Explicitly Linking Human Impact to Ecological Function in Secondary School Classrooms

RECOMMENDED FOR AP Biology

YAEL WYNER, JONATHAN BECKER, BRUCE TORFF

Abstract

Both the old National Science Education Standards *(NSES) and the recent* Next Generation Science Standards *(NGSS) devote significant resources to learning about human environmental impact. Whereas the NSES advocate learning about human environmental impact in a section apart from the science-content learning strands, the NGSS embed them in the core life-science and ecology learning strands. We describe a study that compared the effects of these different approaches on ninth-grade biology student learning. It found that students learned significantly more human-environmental-impact and ecological-function content when human-impact content was embedded in ecology content than when human impact was taught as a discrete unit from ecology.*

Key Words: *Ecology; human impact; curriculum; science standards.*

Scientists and educators recently developed a new set of guidelines for teaching science, in an effort to better prepare American students for a future that is ever more dependent on scientific advances. These guidelines, the *Next Generation Science Standards* (NGSS; NGSS Lead States, 2013), are based on the *Framework for K–12 Science Education* (National Research Council [NRC], 2012). They are designed to replace the *National Science Education Standards* (NSES; NRC, 1996). The NGSS are poised to change the way science topics are taught in the 26 states that have already adopted them and to influence guidelines in other states, just as the NSES previously informed the development of state science education standards. Here, we present an independent study comparing the ways in which the NSES and the NGSS approach learning about environmental topics, and we report on a study that compares the effects on student learning of their different approaches.

The NGSS are poised to change the way science topics are taught in the 26 states that have already adopted them and to influence guidelines in other states.

○ Connecting Human Impact To Ecological Function

Both sets of standards emphasize developing an understanding of the nature of science that will allow students to make informed personal and civic decisions about the future, but the two sets of guidelines approach this aim differently. The NSES seek to advance this goal by including a separate content strand devoted to the personal and social perspectives of science; it is in this content strand that all content on human environmental impact is embedded. The NGSS and the *Framework* take different approaches to the content necessary for making informed personal and civic decisions about the future, specifically in terms of learning about human environmental impact. Instead of keeping this content separate in its own content strand as the NSES do, the NGSS embed this content within the core ecosystem and biodiversity life-science learning strands. By linking human impact to these learning strands, the NGSS highlight their intimate connections. These learning strands show that an understanding of human environmental impact is often predicated on prior learning of basic ecological principles and interactions and that learning how humans affect the natural world is preceded by learning how the natural world functions in the absence of human influence. The core ecosystem and biodiversity life-science learning strands described in the *Framework* and laid out in the NGSS demonstrate this sequential pattern of learning natural ecosystem dynamics and biodiversity before learning how humans affect ecosystems and biodiversity.

This method of studying functioning ecosystems first, followed by the study of how humans affect them, is logical; it would be difficult for students to understand the precise effects of humanity on ecosystems without first understanding how ecosystems function without human influence.

The American Biology Teacher, Vol. 76, No. 8, pages 508–515. ISSN 0002-7685, electronic ISSN 1938-4211.
DOI: 10.1525/abt.2014.76.8.4

Yet this sequential pattern of learning human impact after learning ecosystems was previously interpreted in the NSES in a manner that artificially separated human impact from ecological function. In an effort to emphasize the personal and civic importance of human environmental impact, the NSES separated human impact and ecology into distinct units of study and defined them as two completely different content standards. Ecology was situated as part of the life-science content standards, and human-impact content was classified as part of the "science in personal and social perspectives" standards.

The classification of ecology and human impact into separate content strands can be seen in practice as distinct units of study in environmental science textbooks and in district guidelines for biology scope and sequence (most biology textbooks have only small sections devoted to ecology, and much of the exploration of human impact is in environmental science textbooks; Schachter, 2005; Arms, 2008; San Bernardino City Unified School District, 2008; Middletown City School District, 2010; Miller & Levine, 2010). Yet in some school districts, including New York City, the district that is the focus of the present study, ecological function and human impact are even further separated into different semesters or years of study (Telluride Mountain School, 2007; New York City Department of Education, 2014).

A review of New York City's scope and sequence guidelines for biology shows this separation of topics. In the fall semester, the guidelines mandate 22 class periods devoted to ecological relationships and interactions; in the spring, the guidelines mandate 15 class periods devoted to human influences on the environment. None of the 19 content standards addressed in the fall ecology semester are addressed in the spring human-influences-on-the-environment semester, and none of the 8 spring human-influences standards are addressed in the fall ecology semester. The separation of ecology from human impact demonstrated in New York City's scope and sequence guidelines is likely replicated in other parts of New York State, because the statewide content standards, developed from the NSES, separate ecology and human impact into different learning strands as well (New York State Department of Education, 2014).

Additional evidence of NSES-driven separation of human-impact content from ecology content is found in six ecosystem units disseminated online through the National Science Teachers Association (2014). These ecology units, grounded in the NSES and developed with National Science Foundation (NSF) funding, almost entirely exclude humans and human impact. For example, these units include a simulation activity on the effect that limiting resources has on the abundance of roaming deer. This would be a good point to introduce the impact of people on deer populations, since deer overpopulation today is directly linked to the human role in eliminating wolves from the deer food web through wide-scale hunting. Yet nowhere in this activity are students asked to consider the role of humans in the disruption of factors that historically limited deer abundance. Excising human impact from this example misleads students by omitting the importance of human impact to ecological function, thereby causing them to have an incomplete understanding of the ecological interactions that limit deer population growth.

○ Research Question

In this research, we hypothesized that bringing human impact together with ecological interactions, as the NGSS advocate, can help students develop a more holistic view of ecology and human impact. Specifically, we asked:

To what extent can units designed to explicitly link human impact to ecological function through daily life actions improve student learning of the basic principles of ecological function and of human impact on the environment?

○ Materials & Methods

Ecology Disrupted: A Method for Explicitly Linking Human Impact & Ecology

We developed a method called "Ecology Disrupted" to explicitly link human impact to ecological function in ninth-grade biology classrooms (Wyner & DeSalle, 2010). The goal of this approach, developed as an NSF-funded initiative, is for students to learn about the importance and complexity of normal ecological functions by studying the environmental issues that result when people disrupt them. This model uses the same intellectual approach that the field of genetics uses to understand gene function. Just as geneticists learn gene function by studying the phenotypes that result from mutations that disrupt normal gene function, in the Ecology Disrupted model, high school students of biology learn the complexity of functioning ecosystems by studying the environmental issues that result from daily life actions that disrupt normal ecological function. Using ecological disruption to mediate the relationship between environmental issues and daily life unlocks the ecological complexity that connects daily life to environmental issues and shows students the important role that ecology plays in their lives.

This field test is based on two Ecology Disrupted curricular case studies (available from http://www.amnh.org/explore/curriculum-collections/ecology-disrupted) that use ecological principles to explore the relationship between human impact and daily life. The case studies use published data to link human impact to disrupted ecological function. In one case study, students engage with seasonal water-salinity data to learn how salting roads for safe travel disrupts *abiotic* factors and water *runoff* in the Baltimore watershed, eventually leading to saltier drinking-water supplies (Kaushal et al., 2005). In the other examples, students analyze genetic data and maps to learn how highways, built to connect Las Vegas to Los Angeles and help the Vegas economy, disrupt the bighorn sheep's *habitat*, thus making it hard for sheep from different mountaintop *populations* to mate and leading them to become inbred (Epps et al., 2005). Students are asked to consider sustainable solutions to both of these problems and are asked to apply the same methodology to other environmental issues that are caused by different human actions that disrupt the same ecological function.

Research Design

The present study examines the results of a field test of the Ecology Disrupted curriculum in New York City public schools. A quasi-experimental design was employed to examine the main effects of the curriculum as well as any potential effects associated with student demographic characteristics.

The field test took place over two academic years. All the teachers in the study completed questionnaires indicating that they normally follow New York City's scope and sequence guidelines of splitting ecology and human impact into different units, with the ecology unit preceding the human-impact unit. In the first year, teachers gave pretests and posttests before and after teaching their regular human-impact curricular units. Regular implementation of their human-impact units consisted, on average, of eight class lessons, covering content like pollution, habitat destruction, climate change, and loss of biodiversity. In the second year, the same teachers gave pretests and posttests before and after teaching the Ecology Disrupted replacement for their regular human-impact curricular units. The pretests and posttests were designed to assess student knowledge of ecological function and human impact. During the second year of the study, before teaching the Ecology Disrupted curriculum to the treatment group, the teachers participated in a full-day professional development session about using the Ecology Disrupted resources.

The students in the classes of the participating teachers during the first year served as the control group, while the students in those same teachers' classes in the second year were in the treatment group. The lack of true, random assignment is a potential threat to validity, but this particular design also nullifies the potential confounding of teacher effects. That the students in the treatment and control groups had the same group of teachers is a strength of the design of the study.

Numerous methods were used to recruit teachers into the field test. First, an invitational flier was distributed through one of the Ecology Disrupted institutional partners, a well-known and frequently visited educational organization. Second, fliers were distributed at professional meetings of science educators in the city in which the study was to take place. Third, a high-level administrator in the office of the school district serving the city where the study took place disseminated the flier to secondary school principals and announced the opportunity in a teachers' union newsletter. Fourth, key stakeholders, including university faculty members and school district personnel, actively worked to recruit teachers. Finally, the project's principal investigator, with the assistance of a graduate assistant, visited five public high schools to directly recruit participants.

Fidelity of Implementation

"Fidelity of implementation" has been defined inconsistently across the educational research base, thus making the construct seem amorphous (O'Donnell, 2008), but "overall, fidelity of implementation seems to be synonymous with adherence and integrity" (O'Donnell, 2008, p. 39). We used this framework to conceptualize fidelity of implementation for our study. As such, we sought to determine whether the curriculum was implemented as described.

Documenting fidelity required a multipronged approach (O'Donnell, 2008). First, teachers were asked to complete lesson logs to document implementation fidelity. From the teachers' responses, we found that they did not deviate significantly from the curriculum, although a few teachers reported some technical difficulties with some of the media components of the curriculum. In total, teachers were asked to complete 63 curricular components. We found that, on average, they did not cover 4.14 components, with the typical teacher skipping only 2 components. We also observed implementation in the classrooms of 16 teachers and found that our classroom observation data of teacher implementation agreed with teachers' reports of their implementation.

Additionally, we held "exit" focus groups with the teacher-participants. Three such focus groups occurred at the end of the second year of the study; two took place at participating high schools, and one at a partner institution. All the teachers who completed the testing completed an online survey that asked a number of questions aimed at documenting what worked and what did not work about the curriculum. These data, too, indicated that the teacher-participants were serious and thoughtful in their efforts to implement the curriculum. Consistent with what we learned from the lesson logs, observations, and focus groups, the data indicate strong fidelity of implementation.

Development of Student Assessment

Initially, 23 candidate multiple-choice (MC) items and 24 candidate constructed-response (CR) items were drafted to cover the range of topics inherent in each of the two curriculum objectives. Both the MC and the CR items were evaluated in pilot testing that occurred prior to field testing. The pilot included 239 students of 6 different teachers who responded to the items in their schools in the same city where field testing was held. Data reduction procedures (factor analysis and internal-consistency reliability analysis) were performed on the dataset to select the best-performing items for use in the final assessment instrument. Factors were selected by examination of the scree plot, use of the eigenvalue-greater-than-one rule, and a parallel analysis.

The assessment of student learning during the Ecology Disrupted pilot study evinced satisfactory psychometric characteristics. The MC items were analyzed with exploratory factor analysis (using the principal component method with varimax rotation). These analyses began with the full set of 23 MC items, followed by numerous analyses focused on subsets of items. The best-performing model included six items, with three for each curriculum objective. The Keyser-Meyer-Olkin measure of sampling adequacy (KMO) was 0.76, which indicated that the sample was satisfactory for factoring. The model accounted for 59% of the variance in students' responses. The selected items produced pattern-structure coefficients ("loadings") ranging from 0.44 to 0.81 (average = 0.69). Cronbach's alpha (a measure of internal consistency and, thus, reliability) for the factors was 0.39 and 0.55, respectively, yielding an overall alpha of 0.50. These reliabilities are moderate, likely because of differences in the difficulty the items posed for participating students. Although the factor-analytic results make clear that the items were measuring similar constructs, differences in item difficulty apparently produced situations in which some students found an item difficult while others did not. This is not unusual when there are multiple items tapping a factor in a format with one correct answer (the "key") and three distractors, but the items vary in difficulty. Had the pattern/structure coefficients ("loadings") been low, there would be cause for concern that the factor was poorly assessed; but the loadings were satisfactory for both factors measured with MC items.

Similar procedures were used to analyze the candidate CR items (KMO = 0.66). Data reduction resulted in a two-factor, five-item model that explained 65.1% of the variance in students' responses and loadings that ranged from 0.57 to 0.93 (average = 0.68). The overall alpha was 0.70. The statistics support the utility of the assessment instrument for tapping the two curriculum objectives (ecological function and human impact), each in two ways (MC and CR).

Participants

There was a high level of cooperation from the teacher-participants throughout the 2 years of the study. The resulting sample includes

Table 1. Student demographic characteristics, by group.

		Control Group (n = 1103)	Treatment Group (n = 1131)
Gender	Male	43.9%	47.1%
	Female	56.1%	52.9%
Race	Caucasian	16.4%	16.9%
	African-American	21.5%	17.3%
	Latino/a	28.5%	31.7%
	Asian	17.6%	19.9%
	Other	16.0%	14.1%

"matched" classrooms: classes of students taught by teachers who submitted data for at least one class during the control year and at least one class during the treatment year. For these analyses, the only data used were those of students from whom pretest, posttest, and demographic data were collected.

Ultimately, the data are from 2234 students taught by 26 teachers across 16 different high schools. Table 1 disaggregates that sample by student gender and race. The treatment and control groups are reasonably similar with respect to size, gender, and race.

Assessment of Student Performance Data

Initially, two raters who had no knowledge of the research design completed a tuning process in which they scored sample data and discussed their responses. Once this tuning process appeared to produce a satisfactory level of inter-rater reliability, the raters scored all items in 61 examinations from the actual research data (1.4%). This procedure resulted in an overall level of agreement of 93%, with 94% and 92% agreement, respectively, for items measuring students' understanding of ecological function and human impact. The level of agreement for individual items ranged from 87% to 97%. This high level of inter-rater reliability allowed the raters to split the remaining data, which were scored by one rater only and entered into SPSS for statistical analysis.

○ Results

Assessment scores were calculated as the percentage of correct responses. On the assessment as a whole, the mean pretest score for the control group (50.9%) was significantly higher than that for the treatment group (47.1%) ($F = 19.65$, $P < 0.01$, $\eta^2 = 0.009$), although the effect was small. However, on the posttest, the mean score of the treatment group (62.8%) was significantly higher than that of the control group (54.2%) ($F = 86.87$, $P < 0.01$, $\eta^2 = 0.037$). On average, the treatment group got 15.7% more correct items on the posttest than on the pretest, compared to just 3.3% for the control group (Table 2).

Similar growth favoring the treatment group can be seen when breaking the assessment down into the subtests. Across both subtests, the treatment group made statistically significant greater gains than the control group ($P < 0.01$).

We used linear regression analyses to examine the statistical significance of observed differences in means controlling for race and gender. The outcome variable was the student score on the posttest,

Table 2. Pretest and posttest subtest scores by treatment-control (% correct).

	Control Group (n = 1103)		Treatment Group (n = 1131)	
	Mean	**SD**	**Mean**	**SD**
Overall				
Pretest	50.92	0.20	47.09	0.20
Posttest	54.24	0.22	62.82	0.22
Ecological Function				
Pretest	54.41	0.24	50.66	0.24
Posttest	58.24	0.24	67.61	0.24
Human Impact				
Pretest	46.87	0.24	42.97	0.22
Posttest	49.78	0.25	57.33	0.24

and the predictor variables were pretest scores, race, and gender. Because the students self-reported on one of five racial categories, race was included by entering four dummy-coded variables into the model. "Latino/a" was the reference group for race. All models met all the assumptions of linear regression. First, we inspected a plot of residuals versus predicted values for evidence of linearity of the relationship between the dependent and independent variables. Second, we looked at a plot of residuals versus time and predicted values to ensure homogeneity of variance. Finally, we inspected a normality probability plot of the residuals and found the error distribution to be within acceptable limits. That is, we found no outliers in the pretest or posttest data. Low variance-inflation values indicated no problems of multicollinearity.

For the assessment as a whole, the model was significant ($F = 208.94$, $P < 0.01$) and predicted 39.7% of the variance in the posttest score. Group assignment was a significant predictor of posttest scores, controlling for pretest performance, race, and gender. Being a student in the treatment group was associated with a 0.25 increase in the score on the assessment, controlling for race and gender. Neither gender nor race had any significant effect on the posttest score. Hence, being exposed to the Ecology Disrupted curriculum had a positive and statistically significant impact on student assessment scores, above and beyond the effect of the pretest score (Table 3).

Similar results were yielded by models for the subtests. For the ecological-principles subtest and the human-impact subtest, the treatment proved to be a statistically significant predictor, above and beyond the effect of the pretest score and controlling for race and gender. For the ecological-function subtest, being a student in the treatment group was associated with a 0.23 increase in the score on the assessment, controlling for race and gender. For the human-impact subtest, being a student in the treatment group was associated with a 0.20 increase in the score on the assessment, controlling for race and gender (Tables 4 and 5).

In sum, the Ecology Disrupted curriculum had a statistically significant positive impact on student achievement. Considering the assessment overall, being a student in the treatment group was associated with a 0.25 increase in the score on the assessment. Given that

Table 3. Regression coefficients for full assessment (posttest).

	Unstandardized Coefficients		Standardized Coefficients		
	B	SE	β	t	P*
(Constant)	0.214	0.013		17.096	0.000
Treatment	0.111	0.007	0.250	15.046	0.000
Female	−0.003	0.007	−0.007	−0.436	0.663
White	0.001	0.011	0.002	0.098	0.922
Black	0.001	0.011	0.003	0.133	0.894
Asian	−0.003	0.011	−0.006	−0.306	0.760
Other	−0.005	0.012	−0.008	−0.413	0.679
Pretest	0.651	0.018	0.602	36.054	0.000

Note: $R^2 = 0.452$ ($P < 0.01$). *Significant at $P < 0.01$.

Table 4. Regression coefficients for assessment subtest – ecological functions.

	Unstandardized Coefficients		Standardized Coefficients		
	B	SE	β	t	P*
(Constant)	0.311	0.014		21.548	0.000
Treatment	0.112	0.009	0.228	12.592	0.000
Female	−0.002	0.009	−0.005	−0.254	0.800
White	0.015	0.013	0.023	1.103	0.270
Black	−0.010	0.013	−0.016	−0.761	0.447
Asian	0.006	0.013	0.010	0.481	0.630
Other	0.000	0.014	−0.001	−0.032	0.974
Pretest	0.498	0.019	0.487	26.697	0.000

Note: $R^2 = 0.452$ ($P < 0.01$). *Significant at $P < 0.01$.

Table 5. Regression coefficients for assessment subtest – human impact.

	Unstandardized Coefficients		Standardized Coefficients		
	B	SE	β	t	P*
(Constant)	0.226	0.014		16.736	0.000
Treatment	0.098	0.009	0.199	11.286	0.000
Female	0.001	0.009	0.001	0.075	0.941
White	−0.001	0.013	−0.001	−0.057	0.954
Black	0.008	0.013	0.012	0.603	0.547
Asian	−0.006	0.013	−0.010	−0.488	0.626
Other	−0.012	0.014	−0.017	−0.876	0.381
Pretest	0.581	0.019	0.546	30.800	0.000

Note: $R^2 = 0.452$ ($P < 0.01$). *Significant at $P < 0.01$.

the standard deviation of the total gain scores, across treatment and control groups, was 0.17, we conclude that student achievement increased more than one standard deviation and that this improvement is attributable to the Ecology Disrupted curriculum. There were no differential effects of the curriculum by race or gender. The positive effects of the curriculum are available to all students, a noteworthy finding in a study conducted in a racially diverse urban school district.

○ Discussion

These findings show that integrating human environmental impact and ecology into one study topic can improve student learning of concepts related to both human impact and ecology. Integrating these topics allows the study of human impact to be used to understand ecological function, thereby helping students develop a better understanding of both topics. Seeing environmental issues as the result of daily life actions that *disrupt normal ecological function* helps students better understand normal ecological interactions and the complex and cascading effects on ecosystems of everyday human actions.

These findings show that this approach is useful for helping students understand the concepts underlying ecological function and human environmental impact by allowing students to see how these topics are intimately linked. It should be noted that because our study's results were obtained in a single trial, replication research is needed to strengthen the case for the benefits of the Ecology Disrupted approach. Moreover, the study was conducted in an urban setting, and it is possible that students in suburban and rural areas might respond differently to the curriculum. Similarly, the study was field-tested in the northeastern United States, and students in other geographic areas might perform differently. Finally, no distinction was drawn between general-education students and other populations (i.e., special-education students or English language learners), so it remains unclear how the intervention might affect those populations.

○ Conclusion: Implications for Bringing Human Impact & Ecology Together

Our findings show that including human impact and ecology in the same learning strands, as the *Framework* and the NGSS advocate, is more effective for student learning of these concepts than the NSES's organization of these topics into separate strands. Importantly, increasing the ability of students to understand the complex interplay of humanity with ecological interactions may help students become better-prepared citizens, able to make the kinds of informed decisions about the environment advocated by the old *National Science Education Standards* and the new *Next Generation Science Standards*.

○ Acknowledgments

This research was supported by grants from the National Science Foundation (NSF; grant nos. 733269 and 0918629). All opinions expressed are those of the authors and not of the NSF. We thank S. Gano, R. DeSalle, R. Kinzler, S. Fotiadis, D. Silvernail, A. Bickerstaff, S. Bothra, M. Chin, and R. Thorne for their important work in conceiving, developing, and testing the modules. We also thank J. Koch for her contribution to the curriculum and for review of the manuscript. Finally, we thank all the teachers who participated in our professional development and used the curriculum in their classrooms.

References

Arms, K. (2008). *Environmental Science.* New York, NY: Holt, Rinehart and Winston.

Epps, C.W., Palsbøll, P.J., Wehausen, J.D., Roderick, G.K., Ramey, R.R. II & McCullough, D.R. (2005). Highways block gene flow and cause a rapid decline in genetic diversity of desert bighorn sheep. *Ecology Letters, 8,* 1029–1038.

Kaushal, S.S., Groffman, P.M., Likens, G.E., Belt, K.T., Stack, W.P., Kelly, V.R. & others. (2005). Increased salinization of fresh water in the northeastern United States. *Proceedings of the National Academy of Sciences USA, 102,* 13517–13520.

Middletown City School District. (2010). Grade 9 biology – marking period 4: living environment. Available online at http://www.middletowncityschools.org/Portals/0/resources/SBL/9-12Curriculum/Science/Grade9BiologyMP4.pdf.

Miller, K.R. & Levine, J.S. (2010). *Biology*. Boston, MA: Pearson.

National Research Council. (1996). *National Science Education Standards.* Washington, DC: National Academy Press.

National Research Council. (2012). *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Washington, DC: National Academies Press.

National Science Teachers Association. (2014). Scope, sequence, and coordination: a framework for high school science education: based on the National Science Education Standards. Available online at http://dev.nsta.org/ssc/.

New York City Department of Education. (2014). NYC High School Science Regents Scope and Sequence. Available online at http://schools.nyc.gov/Documents/STEM/Science/HSScienceSSRegents.pdf.

New York State Department of Education. (2014). New York State Living Environment Core Curriculum. Available online at http://www.p12.nysed.gov/ciai/mst/pub/livingen.pdf.

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States.* Washington, DC: National Academies Press.

O'Donnell, C.L. (2008). Defining, conceptualizing, and measuring fidelity of implementation and its relationship to outcomes in K–12 curriculum intervention research. *Review of Educational Research, 78,* 33–84.

San Bernardino City Unified School District. (2008). Scope and sequence: Biology 1: high school. Available online at http://www.sbcusd.k12.ca.us/DocumentCenter/Home/View/5734.

Schachter, M. (2005). *Environmental Science.* New York, NY: AMSCO.

Telluride Mountain School. (2007). Scope and sequence. Available online at http://www.telluridemtnschool.org/documents/INTERMEDIATESCOPEANDSEQUENCE2007.pdf.

Wyner, Y. & DeSalle, R. (2010). Taking the conservation biology perspective to secondary school classrooms. *Conservation Biology, 24,* 649–654.

YAEL WYNER is Assistant Professor of Secondary Education at City College of New York, City University of New York, 160 Convent Ave., New York, NY 10031; e-mail: ywyner@ccny.cuny.edu. JONATHAN BECKER is Associate Professor of Educational Leadership at Virginia Commonwealth University, Oliver Hall, Richmond, VA 23284; e-mail: jbecker@vcu.edu. BRUCE TORFF is Professor of Curriculum and Teaching at Hofstra University, Hempstead, NY 11549; e-mail: bruce.torff@hofstra.edu.

(Appendix follows on the next page.)

Appendix: Student Pre–Post Assessment

Part 1

1. Health problems, increased rate of genetic diseases, and changes in characteristic appearance are all possible side effects of
   a. inbreeding.
   b. overdosing on drugs.
   c. acid rain.
   d. global warming.
2. How has the construction of roads negatively impacted the environment?
   a. Roads break habitat into pieces.
   b. Roads make it easier for people to get around.
   c. Crowded roads are filled with traffic.
   d. Cars have decreased global warming.

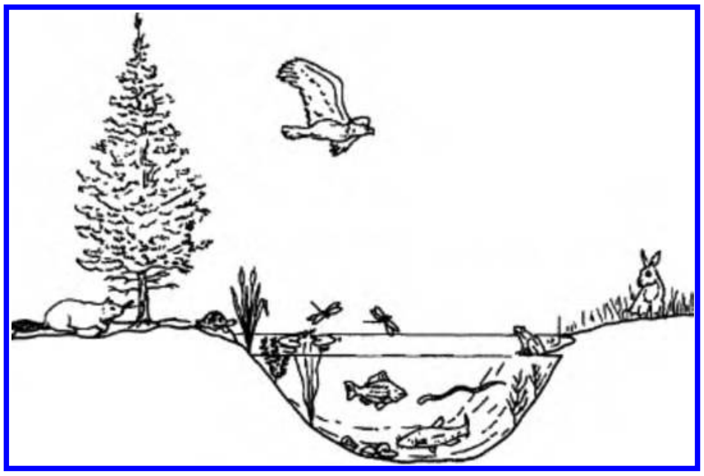

Figure A1. Freshwater pond

3. Which of the following is an abiotic factor in the picture above (Figure A1)?
   a. Water
   b. Bird
   c. Fish
   d. Tree
4. Which group of organisms is an example of a population?
   a. Leopard frogs in a stream
   b. Reptiles in the Sahara Desert
   c. Birds in Colorado
   d. Trees in a forest
5. In order to preserve the Earth for future generations, humans must
   a. make use of technology to develop new pesticides.
   b. put all wild animals in game preserves.
   c. explore ways to eliminate wetlands.
   d. use what they know about ecology to understand the impact of daily life activities.
6. Which statement illustrates how human activities can most directly disrupt an ecosystem?
   a. A hurricane causes a stream to overflow its banks.
   b. Increased wind increases water evaporation from a plant.
   c. Artificial light causes a decrease in insect populations in a river.
   d. The ozone layer shields the Earth from harmful ultraviolet rays.

Part 2

1. Use the paragraph below to answer the following questions.

   The streams in forested and urban areas in the greater Baltimore area are home to animals like fish and snails. The streams are filled with rocks and free-flowing water. In the Baltimore area, when it snows, people put salt on the roads to melt the snow and ice. Some of that salt ends up in these Baltimore area streams.

   a. What new abiotic factor has entered streams?
   b. Explain one example of how changing abiotic factors can benefit the daily lives of people.
   c. Explain another example of how changing abiotic factors can benefit the daily lives of people.
   d. How do you think salt entered the Baltimore area streams?
   e. How might salt affect living things like fish and snails in these streams?
   f. Propose a solution for reducing the impact of people on Baltimore area streams.

2. Use the illustration and paragraph below to answer the following questions.

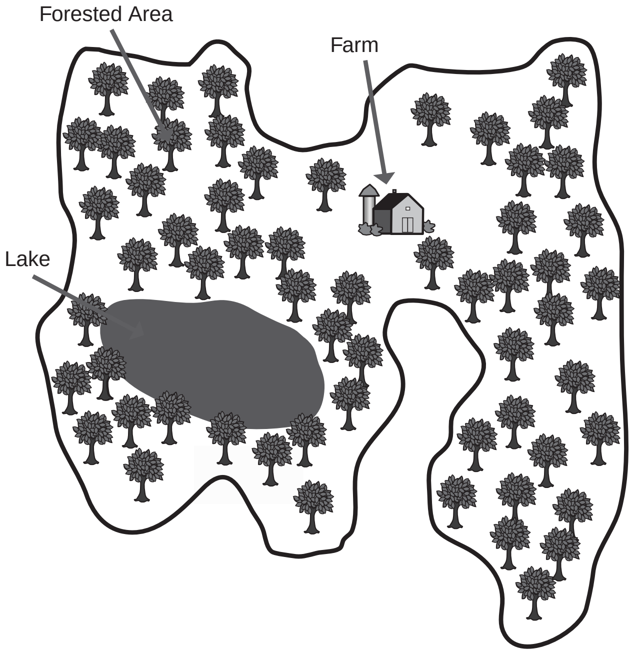

Figure A2. Farm in Upstate New York

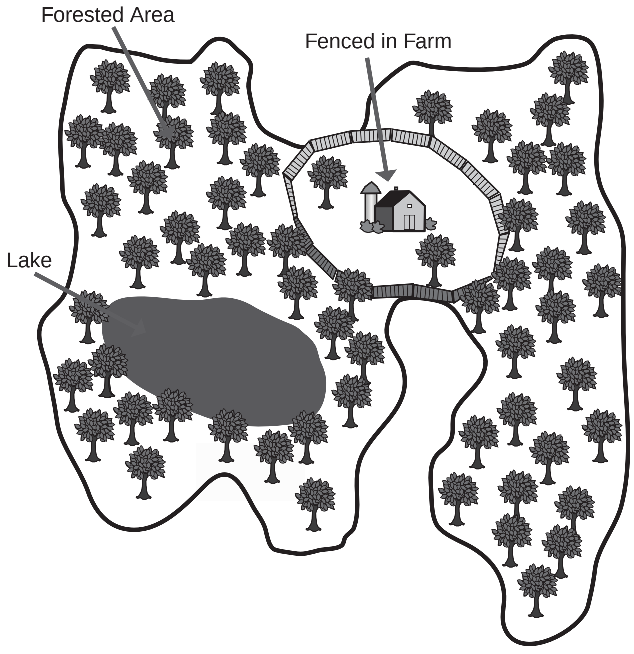

Figure A3. Farm in Upstate New York with a new fence

   The forested mountains of Upstate New York are filled with sugar maples, oaks, and yellow birch trees. They are also home to predators like bobcats. These animals live alone and wander over large areas to search for food and to mate and breed with other bobcats. Recently, a dairy farmer who lives in the area and who supplies milk to New York City residents decided to build a fence around his farm in order to prevent his grazing cows from wandering off (Figures A2 and A3). The farmer is happy with these changes because they allowed him to increase milk production.

   a. How is the upstate habitat being changed?
   b. Explain how building a fence on the farm can affect the bobcat population.
   c. Describe one other example (other than cutting down trees) where changes people have made to habitats have unexpectedly harmed wildlife populations. Make sure you include in your answer the change to the habitat and how that change harms wildlife populations.