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Laboratory Earth: A Model of Online K-12 Teacher Coursework

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ABSTRACT

Laboratory Earth, a series of three NASA-Sponsored, on-line graduate courses for K-8 teachers, was designed to meet a variety of learning styles and appeal to teachers' motivation to learn the content and improve their teaching. This is especially important to teachers as they seek to demonstrate "highly qualified" status to meet No Child Left Behind standards. These graduate-level courses consist of four modules of two to four lessons each. Pre- and post-course surveys indicated significant increases in teachers' (n=51) content knowledge, science teaching efficacy beliefs (STEBI-A), sense of community within the course (LEO) and science teaching enjoyment (STES). Qualitative data indicated teachers valued the cohort system, content aligned to teaching needs, and the instructor's response to requested feedback. Results indicated that online courses can provide valuable professional development opportunities for K-12 science teachers to deepen their knowledge, sharpen their skills, and maintain their knowledge of science developments. Because teachers play an important role in the development of their student's attitudes towards science, it is extremely important that science and education communities collaborate to create courses that use contemporary pedagogy to address the content-knowledge needs of teachers required by National Science Standards criteria.

INTRODUCTION

Through the Nebraska Earth Systems Education Network (Gosselin and others, 1995, 1996, 1999, 2002), we have worked to design professional development opportunities for pre- and in-service K-12 educators related to Earth system science that are learner-, knowledge-, assessment-, and community-centered as advocated by Bransford et al. (2000). Over the past few years, we have transitioned much of our professional development activities from traditional, face-to-face environments to the on-line environment. A recent report on online learning (DOE, 2009) indicates that the on-line environment is an effective educational option across different content and learner types for both undergraduate and graduate students as well as professionals in a wide range of academic and professional disciplines.

Not only are online courses effective, they are an attractive professional development option for educators, who are place-based or have travel and time limitations. These limitations are especially prevalent in much of the Great Plains region and the western United States where many rural teachers live as far as 200 miles from an institution of higher education. In an open-ended response survey item, 211 respondents (29%) spontaneously described that they desired online professional development. As this was unprompted specifically by the survey, the authors argued that the actual fraction of teachers who might take advantage of online professional development is likely much higher (Slater and others, 2009). To meet these needs, we initiated the *Laboratory Earth* on-line, distance-delivered professional development series to improve K-12 educator's knowledge, understanding of content connections, and ability to teach science in the context of the Earth as a system.

One of the major goals of Laboratory Earth is to help improve teacher's content knowledge through the use of effective science teaching methods, which Cox and Carpenter (1991) aggressively argued is required to improve science teachers' skills. The purpose of this paper is two-fold. First, we present the course design and assessment approach used for the courses in the Laboratory Earth series as a potential model for other instructors. Second, we specifically focus on data collected to address the following questions from one of the Laboratory Earth courses, Earth's Natural Resource Systems (or Lab Earth 2) as measures of successful online K-12 teacher professional development:

1. Does the Lab Earth approach achieve the cognitive goal of increasing teachers' knowledge and understanding of Earth science content? and
2. Does the Lab Earth approach improve teacher's self efficacy and beliefs about their ability and confidence to teach science in the context of the Earth as a system?

COURSE DESIGN

The Laboratory Earth course series currently consists of three, graduate-level, distance-delivered, online courses (Table 1). All three courses are designed to use a learner-, knowledge-, assessment-, and community-centered approach that is consistent with research on learning (Bransford and others, 2000; Manduca, 2007). The content for Laboratory Earth is organized according to the National Science Standards (NRC, 1996) criteria for what "must" be taught and what a person should know by the completion of high school. All the courses share the common vision and what we refer to as the I²A philosophy, in which we use an *Inquiry* approach, emphasize the *Integration* of scientific disciplines, and the *Application* of content to the world outside the classroom. Table 6 gives examples of two of the content mastery

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prompts that depict the I²A philosophy. In both of these prompts, students use what they learned through the inquiry-based module activities to integrate and apply the information to a new situation. Laboratory Earth course content is also presented in the context of the Earth as a system following the overarching theme that "Everything is Connected to Everything Else." Our course design provides a framework to help teachers understand the concept of systems and connect the concepts of energy and matter to the scientific phenomena they experience daily.

Participants use the BlackBoard™ course management system via the Internet to access the course modules and to interact with other participant teachers and course instructors. To be sure that all participants have access to the software required, we established a download center where participants could access Adobe, Microsoft, and other products they might need. Participants' need to have Internet access and basic technology skills; such as familiarity with a Web browser, e-mail, word processing, and Internet searching.

With regard to online learning, these courses were not asynchronous, independent study experiences. Rather, participants reflected on their learning through online

TABLE 1. SUMMARY OF MODULES IN LABORATORY EARTH COURSES[1]

	Lab Earth 1: Earth and its Systems	Lab Earth 2: Earth's Natural Resource Systems	Lab Earth 3: Earth's Changing Systems
Module 1	**Earth's Spheres: Linking Science, Systems, and Society**	**Natural Resources and Civilization**	**From the Universe to the Earth and Everything in Between**
	In addition to the opportunity to interact with your new colleagues, we will introduce you to the general characteristics of the four major subsystems, or spheres, of the Earth system.	Investigate what are natural resources and how they are part of a larger system. The systems approach recognizes that humans are dependent on, impact the distribution of, and influence natural resource systems.	Investigate how the Earth has changed through time and space using a systems approach to understanding our Earth and that everything is connected to everything else (ECEE).
Module 2	**Earth's Matter, and their Interaction**	**Rock and Mineral Resource Systems**	**Changes through Geologic Time**
	Topics include mass, density, weight, energy and heat transfer, convection, radiation, and the interaction between energy and matter. Focus on providing examples of where these concepts and principles are important in the Earth system.	Explore basic concepts and principles related to rocks and minerals as natural resources for many of the materials that we use daily. This module focuses on the natural resources that we derive from the geosphere.	Focus on the application of basic concepts and principles to reading the rock record.
Module 3	**Earth in Space**	**Soil Resource Systems**	**Cycling in the Earth System**
	Explore how things move in the sky, the nature of our solar system's planets, some of the major misconceptions about astronomy, and collect and analyze astronomical data.	Investigate the properties of soil and their relationship to the soil forming factors. Understand the importance of soil as a natural resource.	Examine the important role that cycles play in the Earth Systems resulting from an exchange of mass and energy between Earth's four major spheres and related subsystems.
Module 4	**Weather and Climate**	**Water Resource Systems**	**The Environment: Yours, Mine, and Ours**
	Examine the characteristics of the atmosphere and processes that influence the movement and transfer of energy and matter, specifically water, in the Earth's atmosphere. Designed to improve understanding of basic concepts related to weather and climate.	Explore the processes by which water moves through the water cycle. Use the hydrologic equation to understand the importance and limitation of water resources as well as strategies for sustainable use.	Investigate a range of challenges that humans have created as they have interacted with the local and global environment.

[1]**The full syllabi of all the Laboratory Earth courses can be viewed at nesen.unl.edu**

discussion and networking with each other. This type of feedback and interaction promotes self-regulation as students are able to see their own progress toward their learning goals and where they still need to add understanding. The use of the discussion board allows students to evaluate their own understanding compared to their peers. The discussion board also allows students to pose questions in a safe environment. Reflection and self-regulation are important to metacognition and are recognized as major factors in the effective use of on-line learning environments (Schwerin and others, 2006, Waterhouse, 2005, Keller and Slater, 2003b). Laboratory Earth pedagogy encourages participants' intrinsic motivation to learn the course material rather than look to external motivators (such as grades and points) that can detract from authentic, personal learning.

As we have developed and implemented the Lab Earth courses, we have become increasingly committed to taking advantage of the strengths of online delivery that contribute to content knowledge enhancement and promote communication and collaboration (Waterhouse, 2005; Keller and Slater, 2003a; 2003b; Prather and Slater, 2002). The design of the Lab Earth program focuses on a context-based approach in which context and application of science are used as the starting point for the development of scientific ideas (Bennett, Lubben and Hogarth, 2006). For example, in the water resource module, students begin the module through the assessment of their own local water use using a water diary. These data are then compared to other student usage patterns. This is followed by an investigation of where their water resources originate. In the rock and mineral resources module, each person records all the materials they use throughout the day from toothpaste to computers. This is followed by an investigation of the ingredients of individual materials in terms of the source of the ingredients and from where they are mined.

For each course, content materials are organized into four modules that include two to four lessons and multiple activities (Table 2). The Lab Earth courses use a continuum of strategies to meet multiple learning styles (Gardner, 1992; Wang, Wang, Wang, and Huang, 2006) that help participants successfully meet the learning outcomes. This approach recognizes that participants have multiple learning styles and diverse ways to take-in and give-out information. These strategies include direct instruction in the form of voiced-over PowerPoint presentations, group discussions and projects, field-based activities, kitchen labs, simulated experiments, individual reading assignments, online writing responses to open-ended questions, and inquiry-based activities that result in students constructing new cognitive understanding. Visit the NESEN website (nesen.unl.edu) for access to examples of specific methodologies and activities. Assignment deadlines encourage participants to progress synchronously through the course, but also allow individuals to work asynchronously as their schedules allow.

In the Lab Earth courses, we want participants to focus on learning, not grades. Unfortunately, grades have to be issued. Past experiences with teachers taught us that they are often quite anxious about the assignment of course grades. To reduce anxiety, our grading strategy has evolved to a system that use, what we call, content mastery assignments (CMAs) to document participant's mastery of course content. To help everyone acquire the required concept knowledge and understanding, we use an iterative grading system that monitors active participation and on-time, quality completion of assignments and allows participants to revisit and resubmit their assignments and CMAs until they are satisfied with their performance level (i.e., grade).

Although we do not explicitly teach metacognitive skills (planning, monitoring, and evaluating), we provide an opportunity for students to take control, become more confident, independent learners, and employ higher-order skills through the CMAs, Through CMAs, students indirectly use the basic elements of metacognition to achieve the cognitive goal of learning Earth science concepts. According to Livingston (1997), cognitive and metacognitive strategies are closely intertwined and dependent upon each other. CMAs promote the use of learner-based reflection that available research indicates are effective and improve the learning outcomes of students when they pursue learning as individuals in an online environment (Bixler, 2008; Chang, 2007; Chung, Chung, and Severance, 1999; Crippen and Earl, 2007; DOE, 2009, Nelson, 2007; Saito and Miwa, 2007; Shen, Lee, and Tsai, 2007).

TABLE 2. EXAMPLE FROM LAB EARTH 2 OF MODULE STRUCTURE INCLUDING LESSONS AND ACTIVITIES[1]

Module 1. Introduction - Natural Resources: Linking Science, Society and Systems

Lesson 1: Welcome to Earth's Natural Resource Systems

1. Activity 1 – 1 Introduce Yourself
2. Activity 1 – 2 Expectations: Yours, Mine and Ours
3. Activity 1 – 3 What is Your Learning Style Preference?
4. Activity 1 – 4 Discuss the Implications of Learning Styles

Lesson 2: Natural Resources and Civilization

1. Narrated PowerPoint: Natural Resources and Civilization
2. Activity 1 – 5 What Materials Do I Use Each Day?
3. Websites for Activity 1.6
4. Activity 1 – 6 Natural Resources: Developing a common language

Lesson 3: Earth's Spherical Systems

1. Narrated PowerPoint – Earth's Spherical Systems I

Activity 1 – 7 Website Research

Narrated PowerPoint -- Earth's Spherical Systems II

Reading 1 – "Why an Earth Systems Approach?"

Reading 2 – "SpaceShip Earth"

Reading 3 – "Earth's Spheres"

Activity 1 – 8 ECEE Discussion

Content Mastery Activity

[1]The full syllabus of Laboratory Earth: Earth's Natural Resource Systems can be viewed at nesen.unl.edu

TABLE 3. EXPECTED LEARNING OUTCOMES FOR LABORATORY EARTH 2, EARTH'S NATURAL RESOURCE SYSTEMS

1. Describe and explain the basic interactions between the hydrosphere, geosphere, atmosphere, and biosphere.
2. Acknowledge and work with individuals who have different perspectives about natural resources.
3. Develop conceptual models for a variety of Earth's natural resource systems that qualitatively include mass and energy exchange.
4. Demonstrate an understanding of the properties, occurrence and distribution of water and soils.
5. Demonstrate an understanding of rocks and minerals as fundamental Earth resources.
6. Explain the basic chemical and physical processes that control the distribution of Earth's natural resources.
7. Explain the social and economic issues that control the availability of mineral and energy resources.
8. Collect basic data required for the analysis of natural resource systems.
9. Analyze and interpret graphs.
10. Understand the dependence of all people on both renewable and non-renewable resources.
11. Describe the impact of humans as stewards, managers and components of natural resources systems.
12. Demonstrate an understanding about natural resources on other planetary bodies.

RESEARCH DESIGN

We used an action research approach (Sagor, 1993; Dick 2000) in which we collected data throughout the course that informed our instructional approach and provided the basis for making changes as the courses evolved. A mixed-methods research design (Creswell, 2003) simultaneously collected quantitative and qualitative data. Qualitative data and participants' response to feedback prompts, helped illuminate the quantitative results. Regular meetings (throughout the course duration) among the course instructors (science professor, science education professor, and doctoral students in science education) allowed for reflective and formative deliberation on course content and methods.

To address our first question, "Does the Lab Earth approach achieve the cognitive goal of increasing teachers' knowledge and understanding of Earth science content?", we used content questions and content mastery assignments to assess the extent to which participant teachers' understand and apply Earth science concepts as defined by the course's learning objectives. Table 3 provides the learning objectives for Lab Earth 2. Question two, "Does the Lab Earth approach improve teacher's self efficacy and beliefs about their ability and confidence to teach science in the context of the Earth as a system?", was addressed using the *Science Teaching Efficacy Beliefs Instrument* (STEBI-A) (Riggs and Enochs, 1990). The Beliefs About Science (BAS) scale was used to assess the degree to which the participant teachers enjoyed teaching science. We also assessed the degree to which participant teachers felt a sense of belonging and community with the Laboratory Earth Orientation (LEO) scale. The BAS and the LEO scales were created by Lab Earth instructors.

PARTICIPANT TEACHERS

Fifty-one teachers were enrolled in the *Lab Earth 2* course as part of four cohorts. This group of teachers included 31 teachers in Cohorts 1 and 2 (8-week course format) and 19 teachers in Cohorts 3 and 4 (16-week course format). The course materials were designed for adult learners that included K-8 and some high school teachers. Pre-service teachers were also allowed to

TABLE 4. LAB EARTH 2 PARTICIPANT TEACHER DEMOGRAPHICS

Term	N	Gender	School Teaching Level	Weekly Hours of Science Teaching		Total Years of Experience	
				Median	Avg.	Median	Avg.
Spring 2007	19	17 Female 2 Male	5 Elementary 8 Middle 6 High	15	18	10	12
Summer 2007	12	8 Female 4 Male	5 Middle 5 High 2 Preservice	10	15	2	7
Fall 2007	7	3 Female 3 Male	3 High 4 Preservice	0	14	2.5	3
Spring 2008	13	10 Female 3Male	4 Middle 8 High 1 Preservice	25	22	6	8

TABLE 5. EXAMPLES OF CONTENT QUESTIONS FROM LAB EARTH 2

What is soil? How do the soil forming factors influence how rocks become soil? How do the soil forming factors influence the landscape?
How are groundwater and surface water related? How do human activities potentially influence this relationship and how do we know?

participate in the course. Participant demographics are provided in Table 4.

RESEARCH TOOLS AND DATA COLLECTION

Pre- and post-course surveys measured teachers' content knowledge, science teaching efficacy beliefs, science teaching enjoyment, and course cohesion. Feedback prompts elicited participant teachers' evaluative remarks at the end of each module and at the end of the course. The following descriptions define the instruments used in the assessment of these courses.

Content knowledge assessment

Content Questions and Content Mastery Assignments determined the extent to which the teachers learned Lab Earth 2 content as defined by the learning objectives (Table 3). The course instructor developed content questions based on the Earth Science Content guidelines for grades K-12 (American Geological Institute, 1991). Twelve, single-to-multiple-part questions were intended to measure teachers' content knowledge. Table 5 provides examples to illustrate the depth and breadth of knowledge solicited by the content questions.

Evaluation of the content questions provided pre- and post-course measures of participant teachers' content knowledge, integration and organization of content and use of resources. A key component of this content assessment was to ascertain the levels of content understanding as delineated in Bloom's Taxonomy (Bloom, 1994). An assessment rubric generated teachers' scores ranging from zero to two for each of the 12 questions . A score of zero indicated an incorrect response or no response provided. A score of one indicated the response reflected factual knowledge (lower cognitive level response such as a simple definition of the concept); and a score of two indicated the response primarily reflected both knowledge and comprehension (higher level of cognition such as applying the knowledge to a new situation, circumstance, or context).

In Cohorts 1 and 2, content questions were used exclusively to assess content knowledge. Participants were asked to revisit the questions after each module. Feedback from participants, an examination of the work quality for individual activities and modules, and the nature and extent of responses on the course discussion board indicated that participants and the instructional team needed an additional tool to assess the extent to which learning was taking place related to the specific learning objectives for individual modules. For cohorts 3 and 4, Content Mastery Assignments were developed to assess content learning within each module as defined by the learning objectives for the module. The CMAs are provided at the beginning of each module. In theory, this provides the students opportunity to use their metacognitive skills to plan their approaches to complete the task, monitor their learning in the context of their plan as the module progresses, and evaluate their level of understanding after the completion of the task based on instructor feedback. CMAs consist of a scenario that presents a problem or situation and a rubric that outlines the general expectations for their response (see Table 6). Students choose and plan their own presentation approach and format to synthesize their knowledge and understanding of a module's material and to address the scenario. Presentation formats included traditional essays, PowerPoint presentations, newsletters, newspaper articles, concept maps, poetry, photo essays, and movies. If the materials presented do not address the elements of the rubric, the student is asked to reevaluate, revisit and resubmit the activity. The student can resubmit as many times as they want. The goal is for the student to acquire the required concept knowledge and understanding.

Science teaching efficacy beliefs and enjoyment of science teaching

The Science Teaching Efficacy Beliefs Instrument (STEBI-A) (Riggs and Enochs, 1990) assessed teachers' beliefs toward science teaching and learning. The STEBI-A includes 25 items measured on a five point Likert scale ranging from strongly agree to strongly disagree. Scoring

TABLE 6. AN EXAMPLE OF A CONTENT MASTERY ACTIVITY PROMPT FOR LAB EARTH 2

Module 1. The history of human exploration of the Earth has been driven by the quest for wealth and prosperity derived from the elements obtained from rocks and minerals. We use resources from rocks and minerals every day, but these resources are nonrenewable. In the context of your understanding of rocks and minerals as resources, address the following: 1. How has the quest for strategic minerals influenced human history? Provide, at least, one specific example (You cannot use salt!). Be sure to explain what a strategic mineral or material is. 2. What economic factors illustrated in Cookie Mining do you think will have the greatest influence on the future pursuit of rock and mineral resources? It is very important to provide justification for your answer.
Module 2. Every rock tells a story. Rocks and minerals also record the history of the Earth. Our challenge is to learn how to read the clues that rocks provide. 1. Provide an explanation of how the characteristics of igneous, metamorphic, and sedimentary rocks can be used to tell the history of an area. Provide specific examples for each rock type. 2. What is the theory of plate tectonics? How does this theory help explain the relationships between the three major rock types (igneous, metamorphic, and sedimentary) and the rock cycle.

TABLE 7. THE BELIEFS ABOUT SCIENCE (BAS) SCALE (TABLE 7)[1]

1. I enjoy teaching science.
2. The time that I spend teaching science is time well spent.
3. I always look forward to teaching my next science lesson.
4. I like teaching science as much as any other subject.

[1]Participants responded using a five point Likert format (1 = low enjoyment and 5 = high enjoyment.) See text for discussion.

was accomplished by assigning a score of 5 to the positively phrased items (*strongly agree*) and a 1 to the negatively worded items (*strongly disagree*). STEBI-A determines teacher beliefs according to two subscales: Science Teaching Outcome Expectancies (STOE) and Personal Science Teaching Efficacy beliefs (PSTE). The Beliefs About Science (BAS) scale (Table 7) was written by the course instructor to assess the degree to which the participant teachers enjoyed teaching science. The scale included 4 items that used a five point Likert format (1 = low enjoyment and 5 = high enjoyment.)

Course cohesion

The Laboratory Earth Orientation (LEO) scale (Table 8) was developed by the course instructor to assess the degree to which participant teachers felt a sense of belonging and community within the Laboratory Earth Sciences course. The scale included 6 items that use a five point Likert format (1 = low cohesion and 5 = high cohesion).

Formative feedback prompts

Feedback prompts posted to BlackBoard (after the completion of each module) helped to generate insights into the ways in which teachers' measured the benefits of their Laboratory Earth course experiences. These prompts provided formative assessment throughout the course development over four semesters: What is going well? What could have gone better? What suggestions do you have to improve the module? Thus, teachers were encouraged to provide ongoing feedback and thoughtful suggestions for ongoing course improvement. We took this feedback very seriously and it was critical to the development of CMAs.

Scale reliability

Before examining survey results, it was important to

TABLE 9. INTERNAL CONSISTENCY OF SURVEY INSTRUMENTS[1]

Scale	Time	α
STEBI-A (PSTE)	Pre	.93
	Post	.85
STEBI-A (STOE)	Pre	.79
	Post	.75
Laboratory Earth Orientation (LEO)	Pre	.85
	Post	.90
Beliefs About Science (BAS)	Pre	.62
	Post	.68

[1]as determined by Chronbach's Alpha

TABLE 8. LABORATORY EARTH ORIENTATION (LEO) SAMPLE ITEMS

1. I feel that I belong in this online course (Laboratory Earth)
2. I can talk/email to a course instructor or classmate if I have a problem with the course
3. My classmates and instructors think carefully about what I have to say
4. The course instructors and classmates respect my knowledge and experience
5. The course instructors and my classmates care about my learning
6. I feel welcome in this course.

[1]Participants used a five point Likert format (1 = low cohesion and 5 = high cohesion). See text for discussion.

verify that these were psychometrically adequate scales. Since we were not able to conduct a factor analysis on scale data to establish that each was measuring a single construct (requiring at least 250 participants), we conducted a Cronbach's alpha analysis to evaluate the internal consistency of each scale. Cronbach's alpha is a coefficient (a number between 0 and 1) that rates the reliability of an instrument. Values above 0.70 indicate the scale is reliable. Pre- and post-course survey administrations provided two estimates of alpha for each scale. Results (Table 9) indicate the reliability estimates were adequate for the STOE and PSTE subscales of STEBI-A and the LEO. Reliability estimates were not adequate for the BAS.

RESULTS

Pre-post comparisons

Scale totals were computed to be the mean item response across all items in each scale, before and after the *Lab Earth* 2 course. The significance level, alpha, (or the odds that the observed result is due to chance was), was set at a nominal level (.05) as per the conventional control for type-1 or false-positive errors. Given the standard deviations, pre- and post-scores were compared using a Wilcoxon t-test (a non-parametric test used when the population is not normally distributed) (see Table 10).

Content knowledge assessment

Participant teachers' content knowledge was measured by a series of 12 content questions. Teachers in Cohorts 1 and 2 (8-weeks) were encouraged to respond to the 12 content questions after each module (essentially they could take the test as many times as they liked). Teachers in Cohorts 3 and 4 (16-weeks) were directed to respond to the 12 content questions at the beginning and at the end of the course. In an attempt to understand possible differences in participants' overall content knowledge gain, we reviewed the highest content knowledge score of the 8-week participants (who were encouraged to take the test after each module) and the final content knowledge score for the 16-week participants. Before comparing the mean scores (with 24 being the highest possible score), we ran an analysis of variance or ANOVA to ensure the differences between the groups (Cohort 1, 2, 3, and 4) and found there were no

TABLE 10. TOTAL COMPARISON OF PRE/POST-SURVEY MEASURES WITH WILCOXON T TEST

Scale	Pre		Post		Z	Sig.
	Mean	SD	Mean	SD		
STEBI-A (STOE) n = 51	41.49	5.251	43.63	5.067	-2.583	.010*
STEBI-A (PSTE) n = 51	48.18	7.979	50.96	7.017	-2.151	.032*
Laboratory Earth Orientation	24.50	2.915	26.38	3.009	-3.551	.000*
Beliefs About Science	17.72	2.021	18.42	2.001	-2.111	.035*

significant differences between the groups [F(3) = 2.146, p = .103, α = .05]. This implied that the scores were similar and supported our decision to combine the two 8-week cohort and the two 16-week cohort scores for an independent samples t-test to determine the impact of course duration. A Levene's Test showed that the homogeneity of variances assumption was met (F = .125, p -value = .725). Thus, we can assume that the data variances are equal (see Table 11). The t-test results suggest there was a significant difference (t = -2.439, p-value = .017, α = 0.05) between the 8- week course and the 16-week course scores with the test scores on the 16-week course being significantly higher.

To learn more about the 16-week participant content knowledge increase from pre- to post- test, we conducted a Wilcoxon-T-test. There was a significant difference [Z (22) = -4.014, p < .000, α = .05] from pre-test to post-test for the 16-week group. The post-test scores were significantly higher than the pre-test scores (see Table 12). The percent of increase for these teachers (when combined and calculated) was approximately 73%.

Science teaching efficacy beliefs and enjoyment of science teaching

On the Science Teaching Outcome Expectancy (STOE) subscale of the STEBI-A, there was a significant increase [Z(50) = -2.583, p = .010, α = .05] from pre-test to post-test. The effect size (Cohen, 1988) for this increase was (d = .419),), which is considered to be medium, and indicated that the STOE subscale had practical and statistical significance. One potential limitation to the use of STEBI-A for Lab Earth teachers is that it was designed for in-service teachers and a percentage (14%) of pre-service teacher participants may not have known how to respond to questions such as, "When teaching science, I generally welcome student questions." and "If parents comment that their child is showing more interest in science at school, it is probably due to the performance of the child's teacher."

Even considering this limitation, these results imply that the *Lab Earth 2* course had a significant impact on the teachers' belief that knowledge and performance in the classroom can positively impact their students' achievement. On the Personal Science Teaching Efficacy Beliefs (PSTE subscale) subscale of the STEBI-A, there was a significant increase [Z(50) = -2.151, p = .032, α = .05] from pre-test to post-test. These results imply that the *Lab Earth 2* course had a significant impact on the teachers' personal science teaching efficacy.

On the BAS scale, there was a significant difference [Z (50) = -2.111, p = .035, α = .05] between the pre-test and post-test scores. Although the statistical reliability of BAS is suspect, the result is consistent with formative feedback prompts that *Lab Earth* 2 had a favorable impact on the participant teachers' perspective on the extent to which they enjoy science teaching.

Course cohesion

On the LEO Scale there was a significant difference [Z (49) = -3.551, p < .000, α = .05] in pre-test and post-test scores. The effect size for this increase was considered to be medium (d = .634) and indicates that the LEO had practical as well as statistical significance. This implies that the *Lab Earth 2* course had a significant impact on the participants' sense of belonging and community.

DISCUSSION

Participant teachers demonstrated significant increases on both subscales of the Science Teaching Efficacy Beliefs Instrument (STEBI-A) indicating overall increases in teachers' science teaching outcome expectancy (STOE) and personal science teaching efficacy (PSTE). Data also showed that teachers increased their sense of belonging to the Laboratory Earth course (LEO) and science teaching enjoyment (BAS). It seems that the Lab Earth 2 course successfully met our objectives. Further discussion of these results is presented according to our research questions.

Content knowledge assessment

These data presented support an affirmative response to our research question: "Does the Lab Earth approach achieve the cognitive goal of increasing teachers' knowledge and understanding of Earth science content?" These data indicate a significantly greater increase in content knowledge scores for Cohorts 3 and 4 than Cohorts 1 and 2. This increase in scores for the later cohorts might be due to a variety of factors including the use of the CMAs for assessment, length of the course, or participant demographics.

An issue that the CMAs did resolve was our concern about motivational issues related to having teachers revisit the same questions repeatedly (at the end of each module) using content questions. Importantly,

TABLE 11. HOMOGENEITY OF VARIANCES ON CONTENT KNOWLEDGE TESTS

Scale	8 Week Course		16 Week Course		T	Sig.
	Mean	SD	Mean	SD		
Content Knowledge Test	12.00	5.249	15.25	5.820	-2.439	.017*

TABLE 12. PRE- TO POST CONTENT KNOWLEDGE TEST COMPARISONS FOR 16-WEEK COURSE

Scale	Pre		Post		Z	Sig.
	Mean	SD	Mean	SD		
Content Knowledge Test	10.23	5.450	17.68	3.810	-4.014	.000*

individualized responses to the teachers' CMAs material provided important opportunities for addressing misconceptions and encouraged accurate content knowledge – not just final grades or points. Table 13 provides representative examples of our feedback. Given the possibility of 8 total points, teachers seemed satisfied with a score of 7 points and motivated to respond to feedback and re-do assignments until they achieved at least 7 points. CMA's also seemed to reduce teachers' grade anxiety by encouraging creative responses and direct learning applications (module by module). Some teachers took advantage of this assignment to create materials or invent processes they could also use in their own classrooms.

What seemed most convincing, about the real benefit of the CMAs, was the teachers' expressed realization of their own increasing confidence and ability. As one teacher explained, "I feel myself becoming more confident in the content as I am completing this course. I'm learning more than just the basics and can help my students with the application of the science."

Although CMAs are valued tools, an important task we are currently addressing is the refinement of the rubric to include more explicit references to Bloom's cognitive scale and connections to the learning objectives within each module. A review of exceptional products from the previous cohorts will be an important resource for adding more descriptive language to define these assignment expectations. It will be important to continue the Content Mastery Assignment (a constant measure) as a pre-to-post measure of improved content knowledge for the collective cohorts.

In addition to overall content knowledge improvement, teachers expressed realization of the ways in which this course connected to their personal lives. One teacher realized, "I have taken a few online courses and all of them have been 'read this, write that and post a discussion.' With this class, we were connecting the content to our daily lives - how much water you use, what kind of soil is in your backyard."

Teachers also noticed another connection - the ways in which the course activities connected to their classrooms. Teachers realized they were learning content that they could integrate directly into their own classrooms. One teacher indicated, "I'm teaching about geology at the moment and I am gathering all kinds of ideas as we progress." They viewed the course activities as a useful model and explained, "Everything is easy to take into the classroom." One participant summed-up her enthusiasm in all capital letters: "THE BEST THING IS THAT I AM GETTING SOME GREAT STUFF TO USE WITH MY OWN CLASSES."

Although we implemented a grading system that focused on mastery of course material and worked to help teachers feel comfortable about exposing their areas of need by implementing an iterative grading system, a review of teachers' comments suggests they continued to worry about how they were being evaluated. Teachers worried about "getting the assignments done and keeping up on the discussion board" and "assignments [were] listed on the syllabus but not listed in the order of due dates." Some teachers wanted more "feedback on written assignments." While responses to teachers' management issues and concerns were clearly appreciated and helped to reduce anxiety, it was clear that teachers brought a grade expectation with them to this course. So, in fact, they were learning not to focus on their grades as they progressed through the course.

Science teaching efficacy beliefs and enjoyment of science teaching

These data support an affirmative response to our second research question, "Does the Lab Earth approach improve teacher's self efficacy and beliefs about their ability and confidence to teach science in the context of the Earth as a system?" Teacher participants showed significant overall increase from pre- to post-test on the STEBI-A sub-scales of Science Teaching Outcome Expectancy (STOE) and the Personal Science Teaching Efficacy Beliefs (PSTE). Although the BAS has some issues in the context of statistical validity, the results are consistent with STEBI results that teachers' enjoyment of teaching science improved as a result of their Lab Earth experience.

TABLE 13. EXAMPLES OF FEEDBACK FROM THE INSTRUCTOR TO STUDENT ON CONTENT MASTERY ASSIGNMENTS

"I liked the format of your PowerPoint. You made good use of pictures. I would like you to re-visit and provide me with a few more details related to the factors that influence the availability of natural resources. I agree that supply and demand are critical, but both supply and demand have factors that influence them."
"Your description of the movement of groundwater was concise and informative. I would have liked to have seen you provide more discussion of sustainability and the hydrologic equation."
"Your approach is good, but it would be useful to re-visit the PowerPoints on plate tectonics and the rock cycle. Your definition of plate tectonics needs to be modified. The message I get from the slides is that pressure and temperature are the only link between the major rock groups. To link to plate tectonics, you could specify where the various rock types form."

Sense of Community

The LEO data indicated that the participants felt that they were part of a community and that this sense of community was not necessarily a function of the time that the group was together in that there were no significant differences between the 8-week and 16-week cohorts. These results are consistent with feedback from the teachers about how the online environment was useful for interaction and exchanges. Teacher participants "enjoyed exchanging ideas with other class members" and the way in which the assignments and online discussions "really get a person thinking about our resources and how we take care of them." Some teachers had difficulty navigating the online discussion format, but in general teachers appreciated these discussions as a way to share ideas with other teachers. This certainly contributed to the creation of an overall sense of community.

While teachers looked to the "creativity involved with the assignments and the encouragement to interact with each other and continue discussion about what we have worked on," they expected more discussion interactions with the course instructor. As one teacher explained, "In general I would love to hear from [the instructor] more. I realize he is busy . . . but more tidbits of knowledge on the discussion board would have been greatly appreciated." The teachers provided some additional ideas about how they might share more course-related resources via the discussion board. One teacher thought about exchanging "great examples of student work." Another teacher suggested, "Maybe [you could add] a special thread to the discussion board where we share lesson plan ideas, write-ups, useful websites - a thread for resources." So, in all, these teachers looked to the online environment as a way to connect with the course instructor and peer Lab Earth 2 teachers.

Rapid response to formative evaluation

We encouraged and responded to participant teachers' formative feedback throughout their course experiences. Participant teachers were ready with comments and suggestions about module activities and course design. There was a clear pattern of concern and confusion with the lesson modules from the onset of cohorts 1 and 2 that seemed to get smoothed out by the later cohorts. The instructor thoughtfully responded to the limitations and concerns raised by teachers – thus the participant teachers were actually helping to form the final course product cohort by cohort.

Many teacher comments praised the course-provided PowerPoint presentations, websites, and videos. Some teachers raised concern about the difficulty of accessing needed information on the Internet. One teacher complained, "Internet searching is pretty difficult and time consuming sometimes." Another remarked, "I'm not very good with fishing the Internet." Teachers seemed to have the most trouble with the "USGS site for hydrographs."

An important piece of feedback that we are considering as we move forward with the Lab Earth approach is the pacing of an online course for teachers. Teachers identified their frustrations with managing assignment deadlines that fell during busy school times (such as parent teacher conferences and school holidays). One teacher suggested that the instructor "give more time between due dates." Another teacher prompted, "Decide what's really important for us to do as busy teachers." There seemed to be a particular problem with the course assignments in the final module. Teachers explained, "Some of the directions were a bit vague and hard to follow. Others complained, "The last two modules have involved a lot more time." and "This is a terrible time of year to increase the workload." While teachers conferred harsh judgment on the pace and expectations of the course, calendar demands (i.e. Parent Teacher Conferences) are important realities in a teachers' world that need to be considered during the design of on-line courses offered during the academic year.

IMPLICATIONS FOR TEACHING

Participating teachers demonstrated significant increases on both the Science Teaching Efficacy Beliefs Instrument (STEBI-A) and personal science teaching efficacy (PSTE) meaning they feel more comfortable in their individual ability to teach science. As stated above, one teacher explained, "I feel myself becoming more confident in the content as I am completing this course. I'm learning more than just the basics and can help my students with the application of the science."

With each of the modules, teachers created projects and completed activities that they could alter to fit their own curriculum immediately. Participants also had the valuable experience of being able to share ideas with other teacher participants and solve problems surrounding the implementation and execution of the new ideas.

Perhaps most importantly, our results imply that the *Lab Earth 2* course had a significant impact on the teachers' belief that their own knowledge and performance in the classroom can positively impact their students' achievement.

CONCLUSIONS

The Laboratory Earth series is an example of on-line courses that use contemporary pedagogy and technology to improve content-knowledge and attitudes of teachers toward science. This type of effort is important in that educators, especially those who teach K-8 students, play an important role in providing students with the foundation for their success in scientific disciplines. Although the data represent a relatively small sample of teachers, these data gathered over a long duration (four iterations of the same course as guided by systematic data collection, reflection, and analysis) indicate that the approach used to design, implement, and deliver Laboratory Earth resulted in overall improvement of teachers' content knowledge and attitude towards science. The results support the conclusion that appropriately designed on-line course work can be an important component of a long-term effective professional development portfolio that deepens teachers' knowledge, sharpens teachers' skills, and maintains teachers' knowledge of science developments (Harwell, 2003, CORD, 2001, and NCMST, 2000).

Additional measures of improved teachers' ability might include student achievement data such as student test scores, teacher-created student evaluations, observation instruments, student work samples, or action research plans. One pre/post-test possibility would be to have teachers review/evaluate a lesson plan or a student work sample at the onset and completion of the course. This might provide a measure of improved teaching ability, resourcefulness, and content connections. Teachers might be asked to complete a grading rubric on one student sample and make recommendations for re-teaching or improving the lesson plan. This new approach would help to direct participant teachers to apply their new Earth system knowledge in the design of student learning experiences.

Continuous feedback from participants and reflection on and modification of our educational approach resulted in an iterative grading process that uses content mastery assignments as its foundation. CMAs provide an assessment of teachers' content knowledge and ability to make connections at higher cognitive levels. CMAs also provided an important opportunity for teachers to develop their metacognitive skills to plan their approach to completing the task, monitor their learning in the context of their plan as the module progresses, and evaluate their level of understanding after the completion of the task based on instructor feedback.

Laboratory Earth provides another example of how on-line programs, if designed appropriately, are a win-win situation for institutions of higher education and the teachers they serve. For the teachers, online professional development provides convenience that traditional face-to-face professional development may not allow. For institutions of higher education, online courses can serve a larger market of professionals who want and need access to the academic resources.

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