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Lawrence C. Scharmann
University of Nebraska-Lincoln, lscharmann2@unl.edu

Wilbert Butler Jr.
Tallahassee Community College

The Use of Journaling to Assess Student Learning and Acceptance of Evolutionary Science

By Lawrence C. Scharmann and Wilbert Butler, Jr.

Journal writing was introduced as a means to assess student learning and acceptance of evolutionary science in a nonmajors' biology course taught at a community college. Fourteen weeks of instruction were performed, each initiated by student-centered, in-class activities and culminated by a discussion, to elucidate tentative conclusions based on evidence from in-class activities. Students (N = 31) engaged in explicit and reflective writing (i.e., journaling) at four points during the semester, providing responses to the following questions: (a) what influence did the recent in-class activities and discussion have on your understanding of evolution (b) has your view (of evolution) changed (explain your response and provide support or examples of what influenced the change); and (c) what aspects of the nature of science have your observed in recent lessons/activities. Journal entries were coded on a continuum as informed (I), somewhat informed (SWI), or not informed (NI) regarding the accuracy of evidence cited with respect to evolutionary science. Initial journal entries were judged as strongly NI and highly negative toward evolution. Data analyses at the conclusion of the course, however, indicated a statistically significant shift in student responses toward an informed view more consistent with evolutionary principles and less personally resistant to biological evolution.

Evolution, as one such fundamental scientific discovery, should be included as a pervasive explanatory framework in all biology courses. But teaching it as a list of facts to be learned is not enough. It ought to be held up as a model of how good science is done. Teachers need to make clear that evolution is science done right, and it is one of the best examples to illustrate the nature of science.

—Pennock (2005)

Nelson (2000) has long suggested the value of making evolution a pervasive theme in biology courses, especially when coupled with foci on the nature of science (NOS) and active student learning. Jensen and Finley (1996) tested different curricular and instructional strategies on students' understanding of evolutionary concepts. They concluded, consistent with Nelson's recommendations, that more active participation by students in their own learning activities produced greater understanding. Khishfe and Abd-El-Khalick (2002), in addition, strongly recommended that students' learning of evolutionary biology is greatly enhanced if a connection to NOS principles was both explicit and reflective.

In an earlier study, Butler (2008) took advantage of the recommendations that resulted from the Jensen and Finley (1996), Nelson (2000), and Khishfe and Abd-El-Khalick (2002) studies and tested the effectiveness of a NOS-rich, explicit-reflective course versus traditional course environment (i.e., expository lecture) in relation to student learning of evolutionary concepts. Butler reported the following assertions:

1. Students engaged in explicit and reflective NOS specific instruction (NOS-rich environment) significantly improved their understanding of NOS concepts.
2. Students in the NOS-rich section made greater gains in their understanding of evolution than students in the traditional class.
3. A change in students' understanding of evolution does not necessitate a change in students' acceptance of evolution.

Though we were disappointed that the results of this earlier study

TABLE 1

Lesson design for the topic "investigating common descent."

Instructional model element	Lesson description
Step 1. Identify the task, problem, or question.	Degrees of similarity between humans and other primates such as chimps, gorillas, and a common ancestor can be determined by comparing their chromosomes (i.e., DNA). Ask students to form groups of three to five. Direct students to discuss and develop a hypothesis concerning the most logical relationship between humans, other primates, and a prospective common ancestor and to construct a predictive cladogram illustrating their projected relationship. Supply each group with DNA sequences determined for each representative organism, and ask students to compare the resulting sequences. Direct students to then respond to the following (among several other) prompts: Q1. If humans represent the most recent emergent species, which primate is most similar (i.e., exhibits most recent common ancestry), next most similar, and least similar? Q2. What cladogram might be drawn to best represent relationships between these primates?
Step 2. Generate a tentative argument	Students should remain in groups of three to five. Direct students to share their proposed cladogram with other members of the group and the evidence on which it is based. After each member of the group has shared his/her individual proposal, the group should reach a consensus on the most logical cladogram, based on a discussion of the evidence.
Step 3. Interactive poster session	Select three random groups to present their consensus cladogram to the remaining groups for intergroup discussion. Special attention should be paid to the evidence considered (or evidence the presenting group may have failed to consider). Encourage questions from other groups whose consensus cladogram may differ from the one being presented. Finally, supply students with a cladogram representing the consensus position reached by professional scientists using similar data.
Step 4. Write to learn	Direct students to write in their individual journals, illustrating the cladogram they wish to draw, and to consider the following prompts: • What influence did this class activity and discussion have on your understanding of evolution? • Has your view (of evolution) changed? Explain your response and provide support or examples of what influenced the change. • What aspects of the nature of science did you observe in this activity? Provide examples of each.

(Butler, 2008) had little impact on students' acceptance of evolution, we inferred through anecdotal conversations with students that perhaps the assessments used in the study failed to account for students' prior beliefs, a variable found by Winslow (2008) to be crucial in assisting students in reconciling personal religious faith with scientific evidence. Therefore, we sought to test the efficacy of adopting the use of journals as an assessment tool to permit students, through reflective writing, to express their personal beliefs; compare their initial assumptions regarding the value of evolution as a theory (to explain, predict, and solve scientific problems); and gain confidence in using observational evidence gained through active learning to support conclusions.

Design/procedure

The course entitled Introduction to Biological Sciences served as the test classroom. This course was taught at a community college in the southeastern United States. The course was available as a single section, meeting twice each week (75 minutes per class meeting) for 14 weeks. The class was intended for nonscience majors and designed to help students better understand the major biological concepts in plant life, animal life, cell biology, anatomy, reproduction, development, genetics, evolution, and taxonomy. Key concepts were introduced through active student participation using an inquiry instructional strategy modified from Sampson and Grooms (2010). A sample lesson design for the topic "investigating common descent" is shown in Table 1.

As shown in Table 1, this student-centered pedagogy encourages active learning, generates personal observations, encourages group discussion of evidence, and considers the merits of each individual's observations prior to constructing a consensus position. In addition, Step 4 allows individual students to present their own conclusions concerning the evidence, even if their position is different than the consensus reached by the other members of the group.

Research questions

To test the use of journals as an assessment tool in our course, we posed two research questions:

RQ1: Does the use of journaling in an introductory biology course for nonmajors encourage students to construct accurate representations of evolutionary science?

RQ2: Does the use of journaling enhance individual students' efforts to reconcile evolutionary science with personal prior beliefs?

Study participants

Thirty-one students (20 females, 11 males), enrolled in a community college introductory biology course, participated in the study. The ages of the participants ranged between 19 and 50 years of age; average age was 25.5 for females and 21.7 for males. Participating students came from majors other than science. (Note: The coauthor taught the course, while the primary author served as an independent observer of the course content, oversaw the fidelity of instructional model used, and served as an independent interrater of student journal entries.)

We administered a Locus of Control (Rotter, 1966) questionnaire to determine the representativeness of the students participating in the study. Locus of Control has a pertinent history in measuring populations likely to be resistant to scientific processes, such as control of variables, the power of experimental design, and an attribution of cause/effect relationships (Lefcourt, 1976). Individuals possessing an internal locus, according to Lefcourt, attribute personal effort to better performance (i.e., cause/effect); recognize the need to control variables within an experimental design to obtain meaningful data; and, therefore, find evidence through observation and inference to be compelling. Alternatively, individuals more external in their locus attribute personal success to luck, chance, and powerful others, and view experimental designs as abstractions that have little meaning for them.

The overall student population participating in this study possessed a normal distribution (${}_{0.95}\chi^2 = 3.55 < 9.49$; $df = 4$) with respect to locus of control. An examination of subpopulations, both for males (${}_{0.95}\chi^2 = 0.21 < 5.99$; $df = 3$) and females (${}_{0.95}\chi^2 = 0.84 < 5.99$; $df = 3$) also resulted in normal distributions. Therefore, we were confident that the students enrolled in the current course were no different from the general population in their prospective resistance to scientific theories, findings, and conclusions.

The course instructor, at the beginning of each class session (beyond the first meeting), reminded students to write in their journals any observations and inferences concerning the previous class session in which they noted a connection with evolutionary theory, especially with respect to one or more of its tenets (i.e., the derivative principles subsumed within evolutionary theory; see Mayr, 1991). To validate the fidelity of instructional implementation, the observer performed several classroom observations to witness firsthand the quality of student–student and teacher–student interactions taking place within the classroom environment. The observer also witnessed consistent unbiased communication from the instructor, such as: "Remember, I am only concerned where your evidence leads you. I am not judging you as right or wrong. I want you each to feel comfortable discussing the evidence (i.e., observations and inferences) with one another and with me."

Grades in the course consisted of student performance on weekly quizzes, homework, and tests. The reflection journals were ungraded and used independently to provide evidence to answer the research questions. Students submitted their journals to receive feedback from the instructor four times during the semester—after the first, fifth, ninth, and 13th weeks of class. These weeks were selected to provide periodic checks and discern trends in the direction of the students' reflections. After reviewing the students' journals, the instructor posed additional questions for students to consider and encouraged them to use evidence from class activities to support a conclusion. The instructor was careful not to criticize students' conclusions, interject new evidence, or even reinforce good answers as to not bias the direction

TABLE 2

Scientific accuracy of representations of evolutionary theory.

	Accuracy of representations of evolutionary theory (%)		
Journal entry number (week)	NI	SWI	I
1 – Week 1	29	68	3
2 – Week 5	23	65	12
3 – Week 9	31	50	19
4 – Week 13	10	29	61

Note: NI = not informed; SWI = somewhat informed; I = informed.

of future entries. Instead, the instructor asked students to respond to the following critical questions:

- What influence did the recent class activity and discussion have on your understanding of evolution?
- Has your view of evolution changed? Explain your response and provide support or examples of what influenced the change.
- What aspects of the nature of science have you observed in the lessons/activities so far? Provide examples of each.

The journal entries did not influence the grade students received; however, the instructor did document the effectiveness of the journals by coding student journal entries as one of the following: Not Informed (NI)—provides evidence without reference, or insufficient inference with evidence that does not support it; Somewhat Informed (SWI)—draws a sufficient inference but is not supported by appropriate evidence or makes at least one incorrect assertion about the evidence; and Informed (I)—draws a sufficient inference supported by appropriate evidence (in a direction consistent with an accurate scientific explanation).

We used a constant comparative method (Ary, Jacobs, Razavieh, & Sorensen, 2006) in the interpretation of the qualitative data collected from student journal entries. The instructor submitted a random sample of 10 journal entries to the observer. The instructor and the observer then scored the entries independently and compared findings. They discussed their respective interpretations and rationales for assigning respective codes before reaching a consensus on the initial 10 journal entries. The instructor then submitted two subsequent random samples of 10 entries for coding, each resulting in the 90% agreement threshold suggested by Ary et al. (2006). The instructor then scored the remainder of the journal entries.

Findings and analysis

Journal entries were assessed across the semester at 4-week intervals to answer the first research question: Does the use of journaling in an introductory biology course for nonmajors encourage students to construct accurate representations of evolutionary science? The assessment of accuracy is summarized in Table 2. An examination of the first journal entries (Week 1) in comparison to the fourth entries (Week 13) yielded a statistically significant change in students' perspectives on evolution, in a direction consistent with those of practicing scientists ($\chi^2 = 104.18$; $p < 0.001$; $df = 5$). Thus, from a content perspective, students progressed in their ability to use evidence to accurately represent perspectives of evolutionary science over the course of the semester. It is not unusual for students to better comprehend the tenets of evolutionary theory as a result of a course of instruction; however, our current study went a step further by intentionally targeting students' prior beliefs as a complement to learning the content. Hence, the second research question could be investigated. In Week 5 and Week 9, as illustrated in Table 2, students were still reluctant to express a reconciliation of their personal beliefs with their emerging understanding of evolutionary processes.

In quantitative terms, student reluctance to reconcile prior beliefs with evidence presented is indicated in Table 2 by the high percentage of student entries coded as "somewhat informed." However, by Week 13, students were more willing to express an emerging reconciliation with prior beliefs as a complement to their content understanding (as noted in Table 2, in which 61% of student entries were classified as being "informed" representations of evolutionary theory). Statements of reconciliation are exemplified in the following student journal entries:

> . . . I learned we are related to the chimp but did not actually evolve from the chimpanzee. Also, evolution doesn't try and disprove religion. This class in specific has changed my view on the way evolution works in so many ways. Another example is how organisms don't adapt

to their environments but rather are born into them. Also, I now understand the natural selection part of evolution much more clearly. Overall this class has changed my perspective on evolution drastically by doing these activities. (*Student 2*)

At the beginning of the semester, my thoughts about evolution were very dismissive. I had the attitude of questioning why we even had to learn about this. . . . I never realized how many misconceptions I had perceived from evolution until this class. . . . I have also learned that science is empirically based and that scientists are trying to answer unknown answers through data and inferences. I now know that evolution is meant to not crush someone's faith, but to try to put answers where questions are raised. I am really glad that I got to take this class and further my knowledge about this theory, and although I still have some reservations and questions about evolution, I have come to accept it and understand it is important to learn about. (*Student 18*)

I now realize that evolution does not attempt to disprove my religion, it only shows how evidence provides the information needed to understand how living organisms thrive . . . Evolution has definitely changed my perspective on how I understand life as we know it. (*Student 21*)

The beauty of everything that we have learned and all the activities throughout the semester is to remember the aspects of science . . . [as] subjective, tentative, empirically based, inferential, and function between theory and law. The visiting professor . . . brought up that theories are a powerful tool to solve certain problems. . . . The theory of evolution should not, in any way, take away from anyone's faith. (*Student 28*)

The benchmarks of science are subjective, tentative, and inferential, while also being empirically based evidence. When applying these standards to religion, one can recognize [that a religious] explanation does not adequately explain evolution. Whereas religion is more a belief, science is more a tool. (*Student 31*)

I have come to understand that evolution is not trying to disprove or fight religion. I have loved being able to come up with our own conclusions based on what we observed and what we know when conducting experiments in class. (*Student 32*)

Discussion and conclusions

The use of journals as an assessment tool resulted in a progressive increase in students' accuracy in representing evolutionary science (and NOS) concepts in a direction consistent with those of practicing scientists. In addition, by incorporating reflective journals into the class structure, students were more likely to commit to more accurate scientific representations of evolutionary theory because journaling permitted honest, introspective expressions of students' beliefs. The results show support for the following assertions:

- evolution should be explicitly integrated as a course theme;
- students must be provided with explicit opportunities for personal reflection (e.g., use of journals etc.)—early and repeated—concerning NOS issues; and
- relatively permanent reconciliation of evolutionary theory with prior beliefs depends on the use of a nonthreatening instructional environment and method of assessment.

The first assertion is consistent with over 20 years of evolution education research, stemming from a 1992 National Science Foundation funded Evolution Education Research Conference (Good et al., 1993). The second assertion regarding the effectiveness of explicit-reflective NOS instruction has been broadly reported and the results have been consistent in improving NOS understanding for a variety of study participants (Abd-El-Khalick & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002; Scharmann, Smith, James, & Jensen, 2005). The third assertion, however, has only recently received attention at the postsecondary level (Nelson, 2007; Winslow, Staver, & Scharmann, 2011). The inclusion of journals as an assessment tool not only allows students to explore their current belief system but also assists students in a transition from little to no understanding of evolutionary theory to a recognition that scientific theories (such as evolution) play an important role in providing us with a tool to answer scientific questions and solve scientific puzzles. ■

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Lawrence C. Scharmann (lscharmann2@unl.edu) *is a professor and chair of the Department of Teaching, Learning, and Teacher Education at the University of Nebraska–Lincoln. Wilbert Butler, Jr., is an associate professor of biology at Tallahassee Community College in Tallahassee, Florida.*