Learning Gains and Response to Digital Lessons on Soil Genesis and Development

Martha Mamo[1], James A. Ippolito[2], Timothy A. Kettler[3], Ronald Reuter[4], Dennis McCallister[5], Patricia Morner[6], Dann Husmann[7], and Erin Blankenship[8]

ABSTRACT

Evolving computer technology is offering opportunities for new online approaches in teaching methods and delivery. Well-designed web-based (online) lessons should reinforce the critical need of the soil science discipline in today's food, energy, and environmental issues, as well as meet the needs of the diverse clientele with interest in agricultural and/or environmental disciplines. The objectives of the project were to: (1) develop web-based lessons in soil genesis and development and (2) evaluate context-based case studies or application lessons (agronomic, environmental, and ecological situations) to teach soil genesis and development. Six principles lessons, along with three applications lessons, were developed for use by undergraduate soil science courses. Pre- and post-tests were used to assess learning gains. A postactivity survey was also used to assess perceptions of the web-based lessons by student users. Students' test performance from pre- to post-test improved by 69%. Although there were no differences in post-test gains among learning styles, or between genders, the students majoring in professional golf management had higher post-test gains than other majors. Since their inception in 2006, lessons have continued to be both primary and supplemental resources for multiple courses serving over 140 students each year at the University of Nebraska-Lincoln and Oregon State University-Cascades. The lessons will be especially useful for teachers who do not have extensive training in soil science yet cover the subject as part of a basic earth science course. *© 2011 National Association of Geoscience Teachers*. [DOI: 10.5408/1.3651402]

INTRODUCTION

The Soil Science Society of America recently emphasized the potential of soil science to help solve the critical global needs in food security, the environment, and alternative energy (Lal, 2007). Soil science has the potential to produce quality graduates to help solve these major global-scale problems. However, soil science education has traditionally focused on the agricultural audience, thus in the past has fallen short of demonstrating the relevance of soil to students from nonagricultural disciplines, thus the need to broaden the application of soil science and disseminate materials via web-lessons.

A survey of web-based resources suggests that existing educational materials are not meeting the needs described above. Materials that are available seem to occupy two poles in the educational spectrum. On one extreme, there is an extensive array of learning resources aimed mainly at primary and middle school. These resources are illustrated by the web site maintained by the Natural Resource Conservation Service (NRCS) National Soil Survey Center (http://www.statlab.iastate.edu/soils/nssc/educ/edu_k-12.htm) by NASA (http://soil.gsfc.nasa.gov/) and by the Dig It exhibit of the Smithsonian's National Museum of Natural History (http://forces.si.edu/soils/index.html). These sites contain resources on different aspects of soil focusing on primary and secondary school audiences. The other educational extreme found in current web-based resources consists of postsecondary level courses in soil science. These offerings are considerably less common than the resources available for primary and middle school. One illustration of such a course can be found at Oregon State University & (http://ecampus.oregonstate.edu). The description of the course, however, suggests that its content and methodology are typical of classroom courses in soil science, only offered at a distance primarily using video. Other learning resources include one at Idaho State University on soil orders (http://soils.cals.uidaho.edu/soilORDERS/). This site uses images, pictures, and maps to describe the 12 USDA soil orders. While the resources mentioned above are important and very useful in meeting some needs in the area of soil science, there is still a large gap that needs to be filled to increase the digital database of well designed soil science resources for undergraduate education. This is especially critical as many nonagricultural institutions are offering courses in soil science as part of their curriculum (Landa, 2004).

A computer-driven dual approach that links the general "principles" of soil science to various "application stories," or problem-based learning, can broaden the student audience and application disciplines for what might otherwise be a traditional course. Compelling stories that link soil science principles will broaden the student audience, increase self-efficacy (Ketelhut, 2007), increase student time-on-task, and extend the relevance of soil science (Keppell *et al.*, 1998; McAlpine and Clements, 2001). The

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[1]279 Plant Science, Department of Agronomy and Horticulture, University of Nebraska, Lincoln, NE 68583; mmamo3@unl.edu
[2]3793 N 3600 E, USDA-ARS-Northwest Irrigation and Soils Research Laboratory, Kimberly, ID 83341; jim.ippolito@ars.usda.gov
[3]279 Plant Science, Department of Agronomy and Horticulture, University of Nebraska, Lincoln, NE 68583; tkettler2@unl.edu
[4]2600 NW College Way, Department of Forest Resources, Oregon State University, Bend, OR 97701; ron.reuter@oregonstate.edu
[5]279 Plant Science, Department of Agronomy and Horticulture, University of Nebraska, Lincoln, NE 68583; dmccallister2@unl.edu
[6]279 Plant Science, Department of Agronomy and Horticulture, University of Nebraska, Lincoln, NE 68583; pmorner2@unl.edu
[7]300 Agricultural Hall, Department of Agricultural Leadership, Education and Communication, University of Nebraska, Lincoln, NE 68583; dhusmann2@unl.edu
[8]340 Hardin Hall North, Department of Statistics, University of Nebraska, Lincoln, NE 68583; eblankenship2@unl.edu

objectives of the project were to: (1) develop web-based lessons in soil genesis and development and (2) evaluate context-based case studies or application lessons (agronomic, environmental, and ecological situations) to teach soil genesis and development.

CONTEXT

At the University of Nebraska-Lincoln (UNL), Soil Resources (AGRO/HORT/SOIL 153) annually serves up to 280 students (>100 students/semester). It is a fundamental course for many students majoring in the College of Agricultural Sciences and Natural Resources (CASNR) and is beneficial for other students of diverse majors in the social, biological, and physical sciences as well as future educators on the primary and secondary school level. Since 1988, the course has been taught using an active small-group learning style covering 25 soil science topics. The majority of these topics are student centered activities completed in small group.

In this study, 34% of the participants were in traditional agriculture-related majors while the remainder consisted of environmental sciences majors, horticulture, professional golf management, or other. The class-standing was 27% each freshmen and junior, 24% sophomore, 20% senior, and 3% postgraduate. The University of Nebraska undergraduate population is 85% non-Hispanic white with Hispanic and African-American at less than 3% each. Although, race and socioeconomic information were not obtained formally, participants in the study were all white except for 1 to 2 students who appeared to be of Hispanic background.

LESSON OBJECTS

To support the activities just described, two types of educational objects, principles and applications (i.e., situated case study) lessons, were developed between 2005 and 2006. Principles and context specific case study lessons were developed modeling "backward design" (McTighe and Wiggins, 2001), where learning outcomes and assessment were first defined before lesson topics development.

The conceptual framework for these lessons was that situated case study or application lessons can provide the spark for student learning and that these application lessons can be backstopped with the principles lessons to impart fundamental knowledge (Fig. 1). The model framework was that principles and application lessons give learners the opportunity to apply the same concepts to new and different situations. In this case, the application lessons were context-specific for the user to broaden the relevance of soil science principles. The advantage of developing separate principle and application lessons is to provide the opportunity for students to learn how to apply the same principle to new situations. This restructuring (Keppell *et al.*, 1998) approach reinforces the principles lesson and strengthens the abilities of the learners to think creatively and critically.

The theoretical framework underlying the "backward design," or application lessons approach, emphasizes the importance of helping students become independent thinkers and learners rather than simply being able to retrieve knowledge facts (Cognition and Technology Group at Vanderbilt, 1992). Barrows (1986) stated that the possible objectives of this learning style include structuring knowledge for future work learning, developing effective reasoning processes and self-directed learning skills, and increasing motivation for learning. Thus, by following "backward design," student understanding should increase and concomitantly test scores should improve. Penuel *et al.* (2008) examined an application lessons approach with students studying Earth systems science. The authors found these students scored higher than control group students on a standards-based test of Earth science knowledge. Srinivasan *et al.* (2007) used a similar approach with medical students, noting that a "backward design" model was preferred by 89% over the traditional learning method because of fewer unfocused tangents, less busy-work, and more opportunities for clinical skills application.

Project team members who included course instructors, instructional design, and evaluator first met for a two day retreat at UNL to define learning outcomes and then define topics of principles lessons and case study scenarios, and lesson assets (questions, animations, etc.). The seven instructors from the UNL, Colorado State University

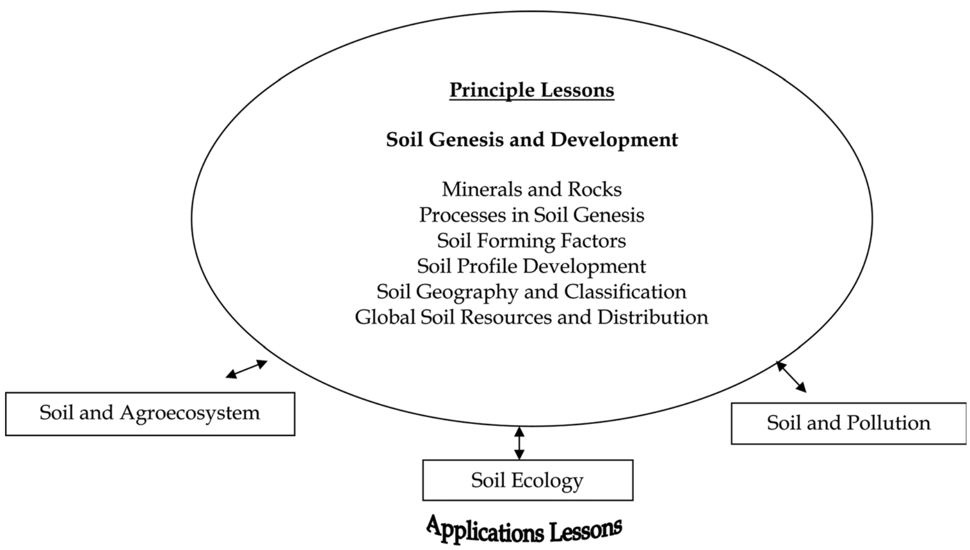


FIGURE 1: Conceptual framework depicting the layout of the principles and applications lessons on soil genesis and development.

TABLE I: Learning objectives developed for the soil genesis and development E-lessons at the plant and soil sciences E-library.

	Learning objectives
1	Classify rocks according to the major rock types.
2	Describe the influence of parent material on soil properties.
3	Define and distinguish physical, chemical, and biological weathering processes.
4	Describe how rock and mineral properties and environmental factors influence the weathering of rocks and minerals into soil.
5	Identify the five factors of soil formation.
6	Explain the effects of each soil forming factor on soil formation.
7	Explain how types of parent material differ in terms of mode of deposition and degree of sorting.
8	Describe the four major processes of soil formation.
9	Describe how the processes of soil formation redistribute soil materials in vertical and horizontal dimensions.
10	Explain the soil forming process(es) is/are dominant in each soil horizon.
11	Develop a profile horizon sequence based on given soil properties.
12	Describe the general conditions of a given soil profile based on the soil forming factors.
13	Introduce the structure of the USDA soil taxonomic system.
14	Discuss the defining characteristic(s) of each of the 12 soil Orders.
15	Apply the concept of soil forming factors to the formation and occurrence of each of the 12 soil Orders.
16	Identify regional scale occurrences of soil Orders in the United States.
17	Identify and describe the roles of soil in the global ecosystem.
18	Identify cultural and environmental factors which affect the ability of soil to function.
19	Evaluate the nature and extent of the global soil resource.

(CSU), Oregon State University (OSU), and Trinity College (Connecticut) developed the principles lessons based upon their topic knowledge and teaching experience to address 19 learning objectives (Table 1). The content of these lessons assumed no previous soil science studies and was directed to an introductory postsecondary level audience.

Structure of Principles Lessons

The principles lessons were intended to teach fundamental concepts that are critical for students to understand in an introductory college-level earth science and/or soil science course. The principles lessons were as follows:

Lesson 1: Rocks and Minerals

Lesson 2: Processes of Weathering

Lesson 3: Soil Forming Factors

Lesson 4: Soil Profile Development

Lesson 5: Soil Classification and Geography

Lesson 6: Global Soil Resources and Distribution

Interactive flash animations, experiential learning activities, transfer problems, embedded questions, images, and text are primary instructional elements in these lessons (Fig. 2). The lessons were designed as portable instructional objects to provide future instructors with information-rich resources to present problems and the option of using the lessons' content in a variety of learning situations.

Structure of Application Lessons

The key instructional design feature to the application lessons was the creation of an interactive dynamic between the discipline and the learner (Fig. 1). The application lessons were as follows:

Food Production: Agroecosystem Soil, Food, and Fiber

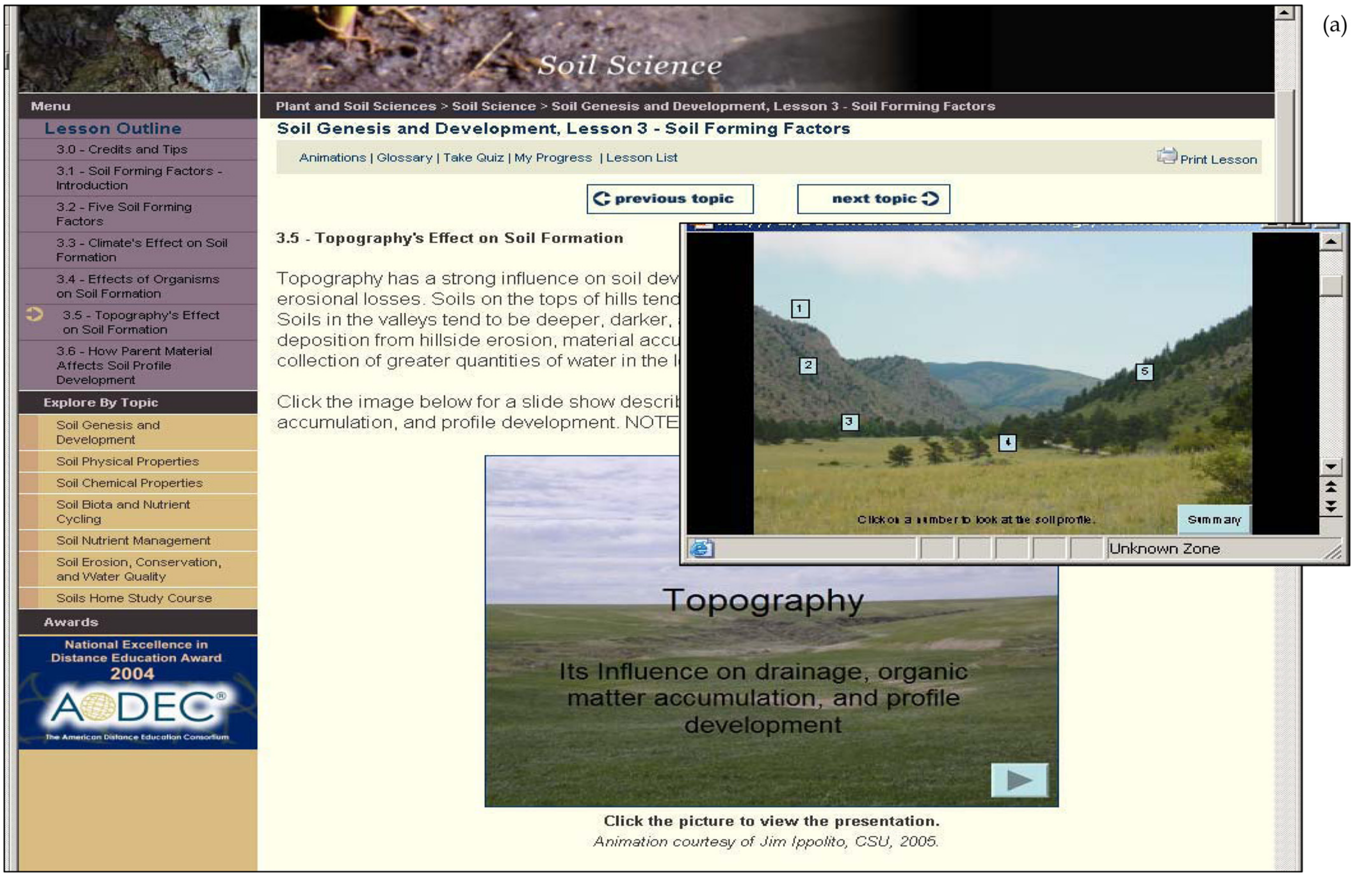
Environmental Management: Biosolids Additions and Soil Formation

Ecology: Soils and Salts, the Case of the Salt Creek Tiger Beetle

Each application lesson introduces the situation or case with some background information and states the problem (Fig. 3). Within each application lesson, a series of questions are asked with hyperlinks below each question to refer students to one or more of the appropriate principles lessons sections (Fig. 3). Each student then identifies major concepts and principles and writes a response to the question on a worksheet. The questions in each case study are objective; thus, once a student chooses an answer, he/she can check if the answer is right. The check feedback provided by lesson developers for incorrect or correct answers were added based on surveys and round table discussion made with students during the informal evaluation of lessons in 2005. The check feedback also allows the student to rethink the concepts being addressed. At the end of the case, the student restates the problem and makes the recommendations.

DEVELOPMENT PROCESS

Lesson development and evaluation included internal peer review of lessons and two forward feedbacks or informal implementation. The forward feedbacks in fall 2005 and spring 2006 allowed the team to refine lesson content, navigation, and overall instructional design. Formal implementation was completed in fall 2006 after revisions were made based on internal peer lesson reviews, student



(a)

FIGURE 2: (Color online) (a) Examples of a topography animation; (b) embedded exercise; (c) embedded experiential activity; and (d) embedded questions in the Soil Genesis and Development principles lessons. To view and/or use the lessons please visit http://passel.unl.edu/pages/ and click on the "Soil Science" then click on "Soil Genesis and Development."

forward feedbacks, and students' roundtable discussion. Development timeline and processes are detailed in Table 2. The process of lesson development and evaluation required coordination, extensive faculty time commitment. It was necessary to defer development of some planned video, simulations, animations, and other useful visualizations due to lack of funds.

FORMAL IMPLEMENTATION

The goal of the project was to create resources with a strategy focused on applying soil science concepts in different context and to also diversify the teaching tools available for our classroom and the geoscience teaching community. Because the study and lesson development was not designed to validate this approach against other approach(es), the team did not deem it necessary to have a control group.

During implementation at UNL, each student independently completed the three application lessons during two 2-h periods using notebook computers in the classroom. The instructor was available while each student worked to answer content questions and deal with technical computer issues. Each student completed a written worksheet associated with each case study and turned in the worksheet at the end of the session (Table 3).

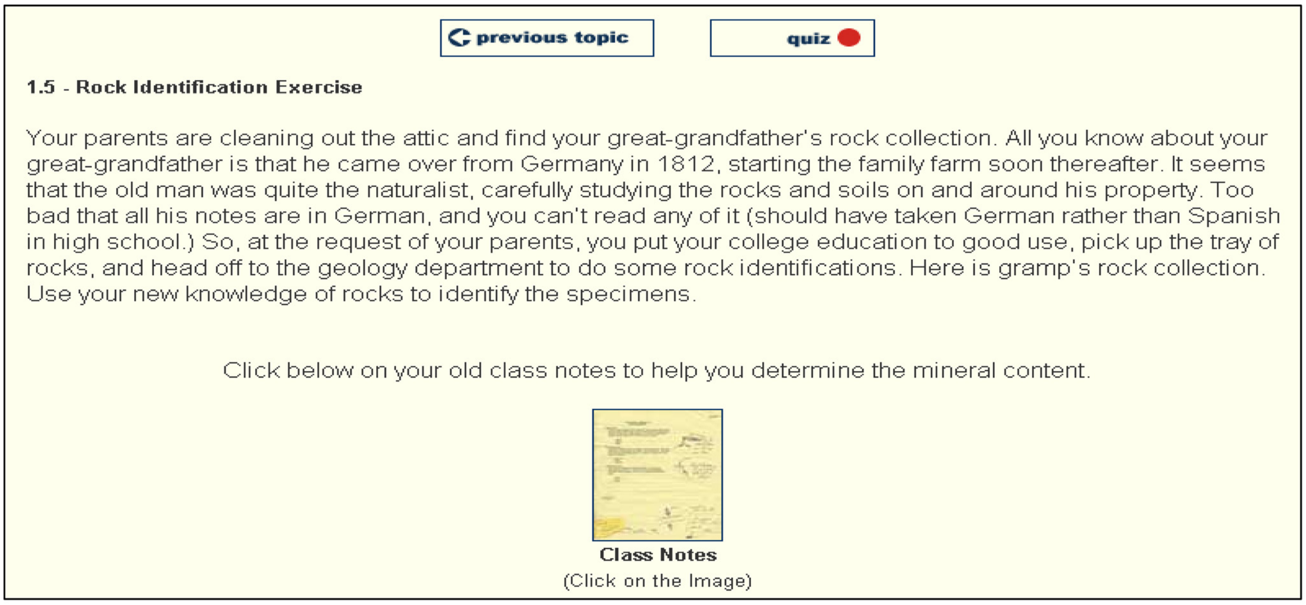
ASSESSMENT TOOLS

Pre- and Post-Test

Fifty objective questions were developed collaboratively by instructors at UNL, CSU, and OSU. These questions were designed to be used in an online testing system to allow both traditional multiple choice questions but also embed images, some interactive, such as maps and soil profiles in the question. Based on instructors' experience, 75% of the test items were lower level on Bloom's Taxonomy (Knowledge and Comprehension) and 25% of the test items were higher level on the Bloom Taxonomy (Bloom, 1956). The same test items were used for both the pretest and post-test as described below.

Pretest: A pretest was administered to students the day of the activity. Each student was given 60 min to complete the pretest before the activity began.

Post-test: A post-test was administered to students within the same week after completing the three applications lessons. Each student was given 60 min to complete the post-test.



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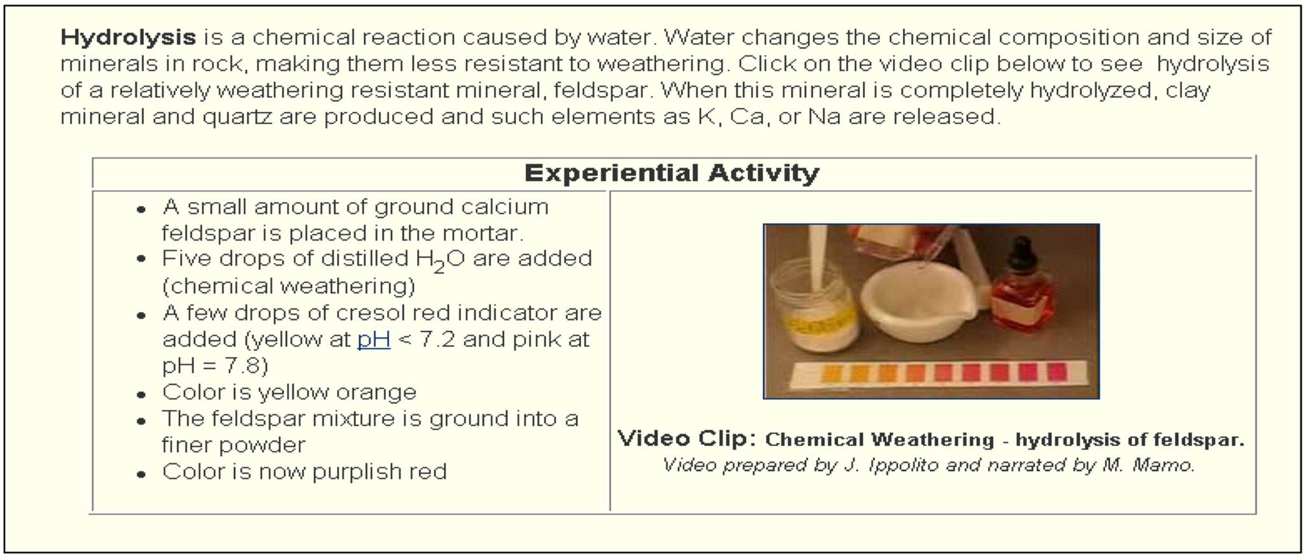

(c)

FIGURE 2: (Color online) continued

Learning Styles Inventory

The Kolb's (1984) Learning Styles Inventory (LSI) is an instrument that categorizes student learning style. Each student was presented with 12 phrases, each with responses designed to identify how the student learns and deals with ideas and situations in their everyday lives (Mamo *et al.*, 2005). The student ranks the responses from 1 to 4 (4 = most like the student, 1 = least like the student) based upon how they see themselves as learners. The rankings for each response category are totaled and used to create a score to place the student in 1 of 4 learning style categories (Mamo *et al.*, 2005):

Divergers, learners who combine concrete experience with reflective observation;

Accommodators, learners who combine concrete experience and active experimentation;

Convergers, learners who combine abstract conceptualization and active experimentation;

Assimilators, learners who combine abstract conceptualization and reflective observation.

Kolb (1984, p. 77-78) characterizes both convergers and assimilators as being less involved with social or interpersonal issues and more attuned to ideas and concepts. In contrast, divergers and accommodators tend to rely on others in their problem-solving efforts. This would suggest that convergers and assimilators would function better in distance educational formats in which they interact primarily with an impersonal program. In contrast, divergers and accommodators would function better in a more social learning environment, even if that were online.

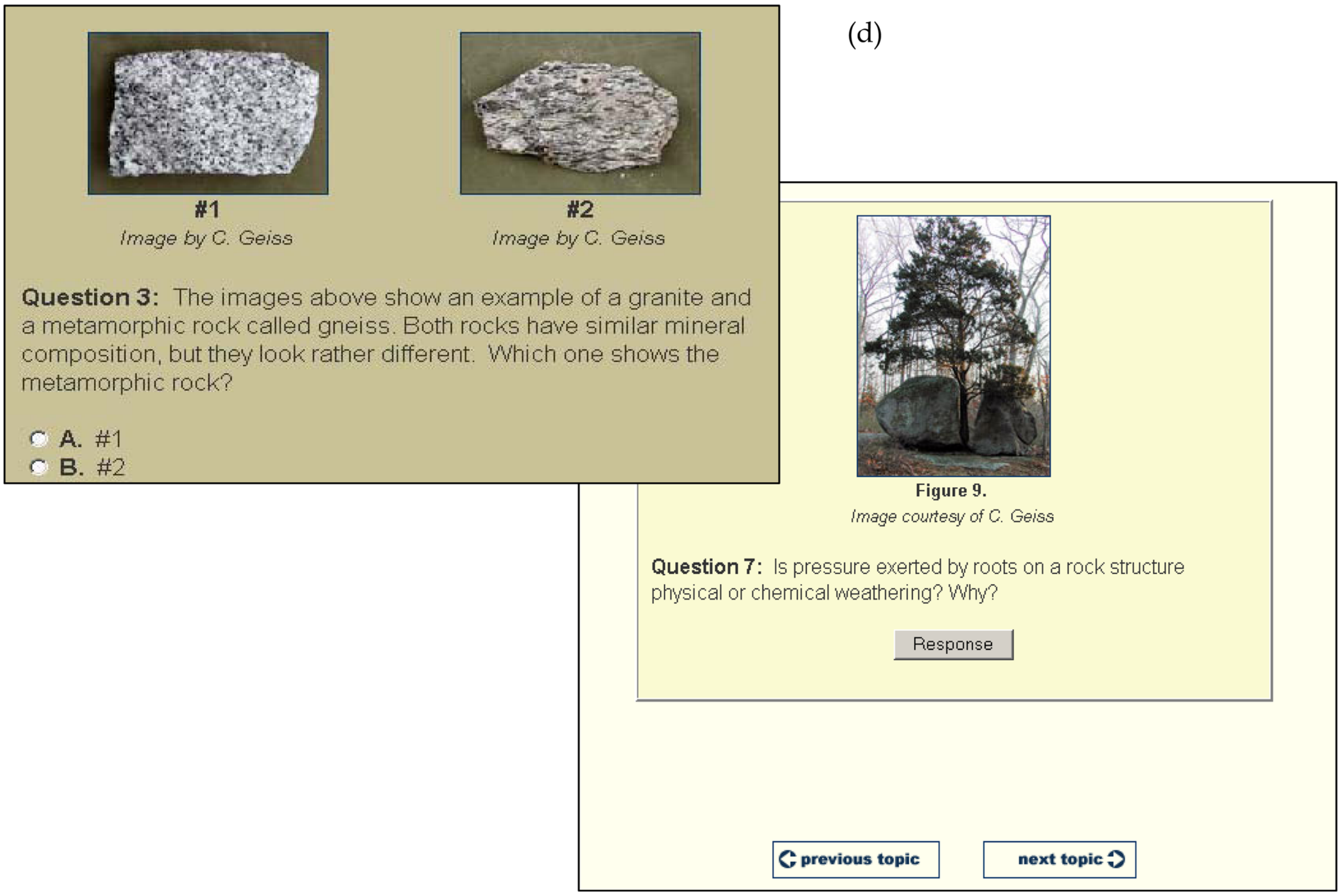

FIGURE 2: (Color online) continued

Post-Lesson User Survey

Students completed a 22-question survey covering lesson-users' experience for each application lesson (Quia, 1998). The questions included aspects of lesson navigation, principle lessons layout and quality, quality of embedded questions, and usefulness of images and animations. A Likert scale of 1 to 5 was used in the survey, where 1 was strongly agree or excellent and 5 was strongly disagree or poor.

Item Analysis

An item analysis is one that examines the response of the student to individual test items (correlation, difficulty level, etc.) and also evaluates the reliability or internal consistency of the test (UCLA Academic Technology Services, 2009). Item analysis was performed for both the pre- and post-test.

STATISTICAL ANALYSES

Differences between pre- and post-test scores among the learning styles were compared using analysis of variance (ANOVA), implemented in SAS version 9.2 (Statistical Analysis System, 2008). An analysis of covariance (ANCOVA) using pretest as the covariate was done to test differences in post-test gains among students of different learning styles, majors, and class-standing. Because of the number of unique majors in the course, majors were pooled into five categories: agriculture, environmental science/natural resources, horticulture, professional golf management, and other. Least significant differences (LSD) were declared significant at the 0.10 probability level.

RESULTS

Informal Evaluation Feedbacks and Revisions

The informal evaluation process in the fall 2005 and spring 2006 resulted in several revisions of lessons. Students thought that the lessons were about the right length and valued the charts, graphs, and pictures as the best resources in helping them learn the concepts and answer questions. Students also used the objective type questions embedded in each lesson as a learning tool and to prepare for the post-test. The bolded words with a link were also helpful. However, students thought that the case study scenarios were too simple.

Some technical difficulty with the links discouraged students from using them for fear of being closed out of the lesson prematurely. The navigation from lesson to lesson was confusing to some students and the thinking questions in the principles were too "time-consuming." From students' suggestions, feedbacks were provided to lesson authors for all questions posed within the application lessons. A video feature explaining lesson feature and navigation was also added as a link opening in a new window. In addition, links to animations and video clips within lesson were made more obvious.

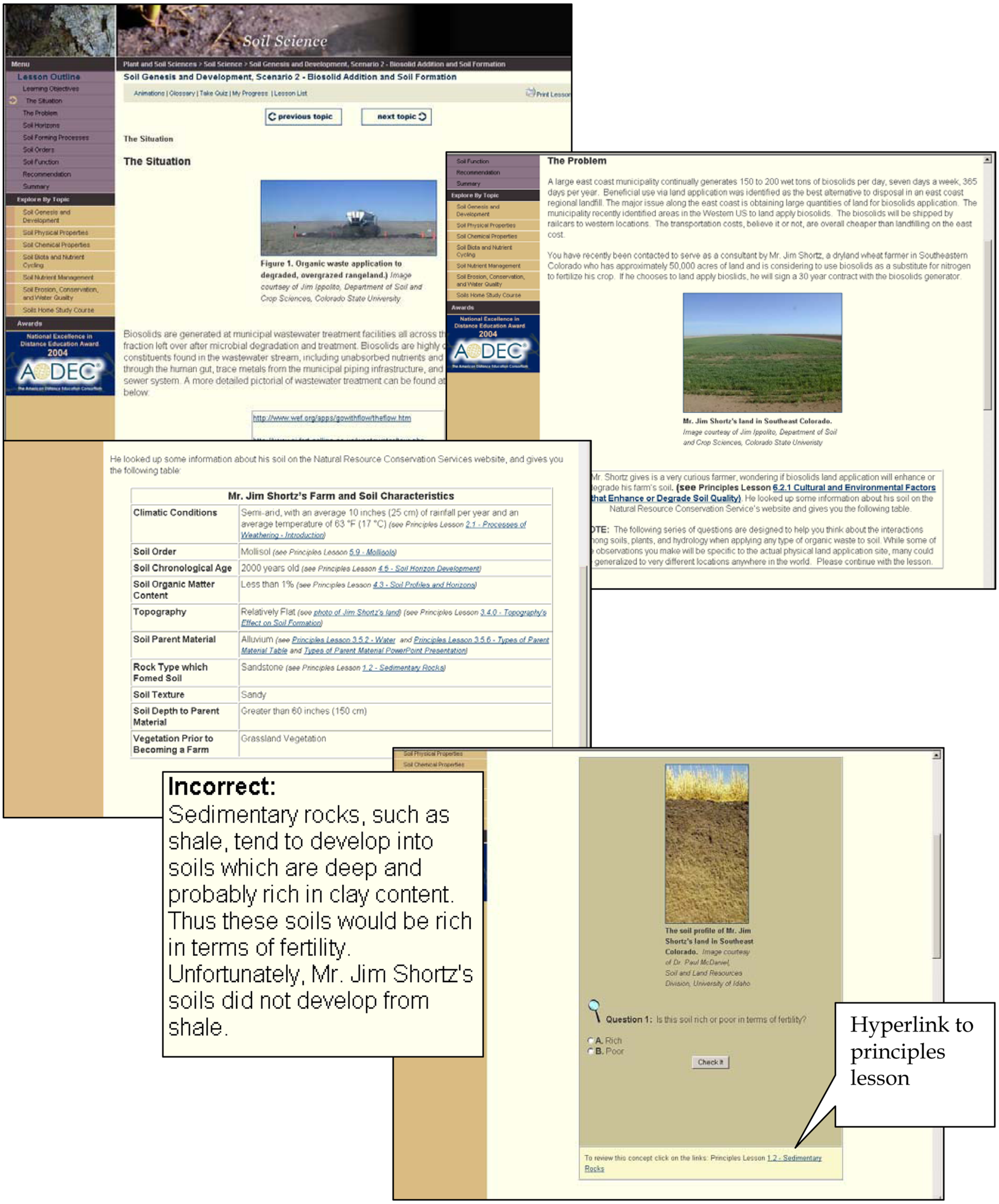

FIGURE 3: (Color online) Examples of an application lesson set-up in the Soil Genesis and Development application lesson. To view and/or use the lessons please visit http://passel.unl.edu/pages/ and click on the "Soil Science" then click on "Soil Genesis and Development."

TABLE II: Timeline and steps in the development of the soil genesis and development E-lessons at the University of Nebraska-Lincoln.

Period	Activities
1/2005-3/2005	• Draft lesson goals, objectives, and outlines developed

4/2005-6/2005	• Draft lessons developed
	• First retreat of PIs and collaborators at UNL
	  • Goals and objectives refined
	  • Assets (animations, interactivity) identified
	  • Review draft lessons and instructional design
	  • Refine plans on assessment and evaluation

6/2005-8/2005	• Principles lessons developed • Principles lessons uploaded on the Plant and Soil Sciences E-Library

8/2005-10/2005	• First forward feedbacks/informal assessment and evaluation at UNL (N = 26)
	  • One case study completed by students
	  • Descriptive survey completed by students
	  • A round table discussion with students

10/2005-3/2006	• Case studies, lesson navigation, and instructional design revised by authors

3/2006-4/2006	• Second forward feedbacks-informal assessment and evaluation conducted (N = 71 at UNL; N = 51 at CSU; N = 9 at OSU)
	  • Three case studies completed by students
	  • Descriptive survey completed by students
	  • A round table discussion with students

8/2006	• Second retreat of PIs and collaborators at UNL
	  • Refine application lessons
	  • Prepare strategies for the formal assessment
	  • First formal implementation made at UNL Soil Resources 153 Course (N = 97)

1/2007-8/2009	• Principles lessons peer reviewed and published by Journal of Natural Resources and Life Science Education. *http://www.jnrlse.org/view/2009/web-lessons-2009.pdf* • Lessons continue to be used at UNL and OSU (>140 students/yr)

Test Analysis

Both the pre- and post-test had good internal consistency with reliability of 0.92 for the pretest and 0.79 for the post-test. On average, 49% of students answered Bloom's lower level (knowledge, comprehension) pretest questions correctly. This increased to 74% answering correctly for the post-test. On average, 40% of students answered Bloom's higher level pretest questions correctly. This increased to 58% answering correctly for the post-test. The test reliability, item analysis, and Bloom categorized items indicated large knowledge gains made after students completed the lessons.

Test Comparison

Average pretest score out of 50 points was 20.9. Student pretest to post-test performance improved by 69% (Table 4). Postbaccalaureate students (N = 5) outperformed undergraduate students on the pretest (P = 0.0330); however, performance was similar among all undergraduate class-standing with the most gain made by sophomores (ANOVA P = 0.9790; ANCOVA P = 0.7495). Pretest performance was similar among majors (P = 0.5972). The professional golf management (PGM) majors at UNL (N = 12) made the highest average score and most gain (17 points) from pre- to post-test. Using pretest as a covariate, the post-test score of students majoring in PGM was higher than that of other majors (P = 0.0171). The least average gain (9 pts) was made by Horticulture majors (N = 18). There were no differences in either pre- or post-test between gender (20% female, 80% male) and no correlation between post-test score and student survey responses, class-standing, learning style, or gender (data not presented).

The normalized gain {[(post-test score − pretest score)/(50 − pretest score)] * 100} in test score indicated

TABLE III: Strategies, sample size, assessment tools used for implementation of the soil genesis and development E-lessons at the University of Nebraska-Lincoln.

Activities	Description
Semester	Fall 2006
Course name	Soil resources 153
N	97
50 Question online pretest	In-class; 1 h
Three E-application lessons	In-class; 2 h
50 Question online post-test	In-class; 1 h
Descriptive survey	In-class; 1 h
Learning style inventory	In-class; 1 h

that the least gain was made by LSI diverger group, although the increase from pre- to post-test was still significant for this LSI group (Table 5). This is consistent with Cox (2008), in his study to assess learning styles and student attitudes toward the use of the computer, who also found that the "Diverging" learning style had the least positive attitude toward the use of technology, although the difference from other learning style groups was not significant. Hu *et al.* (2007) found that English language learners who were abstract thinkers (associated with Kolb's convergers and assimilators) benefited more from instructional technology than did concrete thinkers (associated with Kolb's divergers and accommodators), although the differences were not statistically significant. In this study, there were significant differences in post-test among learning styles at low pretest scores (pretest = 15) with the largest difference of 10.76 between accommodator and diverger (ANCOVA P = 0.0018). However, the differences in post-test among learning styles were not significant at middle (pretest = 20) and high (pretest = 25) scores. Hu *et al.* (2007) note that learning style interacts with delivery medium to produce different student outcomes.

Survey Responses

Students evaluated the effectiveness of the lessons on their ability to evaluate the effects of biosolids additions on soil profile, horizons, etc. at an average of 2.20 for application lesson dealing with Biosolids Application and Soil Formation (Table 6) and an average of 2.71 for the other two application lessons (data not presented). Participants also indicated that the layout and navigation to principles lessons and ability to return to applications lessons were

TABLE IV: Pretest and post-test scores by major and class-standing as assessment for the soil genesis and development E-lessons at the University of Nebraska-Lincoln

	N	Pretest	Post-test
All	93	20.9	35.3
Agriculture	36	23.8	36.7
Environmental sciences/ natural resources	17	21.8	34.7
Horticulture	18	23.8	32.8
PGM	12	21.5	38.7
Other[1]	13	22.5	35.1
P-value		*0.5972*	*0.0522*
Freshman	26	21.6	34.8
Sophomore	23	19.2	35.7
Junior	26	20.7	35.3
Senior	19	21.7	35.7
Postgraduate	3	27.7	34.3
P-value		*0.0330*	*0.9790*

[1]Several other majors and postgraduates having N < 3.

good (2.06-2.39). Students were aware of the availability of hyperlinked glossary terms and indicated accessing the glossary; however, they did not rate its utility highly (3.21).

CONCLUSIONS AND IMPLICATIONS

Gains in post-test scores of students who completed the soil genesis and development online lessons were 69%. The large range in post-test score gains points to the critical need for faculty to devise appropriate strategies to effectively use these online lessons. The results overall did not indicate a differences in cognitive gains among learning style. Although the design of the curriculum did not include simulation, the team of instructors designed the lessons and conducted several forward feedbacks (informal implementation) to facilitate lessons aspects and design for diverse learning style. Instructors at OSU and CSU have used these lessons during the study period as supplemental resources and as homework assignment with some degree of success. This, however, demonstrates that while the technology allows creation of digital lessons

TABLE V: Pretest and post-test scores and gains among learning styles obtained from assessment of the soil genesis and development E-lessons at the University of Nebraska-Lincoln.

Test groups	N	Pretest score	Post-test score	Gain[1]	P-value
Diverger	11	21.4	32.4	38%	0.0004
Accommodator	21	21.0	36.9	55%	0.0001
Converger	36	20.7	35.2	48%	0.0001
Assimilator	22	20.9	36.1	53%	0.0001
Unknown	3	22.3	31.0	31%	-
P-value		*0.99*	*0.07*	*0.22*	

[1]Normalized gain: (post-test score – pretest score)/(50 – pretest score) * 100.

TABLE VI: Survey responses of students at the University of Nebraska-Lincoln, completed after the soil genesis and development E-lesson activities. Scale: 1 = strongly agree or excellent; 5 = strongly disagree or poor.

Survey questions	N	Mean	Std. error
Application Scenario-Biosolid Addition and Soil Formation was a case study designed to demonstrate where, geographically, soil addition of municipal organic wastes occurs and how this addition affects soil profile development.	95	1.09	0.030
As a result of this lesson, how would you assess your ability to describe where geographically soil addition of municipal organic wastes occurs and how this addition affects soil profile development and the use of soils as a sustainable resource?	95	2.66	0.097
I carefully read the list of Goals and Objectives located at the beginning of Application Scenario-Biosolid Addition and Soil Formation.	95	2.51	0.088
The Goal and Objectives located at the beginning of the application scenario "Biosolid Addition and Soil Formation" were clearly stated and easy to understand.	95	2.00	0.092
The questions asked in the Biosolid Addition and Soil Formation scenario were well written and easy to understand.	95	2.29	0.087
The feedback that was given from the questions in the Biosolid Addition and Soil Formation application scenario was helpful.	94	2.31	0.098
The layout of the Biosolid Addition and Soil Formation application scenario was easy to follow.	95	1.94	0.112
The glossary was useful in helping me learn.	91	3.21	0.120
Did you access the glossary at any time during the lesson?	94	1.84	0.038
Were you even aware that there was a glossary available within the lesson?	94	1.72	0.046
Principle lessons were easy to navigate…	93	2.18	0.113
Principle lessons were clearly stated…	93	2.06	0.098
Principle lessons supported the application scenario…	93	2.20	0.089
Navigation to the principle lessons and back to the scenario was easy…	93	2.29	0.116
Principle lessons contributed to my learning…	93	2.25	0.103
Principle lesson material helped answer questions within the scenario…	93	2.23	0.096
Principle lessons helped answer questions within the scenario quiz…	93	2.39	0.098
I like how the principle lessons supported the application scenario…	93	2.26	0.101
The animations were useful in learning the material…	92	2.35	0.108

with graphics, animations, simulations, video, pedagogical sound use or strategies for classroom remains to be critical.

Flexible use of the lessons is one of their strongest attributes. The lessons can be used by both teachers and students in various ways: nonguided learning, or as primary or supplementary references in soil science and other earth science courses. The lessons may be especially useful for teachers who do not have extensive training in the area of soil science yet cover the subject as part of a basic earth science course. For field based courses, for example, all of the principles lessons or portions of the principles lessons can be used as preactivity reading resources or supporting resources. Teachers can also modify the case study or create new case studies and use the principles lessons to support problem solving. Animations can be used as part of the lesson or alone to demonstrate specific concepts teachers may want to emphasize. Questions embedded within the principles lessons can be used as discussion thread for in-class activity and/or as homework assignment to reinforce reading.

Five principles lessons have been peer reviewed and published by an educational journal for use by the public and/or academic institutions. Lessons have continued to be primary and/or supplemental resources for multiple courses serving greater than 140 students each year at both UNL and OSU. The lessons are hosted at the Plant and Soil Sciences E-Library (http://passel.unl.edu/pages), a digital library of 120 lessons and 116 animations that on the average receives 400,000 unique visits annually. As part of the long-term goal to strengthen STEM education and through funds provided by the National Science Foundation, the digital Plant and Soil Sciences library is being redesigned to create an online learning community environment, where users including soil science lessons authors will team up to repackage the learning objects to more efficiently meet their specific academic learning needs and/or outcomes.

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