroek and Roederer 1997, Rutledge and Mitchell 2002, Deniz et al. 2008), but not among high-school or undergraduate students (Bishop and Anderson 1990, Demastes et al. 1995, Brem et al. 2003, Sinatra et al. 2003, Ingram and Nelson 2006, Shtulman 2006). It may be that as one's education level rises, understanding a topic becomes increasingly important for accepting it.

Scientific theories. Though a nonnegligible percentage of the students surveyed may be confused about the meaning of the word "theory" in science, the confusion was less apparent among students in the basic sciences (CBS and CPES). Understanding the concept of scientific theories is important: Understanding this concept was positively correlated with the acceptance of evolution and the Darwin index. This may indicate that improving instruction of the nature of scientific theories at the undergraduate or graduate level (or both) may yield benefits.

Conceptions of evolution. Students at the graduate level exhibited a relatively good understanding of evolutionary mechanisms as assessed by the index scores. On average, students across colleges scored roughly 73 to 76 on the Darwin index, indicating that they most commonly accept Darwinian explanations rather than alternatives. Conversely, the average intuitive index score was around 45 (minimum possible is 20), as were scores on the orthogenesis and saltationism indices. These scores indicate that adherence to non-Darwinian mechanisms is rather low. This level of understanding is much greater than is usually reported for high-school students and undergraduates (reviewed by Gregory 2009).

The correlation between time since taking a course in evolution and the Darwin index scores was positive but marginally nonsignificant (table 1). Interestingly, there was a stronger, negative correlation between previous undergraduate training and the progressionism index, indicating that undergraduate education in evolution helps to correct the misconception that evolution is progressive. The fact that the effect is stronger for patterns than for mechanisms of evolution could indicate that students develop a tendency to prefer Darwinian explanations on their own as they train at an advanced level. More plausibly, this could occur because misconceptions about progress are easier to correct than those about natural selection. This latter interpretation is supported by the finding that even direct instruction in evolution may have only moderate impacts on conceptions of evolutionary processes (e.g., Jensen and Finley 1995, Ferrari and Chi 1998, Nehm and Reilly 2007, Spindler and Doherty 2009), and there may be little difference in understanding between science majors and nonscience majors (Sundberg and Dini 1993).

That said, students who had recently taken an evolution course indicated a higher self-described level of understanding of evolution, which did in fact relate positively with the Darwin index and negatively with the intuitive and orthogenesis indices—that is, students who felt that they had a better understanding of evolutionary ideas generally did.

Application of evolutionary concepts. Whereas the students scored quite well on questions involving rankings of predetermined options, their performance on open-ended questions requiring the application of basic evolutionary principles was less encouraging. In fact, fewer than 30% of the students provided a Darwinian explanation (or an equally acceptable one based on genetic drift) for a question regarding the loss of a complex organ, and only about 21% provided such an answer to a question about adaptation. A roughly equal number called upon only the advantage (or lack thereof) of the feature, making this sort of answer something of a hybrid between Darwinian and teleological explanations. A large percentage of students did not provide any answer to these questions.These misconceptions are not simply a matter of lack of instruction: Non-Darwinian answers were prevalent even among students who had taken an undergraduate course in evolution. This indicates that traditional instruction methods, although they may lead to some understanding of evolutionary mechanisms (as shown by index scores), do not necessarily produce a strong working knowledge that can be applied spontaneously to newly encountered phenomena.

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