Do College Introductory Biology Courses Increase Student Ecological Literacy?

By Kendra Spence Cheruvelil and Xuemei Ye

College introductory biology educators have an opportunity to increase ecological literacy. This research used a pre-/postsurvey design to ask the following questions: (a) What level of ecological literacy do underclass science majors have? (b) What demographic factors are related to ecological literacy? and (c) Does taking introductory organismal biology increase ecological literacy? We found that first-year science majors had relatively high attitudes and perceptions of the environment that were related to motivation, confidence, and future career goals but lower ecological knowledge that was not related to any demographic factors studied. Students exhibited very little increase in ecological literacy after completing an introductory organismal biology class. Therefore, we urge introductory biology instructors to assess whether they are increasing student ecological literacy and provide recommendations for doing so.

Ecological literacy, a term first coined by T. G. David (1974), has received much recent attention, especially in regard to ways to increase levels of ecological literacy (e.g., Jordan, Singer, Vaughan, & Berkowitz, 2009). High ecological literacy is important to prepare scientifically literate citizens and decision makers. Such ecologically literate people can critically read newspapers, engage in thoughtful discussions, seek valid biological information, interpret published tables and figures in the popular press, and make responsible personal and societal decisions (e.g., Demastes & Wandersee, 1992; Jordan et al., 2009). High ecological literacy can also facilitate the responsible use of ecological knowledge to become a more sustainable society (Goudie, 2008).

A recent study argued that the level of scientific (including ecological) literacy among the general population (United States and international) is not known and that it is likely too low to enable effective societal responses to current problems (Jordan et al., 2009). In fact, it is estimated that less than 20% of Americans are sufficiently scientifically literate to understand a science article in a major newspaper, a science-based television program, or a popular science book (Miller, 2002) and that more than 80% of Americans are heavily influenced by incorrect or outdated environmental myths (Coyle, 2008). Recent changes in programs such as those for the new Advanced Placement Biology curricula (www.collegeboard.org/apcentral) may help increase levels of scientific literacy among high school students. Among college students, introductory science courses have the opportunity to increase scientific literacy. Because introductory biology is often the only course that students in many science majors (e.g., physics, chemistry, physiology, microbiology) take that explicitly includes ecological concepts, college introductory biology educators have an opportunity to increase student ecological literacy.

To increase students' ecological literacy, we must understand the level of ecological literacy that students have prior to an introductory biology course, the demographic factors that impact student ecological literacy, and whether introductory biology courses increase student ecological literacy. Recent studies assessing ecological literacy (e.g., Gambro & Switzky, 1996; Jordan, Gray, Demeter, Lui, & Hmelo-Silver, 2010; Negev, Gonen, Garb, Salzberg, & Tal, 2008) include the ecological literacy of college students. Research has found that environmental attitudes and knowledge differed by major and that students who had environmental education lessons (Bruyere, 2008; Rideout, 2005) or had taken at least one environmental science course (Robinson & Crowther, 2001) had higher environmental literacy than those who had not. Low mean ecological knowledge was also found among introductory environmental health students (Morrone, Mancl, & Carr, 2001). These results support the idea that many college students have low ecological literacy that can be positively influenced by coursework.

Some studies of nonstudent adults have found that various demographic factors such as age, income, town size, education, ethnicity, and gender influence ecological literacy (Arcury & Christianson, 1993; Mancl, Carr, & Morrone, 2003; Morrone et al., 2001; Zimmerman, 1996). These results support the idea that relationships between ecological knowledge about (i.e., skills), concern for (i.e., attitudes and perceptions), and response to (i.e., behavior) the environment are complicated and depend on many different demographic factors (e.g., Arcury, 1990; Arcury, Johnson, & Scollay, 1986; Gagnon Thompson, & Barton, 1994). However, few studies have documented the level of ecological literacy for college students and how demographic factors affect college student ecological literacy (as reviewed previously). Further, we know of no published studies that have determined the impact of introductory biology courses, often the only college course students take that explicitly includes ecological concepts, on student ecological literacy.

We assessed student ecological literacy in mainly first-year college science majors using a pre-/postsurvey design in an introductory organismal biology course. We asked three questions: (a) What level of ecological literacy do such students have? (b) What demographic factors are related to ecological literacy? (c) Does completion of an introductory biology course increase ecological literacy? We predicted that ecological literacy would be low before taking the course, that various demographic factors as well as student major would be related to ecological literacy, and that there would be increased student ecological literacy by the end of the semester.

Methods

We assessed student ecological literacy using a pre-/postsurvey design. We developed four questions about student attitudes and perceptions of the environment and seven questions about ecological knowledge and skills. The questions were based on a recent conceptual model of ecological literacy that includes ecological habits of mind, ecological connectivity and key concepts, and self-knowledge with respect to human action and environmental linkages (Jordan et al., 2009). See the next section, Tables 1–3, and Figure 1 for the Likert-type survey questions and descriptions of how the answers were scored. The pre-/postsurveys were administered in two ways depending on the type of question: via an online survey (www.SurveyMonkey.com) or an ungraded, in-class, paper-and-pencil assignment. We collected data on each student's gender, ethnicity, sexual orientation, citizenship, last math course, number of biology courses previously completed, number of nonbiology science courses previously completed, learning (dis) ability, anticipated career, and self-reported motivation and self-confidence levels. Student participation was voluntary, and survey results were confidential, were de-identified before being provided to the instructor, and were not analyzed until after the course was completed and grades were submitted (exempt Institutional Review Board #09-1132).

Pre-/postsurveys were administered to undergraduate students in the first author's Lyman Briggs College Introductory Organismal Biology class (LB144) during spring 2010. The class included 111 students (science majors, mainly human biology or physiology), of which 90% were freshmen, 67% were female, 38% were non-Caucasian, and 43% had low-math preparation (as determined by university math placement exams). This four-credit class requires students to attend two 80-minute classes and one 3-hour combined recitation and lab per week. Four of the seven course learning goals were directly or indirectly linked with increased ecological literacy, as follows: (a) demonstrate good science process skills, especially hypothesis formation and testing, inference, prediction, interpretation, and experimentation; (b) explain the theory of evolution, the mechanisms behind the theory, and how evolution is connected to ecology, genetics, and biodiversity; (c) demonstrate ecological literacy, especially the linkages between the

TABLE 1

Most common words students used to describe nature.

Word
Animals
Trees
Plants
Environment
Outdoors
Beautiful/beauty
Life
Water
Air
Forest(s)
Green
Grass(lands)
Peace/peaceful
Weather
Wild/wildlife
Earth
Sun
Lakes/Great Lakes
Bugs
Oceans

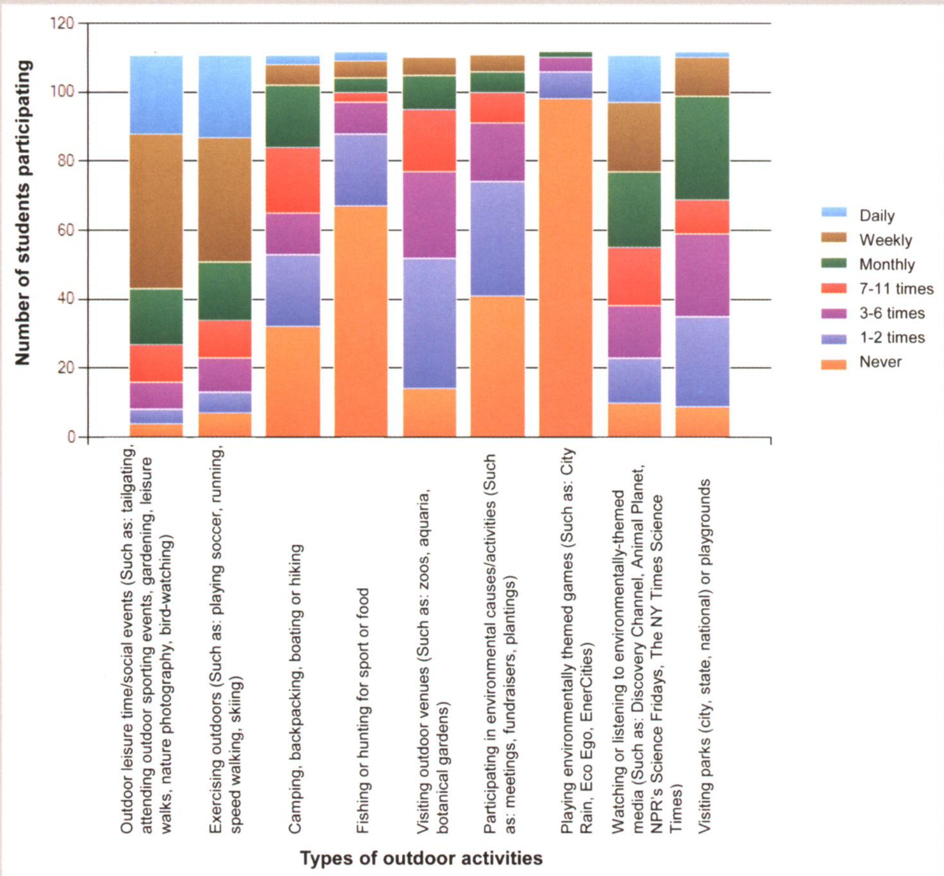
Note: Responses to the question: "The word nature often means various things to people. Using at most 2 minutes, write a list of words and phrases that you associate with nature." Words listed in descending order of frequency of use from 65% to 10% of respondents listing that word. Survey administered online with 106 student respondents.

environment and organisms (including humans); and (d) develop an understanding of and appreciation for the complexity and diversity of Earth's organisms and the endeavors necessary to understand them.

During the class, the instructor used semester-long base groups of three to five students (Johnson, Johnson, & Smith, 2006) and a "bookends" instructional model (Johnson, Johnson, & Smith, 1998), with mini-lectures interspersed with small-group exercises, individual writing, personal response pad (i.e., clicker) questions, and other group active/collaborative learning activities. Three to four weeks each were spent on evolution, genetics, diversity of life, and ecology. Evolution was also revisited throughout the semester to reinforce the idea that evolution provides the underlying framework within which all of biology can be understood. Each combined recitation/lab period was made up of 19 to 24 students working in their base groups. The instructor used the "teams and streams" model of laboratory instruction (Wilterding & Luckie, 2002) that has base groups (teams) work on guided inquiry-based projects (streams) of 4–6 weeks duration. There were three streams with the titles of Doing Biology (e.g., practicing scientific methods, hypothesis development, statistics), Comparative Biology (i.e., understanding the diversity of life in a phylogenetic framework; Smith & Cheruvelil, 2009), and Ecology and Animal Behavior. For this last stream, students carried out a 5-week research project that began with them observing patterns in nature and formulating questions and hypotheses about those patterns, then conducting a literature review, designing and implementing an ecology or animal behavior field or lab study, conducting statistical analysis and interpreting the results, and finally writing and presenting a research poster in a way that mimics what ecologists do at professional meetings.

FIGURE 1

Student participation in outdoor activities. Statement: For each activity below, please tell us how much time you spent participating in each activity during the past 12 months. Survey (pretest) administered online with 108 student respondents. Responses in stacked bars are in the same order top-to-bottom as depicted in the legend.



Pre-/posttests were administered during the first and the last week of the semester, respectively. We used pretest responses to assess the incoming level of student ecological literacy and to quantify the demographic variables affecting incoming student ecological literacy. For each question, we ran a *t*-test or an analysis of variance (ANOVA) with each demographic variable as a factor. Changes in student ecological literacy were quantified two ways. First, we calculated learning gains (posttest score – pretest score; Weber, 2009) that indicate the change in attitude, perception, or knowledge after taking introductory organismal biology. Therefore, a positive learning gain indicates that a student received a higher score on the posttest than on the pretest. Second, we conducted chi-square tests to determine if the number of students who chose each answer differed between the pre- and posttest. Student respondents who did not complete either the pre- or the posttest were removed prior to conducting analyses, resulting in a sample size of 93–108 students, depending on the question. Statistical analyses were performed with Systat (Version 12) and an online chi-square calculator (http://www.opus12.org/Chi-Square_Calculator.html), and we report significant effects as those with $p < .05$ or $.10 < p > .05$.

Results

Pretest responses indicated that the students appreciated the importance of the environment. When asked to write a list of words and phrases that they associated with "nature," the majority of responses were simple, one-word nouns or adjectives such as *animals*, *water*, and *peaceful* (Table 1). However, students also reported participating in outdoor leisure/social events, conducting outdoor exercise, and watching or listening to environmentally themed media at least monthly (Figure 1). In addition, over 75% of students reported agreement with all four statements about the value of the environment (answers of 4 or 5 in Table 2). These responses seem to indicate that this population of students had an appreciation and concern for the environment and used the out-of-doors on a regular basis.

On pretests, students scored on average 4.3–4.5 out of 5 on questions related to how biology research is conducted, the idea that humans are part of the "natural world," the idea of limiting resources, and the factors that influence a species' range (Table 3, Questions 2, 5, 6, and 7, respectively). However, this population of students averaged just 3.2 and 2.3 out of 5 on questions related to extrapolation and uncertainty, respectively (Table 3, Questions 1 and 3), and were not sure whether ecology and environmental science were synonymous (average score = 3.3; Table 3, Question 4). These results indicate that there was certainly room for these students to increase their ecological knowledge, and they provide evidence of the important role introductory biology classes can have for increasing the ecological literacy of students who may never take another ecological or environmental course (e.g., premed students).

At the beginning of the semester,

TABLE 2

Number of student responses to pre- and posttest environmental attitude and perception questions, average change in attitudes and perceptions (posttest score – pretest score), chi-square *p*-values for those changes, the demographic variables that were significant effects in a *t*-test or ANOVA, and the *p*-value for those effects.

Pre/posttest student responses						Mean change (SD)	Chi-square *p*-value	Significant demographic variables[a]	*t*-test or ANOVA *p*-value
Question	1	2	3	4	5				
1. I enjoy being outdoors.	6/0	7/4	9/12	32/26	54/61	0.3 (1.0)	.0774	NA	NA
2. I place a high amount of worth/value on the environment and all that it provides organisms (including humans).	2/0	2/3	13/16	50/41	41/43	0.5 (0.7)	.4516	motivation; confidence	.089; < .0001
3. I am concerned about decreases in the Earth's species diversity.	3/2	2/4	20/21	44/40	39/34	−0.1 (1.1)	.7236	confidence	< .0001
4. I believe that human activities negatively impact the environment and other biological organisms.	3/1	3/0	18/21	31/38	53/42	−0.1 (1.0)	.1615	confidence	.005
Total						0.4 (2.6)	.0228	motivation; confidence; career goals	.078; < .001; .007

Note: Likert scale: *totally disagree* = 1, *somewhat disagree* = 2, *no strong feelings* = 3, *somewhat agree* = 4, *totally agree* = 5. SD = standard deviation, NA indicates no significant effects of any demographic variables. Survey administered online with 108 student respondents.

[a]Unable to complete analyses because of low sample size of minority responses for the following demographic variables: sexual orientation, citizenship, and learning (dis)ability.

students' attitudes and perceptions of the environment were related only to motivation, confidence, and future career goals. Pretests showed that students who were less motivated for the course, were less confident in their scientific abilities, or indicated a goal of becoming a medical doctor had lower overall environmental attitudes and perceptions (ANOVA, $p = .078$, $< .001$, and $.007$, respectively; sum of scores for Questions 1–4 in Table 2). However, no significant effects of these three (or any other) factors for which we had sufficient sample size to include in analysis (gender, ethnicity, last math course completed, number of biology courses previously completed, number of nonbiology science courses previously completed) were found for student ecological knowledge at the beginning of the semester (*t*-test and ANOVA, *p*-values = .24–.76). These results provide further evidence of the complicated nature of relationships among attitudes, perceptions, and knowledge of such populations of college students.

Student learning gains in environmental attitudes/perceptions and ecological knowledge/skills were inconsistent across questions, with gains very close to zero (i.e., no gain) and confidence intervals including zero (last column of Tables 2 and 3). Chi-square tests indicated no significant change in responses between pre- and posttests for any aspect of ecological literacy (Tables 2 and 3), except for the question that asked students whether ecology and environmental science were synonymous (Question 4 in Table 3; $p = .0004$). Because there was no consistent change in ecological literacy, we did not quantify the effects of demographic variables on changes in student ecological literacy.

Discussion

If high ecological literacy is one of the goals that universities have for graduating college students, then it follows that instructors need to assess the effect of their course in meeting this goal. At many colleges and universities, an introductory biology course may be the only course completed by science majors that explicitly includes ecological concepts. In fact, we conducted a web search of biology major requirements at Big Ten universities (of which Michigan State University is one) and found that only 2 of these 11 universities require their biology majors to take a general ecology course. Although not necessarily representative of all institutions of higher learning, this fact demonstrates the importance of college introductory biology instructors assessing ecological literacy in their classes. If ecological literacy is low after completing introductory biology classes, then educators will need to decide whether an introductory course is the right place to significantly increase ecological literacy.

TABLE 3

Student ecological knowledge mean scores, learning gains, and chi-square *p*-values.

Ecological knowledge question	Mean score (SD)	Mean gain (SD)	Chi-square *p*-value
1. Results from a recent study of turtles in Michigan lakes should apply well to future turtles in most lakes in North America.	3.2 (1.3)	−0.1 (1.7)	.8595
2. Scientists learn about relationships among organisms and their environment primarily through field and lab studies.	4.3 (0.7)	−0.1 (1.0)	.7744
3. If there is "uncertainty" about the values that go into a scientific mathematical model, the results cannot be used to make policy such as laws and regulations.	2.3 (1.2)	0.3 (1.4)	.4582
4. "Ecology" and "environmental science" are the same thing.	3.3 (1.1)	0.6 (1.3)	.0004
5. The environment and organisms are tightly linked, but humans are separate from this natural world.	4.3 (1.0)	0.1 (1.1)	.6888
6. For any population (group of organisms of the same species in a particular place and at a particular time), available resources can limit their growth (example resources: water, food, space).	4.4 (1.0)	0.1 (1.2)	.1860
7. Where a species lives is influenced by relationships among the species and its environment as well as its evolutionary history.	4.5 (0.7)	−0.1 (0.9)	.8701
Total (out of 35)	26.4 (3.0)	−3.5 (3.4)	.4208

Note: Same Likert scale as in Table 1, then scores were coded in descending order from 5 to 0, with 5 assigned to the most correct answer and 0 the least correct answer. Therefore, the high score for each question was 5 and the total high score was 35 points. Survey administered in the classroom with 93 to 94 student respondents depending on the question. SD = standard deviation.

If so, instructors will need to revise their introductory courses; if not, educators might revise the curricula to require upper-level ecology coursework of more science majors.

We found that students in our introductory organismal biology class had relatively high attitudes and perceptions of the environment prior to biology coursework and that these attitudes and perceptions were related only to motivation, confidence, and future career goals. In contrast, students had relatively low ecological knowledge, and no demographic factors studied were related to that ecological knowledge. Perhaps most important, even with a self-described enthusiastic ecologist as the professor, we found no increase in any aspect of ecological literacy after completing this introductory biology course. Therefore, we urge introductory biology instructors to seriously consider the impact of their class on student ecological literacy.

Relatively high pretest scores, low statistical power, or survey questions with low validity or reliability may have contributed to us finding little to no increase in ecological literacy after completing our introductory biology course. Therefore, future work can make use of normalized learning gains (Weber, 2009), should have larger sample sizes, and should use a set of validated and reliable questions (e.g., those in Morrone et al., 2001) to assess changes in student ecological literacy. Alternatively, our finding of no increase in student ecological literacy may indicate that this introductory biology course did not meet its learning goals. Two possible reasons for this result include the timing of the ecological content and the format of the class.

First, this course included four class and five lab weeks of ecology materials and activities at the end of the semester. This is often the pattern in introductory biology courses; a web search of Big Ten university introductory majors biology class syllabi found that all five syllabi that were available online discussed ecology for the last 4–6 weeks of the semester. We speculate that the timing of this subject matter may be important because students are often fatigued and experience waning attention spans at this time of the semester. Future research could compare student ecological literacy in courses that teach ecology at different times of the semester to test this idea.

Second, although the instructor used classroom and lab formats that are active and inquiry based, respectively, future semesters could incorporate materials and teaching methods designed specifically to increase ecological literacy. For example, recent K–12 education researchers have developed content modules and teaching methods that have shown promise for increasing children's' ecological and environmental literacy (e.g., RAFT writing assignments, Groenke & Puckett, 2006; environmental literacy strands, http://edr1.educ.msu.edu/EnvironmentalLit/index.htm). College introductory biology instructors who modify such techniques and content for their classrooms may see an increase in student ecological literacy. However, regardless of why we saw no increase in student ecological literacy after completing this introductory biology class, we suggest that there is a need to assess the impact of introductory biology courses on ecological literacy and to evaluate the generality of our result.

Our experience suggests four ideas for assessing ecological literacy with the goal of increasing levels of student ecological literacy. First, among science majors, those with interests in ecology, zoology, or environmental science are likely to have the highest ecological literacy, and these students are also likely to take future advanced ecology courses. Therefore, it may be most important to target instructional interventions at the other science majors (e.g., human biology, physiology, chemistry). Second, although we might expect nonscience majors to have smaller ecological literacy gains than science majors, we also have a larger opportunity with these students because they may start with lower ecological literacy than do science majors. Third, students with higher confidence and motivation may exhibit larger learning gains. This fact points to the importance of making a personal connection with our students and providing them with experiences that will build their confidence and sense of community in addition to the cognitive, concept-based activities that are normally used by college professors to increase learning. Fourth, we recommend that instructors from a wide variety of institutions with a large diversity of students use a common set of validated and reliable questions (e.g., those in Morrone et al., 2001) and record the results of their assessments in a common data base. With the resulting large dataset of student ecological literacy, we will have high power to detect relationships among demographic factors and ecological literacy.

This dataset could also be used to quantify long-term trends in ecological literacy and the effects of changes in public education (funding and standards), prevailing societal and environmental issues, and political climate on ecological literacy. For example, environmental issues and ecological knowledge may be perceived as less important than other societal issues or biological disciplines during times of recession or war. In contrast, particular events, such as the oil spill in the Gulf of Mexico or declining polar bear habitat, may increase student interest in the environment and in learning ecology. Finally, the political climate can influence both the funding of environmental programs (in schools and communities) as well and public perception of and confidence in science. In order to tease apart these complex and dynamic relationships that affect all aspects of student ecological literacy (i.e., attitudes/perceptions and ecological knowledge/skills), we need a large dataset with common questions that are administered over time, at a variety of institutions (e.g., community colleges, liberal arts universities, state research universities), and across large regions and countries. This reality points to the importance of educators working collaboratively across disciplines, as well as across levels of education, to increase ecological literacy. ■

References

Arcury, T. A. (1990). Environmental attitude and environmental knowledge. *Human Organization, 49,* 300–304.

Arcury, T. A., & Christianson, E. H. (1993). Rural-urban differences in environmental knowledge and actions. *The Journal of Environmental Education, 25*(1), 19–25.

Arcury, T. A., Johnson T. P., & Scollay, S. J. (1986). Ecological worldview and environmental knowledge: The "new environmental paradigm." *The Journal of Environmental Education, 17*(4), 35–40.

Bruyere, B. L. (2008). The effect of environmental education on the ecological literacy of first-year college students. *Journal of Natural Resources and Life Sciences Education, 37,* 20–26.

Coyle, K. (2008). *Environmental literacy in America: What ten years of the NEEFT/ Roper research and related studies say about environmental literacy in the U.S.* Washington, DC: The National Environmental Education and Training Foundation.

David, T. G. (1974). Environmental literacy. *The School Review, 82,* 687–705.

Demastes, S., & Wandersee, J. H. (1992). Biological literacy in a college biology classroom. *BioScience, 42,* 63–65.

Gagnon Thompson, S. C., & Barton, M. A. (1994). Ecocentric and anthropocentric attitudes toward the environment. *Journal of Environmental Psychology, 14,* 149–157.

Gambro, J. S., & Switzky, H. N. (1996). A national survey of high school students' environmental knowledge. *The Journal of Environmental Education, 27*(3), 28–33.

Goudie, C. A. (2008). Institutionalizing ecological literacy: A critical component of the new "green" economy. *Business Perspectives, 19*(3), 16–21.

Groenke, S. L., & Puckett R. (2006). Becoming environmentally literate citizens. *The Science Teacher, 73*(8), 21–27.

Johnson, D. W., Johnson, R., & Smith, K. (1998). *Advanced cooperative learning*. Edina, MN: Interaction Book Company.

Johnson, D. W., Johnson, R. T., & Smith, K. A. (2006). *Active learning: Cooperation in the college classroom*. Edina, MN: Interaction Book Company.

Jordan, R., Gray, S., Demeter, M., Lui, L., & Hmelo-Silver, C. E. (2010). An assessment of students' understanding of ecosystem concepts: Conflating ecological systems and cycles. *Applied Environmental Education and Communication, 8,* 40–48.

Jordan, R., Singer, F., Vaughan, J., & Berkowitz, A. (2009). What should every citizen know about ecology? *Frontiers in Ecology and the Environment, 7,* 495–500.

Mancl, K., Carr, K., & Morrone, M. (2003). Profile of Ohio adults with low environmental literacy. *Ohio Journal of Science, 103*(3), 38–41.

Miller, J. D. (2002). Civic scientific literacy: A necessity in the 21st century. *Journal of the Federation of American Scientists, 55,* 3–6.

Morrone, M., & Mancl, K., & Carr, K. (2001). Development of a metric to test group differences in ecological knowledge as one component of environmental literacy. *The Journal of Environmental Education, 32*(4), 33–42.

Negev, M., Gonen, S., Garb, Y., Salzberg, A., & Tal, A. (2008). Evaluating the environmental literacy of Israeli elementary and high school students. *The Journal of Environmental Education, 39*(2), 3–20.

Rideout, B. E. (2005). The effect of a brief environmental problems module on endorsement of the new ecological paradigm in college students. *The Journal of Environmental Education, 7*(1), 3–11.

Robinson, M., & Crowther, D. (2001). Environmental science literacy in science education, biology, and chemistry majors. *The American Biology Teacher, 63,* 9–13.

Smith, J. J., & Cheruvelil, K. S. (2009). Using inquiry and tree-thinking to "march through the animal phyla." *Evolutionary Education and Outreach, 2,* 429–444.

Weber, E. (2009). Quantifying student learning: How to analyze assessment data. *Bulletin of the Ecological Society of America, 90,* 501–511.

Wilterding, J. H., & Luckie, D. B. (2002). Increasing student-initiated active learning with investigative "streams": A molecular biology example. *Journal of College Science Teaching, 31,* 303–307.

Zimmermann, L. K. (1996). Knowledge, affect, and the environment: 15 years of research (1979–1993). *The Journal of Environmental Education, 27*(3), 41–44.

Kendra Spence Cheeruvelil (ksc@msu.edu) *is an associate professor with a joint appointment between Lyman Briggs College and the Department of Fisheries and Wildlife at Michigan State University in East Lansing, Michigan.* ***Xuemei Ye*** *is currently a medical student at Jefferson Medical College in Philadelphia, Pennsylvania, and an alumnus of Lyman Briggs College at Michigan State University.*