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Design, Implementation and Assessment of an Earth Systems Science Course for Secondary Teachers

Jeffery C. Owen

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**DESIGN, IMPLEMENTATION, AND ASSESSMENT OF AN EARTH SYSTEMS
SCIENCE COURSE FOR SECONDARY TEACHERS**

By

Jeffrey C. Owen

B.S. University of Maine, 1988

A THESIS

Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Teaching

The Graduate School

The University of Maine

December, 2003

Advisory Committee:

Stephen A. Norton, Professor of Earth Sciences, Advisor

Kirk Maasch, Associate Professor of Earth Sciences

MaryAnn McGarry, Associate Professor of Education

Michael C. Wittmann, Assistant Professor of Physics

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An Abstract of the Thesis Presented
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In the fall of 2002 the Department of Earth Sciences at the University of Maine piloted an innovative course developed as a core offering for the new Master of Science in Teaching program. A team of four instructors comprised of two Earth Sciences faculty and two science educators developed the course and implemented it with nine students—six in-service teachers and three pre-service teachers. The course addressed multiple needs of secondary teachers through the integration of instruction in curriculum design, pedagogy, assessment, and classroom-level educational research, and earth systems science content.

The components of instruction taught in the course included: the use of backward planning for determining and prioritizing an instructional unit's learning outcomes; the construction of performance and other assessments matched to learning outcome priorities; the construction and use of inquiry-based learning activities; and the development of classroom level educational research skills for the assessment of

instructional effectiveness. These instructional topics were taught in the context of 11 earth systems science (ESS) topics, selected for their centrality to the discipline and applicability to secondary science curricula according to national and state education standards.

The course met once each week for three hours during the fall 2002 semester. The first hour each week was used for review and enrichment in one of the ESS topics. During the second hour, the ESS topic was the context for a workshop dealing with one of the identified instructional topics. The third hour each week was used to create materials or practice skills associated with instructing or assessing that ESS topic in secondary classrooms.

Data concerning student knowledge, attitudes, and instructional practices were collected during the course using a prerequisite knowledge assessment, pre- and post-instruction assessments, and surveys, all of which were created specifically for the course. Analyses of quantitative and qualitative data indicate that the course strengthened the participants' understanding of the targeted earth systems science concepts and that they understood, could apply, and implement the instructional concepts in the course. The course was valuable to the participants *and* instructors and is a model that may be transferable to other disciplines that are considering the development of courses for secondary teachers.

DEDICATION

This thesis is dedicated to my wonderful wife, Susannah L. Owen.

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Chapter 1

SCIENCE EDUCATION IN TRANSITION

Secondary science education is still in the throes of reform. National and state level commissions and task forces have been making suggestions for changes to the structure of American public education for years, and science education has been a prominent target. The current foci of science education reform include: improving the scientific literacy for *all* students; linking the learning of new concepts with what students already know (constructivism); and promoting the learning of scientific concepts through the study of science as a process (inquiry). Initiatives are underway nationwide to try to accomplish these reforms.

One such initiative exists at the University of Maine. Through a U.S. Department of Education Grant, the University of Maine has established a Center for Science and Mathematics Education Research (the Center) (CSMER, 2003). This Center acts to coordinate the education research activities taking place on the campus and is sponsoring a new Master of Science in Teaching program. Students in this program take specially-designed courses that integrate scientific and mathematics content with research-based pedagogy and assessment, and conduct thesis projects containing a significant education research component. The program is designed to draw more people into the fields of secondary science and mathematics education and provide them with content enrichment and the knowledge and skills to teach and evaluate that content effectively. I was awarded a graduate research assistantship from the Center to help the Department of Earth Sciences design, implement, and assess a research-based course for teachers and students in the MST program.

National and State of Maine Recommendations for Science Education

Two relevant types of documents (and legislation) have appeared during the last fifteen years—those containing performance standards for educational systems and those describing the characteristics of reformed schools and programs. The most notable document containing performance standards, National Science Education Standards (NSES) (NRC, 1995), presented a vision of science education for the United States. In addition to the often-referenced section containing the content standards for student knowledge and skills are less often referenced sections containing standards devoted to: (1) the teaching of science; (2) the professional development needs of science teachers; (3) the assessment programs utilized to make decisions about the effectiveness of various aspects of the educational system; and (4) the nature of reformed science education programs. The NSES indicated that the reform of science education necessary to fulfill this vision requires fundamental changes in the practice of the teaching of science, and that the changes require fundamental changes in teacher education and professional development programs. According to the NSES, teachers need:

- A thorough understanding of the content they teach and they must have the ability to instill accurate and enduring understanding in all of their students.
- To be personally familiar with the practice of science so that their students may learn science as scientists do (i.e., not as a history of what has been learned, but rather as an active inquiry process).
- To become practitioners of education research to accurately gauge the effectiveness of their instruction.

- To design and utilize assessments that are developmentally appropriate and probe the depths of student understanding (NRC, 1995).

Addressing all of these teacher needs, in integrated and comprehensive packages, is part of the revised mission of the teacher education and professional development programs across the country.

One such professional development program is offered by the National Science Teachers Association (NSTA). In 2000, the NSTA formed a task force to investigate how their professional development program should evolve in light of the current needs of science educators and the current focus of the science education reform movement. The task force (National Science Teachers Association, 2001) adopted the following NSES recommendations:

- Promote learning essential science content through the perspectives and methods of inquiry;
- Integrate knowledge of science, learning, pedagogy, and students and apply that knowledge to the teaching of science;
- Build understanding and ability for lifelong learning; and
- Be coherent and integrated.

Another example is the collection of professional development opportunities for science teachers offered by The American Association for the Advancement of Science's (AAAS) Project 2061 since 1994 (Eisenhower National Clearinghouse On-line, 2003). This organization promotes "the use of clear and explicit benchmarks for learning and the alignment of curriculum, instruction and assessment to those benchmarks." This type of targeted integration—content with instruction—is not standard in all professional

development opportunities and in fact is not present in the recommended strategies for professional development made by the Eisenhower National Clearinghouse for Mathematics and Science Education (ENC, 1999). None of the strategies ENC lists have the primary purposes of building knowledge (content and instruction) *and* translating that knowledge into teaching practice. Professional development for teachers focusing on only one of these purposes is not complete.

Maine's legislated learning standards, the *Learning Results* (Maine Department of Education, 1997), also make reference to teaching science and the needs of the teachers. Interdisciplinary approaches to teaching and learning are encouraged, as is the need to teach content in balance with critical thinking and problem solving processes. From the perspective of science education, the document's "Guiding Principles" may be interpreted as supporting all aspects of the scientific endeavor—including the applications of creativity, communication, collaboration and integration, and content knowledge. In the introduction to the science and technology standards one finds, "Helping students develop curiosity and excitement for science and technology while they gain essential knowledge and skills is best achieved by actively engaging learners in multiple experiences that increase their ability to be critical thinkers and problem solvers."

The Maine Commission on Secondary Education described the characteristics of reformed schools and programs (Maine Commission, 1998). The document, *Promising Futures*, is not specific to science education, but the essential elements of the Core Practices have many implications for science education. Among them are that:

- there be multiple pathways to learn essential material

- instructional activities are “hands-on, minds-on” and integrate knowledge with skills
- learning, as often as possible, is applied to student lives and moves beyond knowledge through inquiry and problem-solving to excite and perplex them
- students are grouped heterogeneously
- teachers should make expected learning outcomes explicit to the students and school community, possibly through the use of rubrics.

One of the key recommendations in *Promising Futures* (p. 49-50) is for the reform of professional development opportunities for teachers. “This report calls for educational personnel who understand and respect current-day adolescents, who can tailor learning activities to individual needs without compromising [learning] standards, who can accurately assess student learning and adjust their practices accordingly, and who can collaborate with parents and colleagues. These new responsibilities will, for some staff, require new competencies, new knowledge, and a new disposition. These must become part of our staff preparation programs as well as our certification, evaluation, and professional development practices.”

One implication of changes in the type of opportunities offered for teacher professional development is the need to change the teachers’ perceptions about the value of taking additional courses in education. According to data compiled by The K-12 Teaching Task Force at the University of Maine (2001), secondary teachers in Maine place a significantly higher professional development value on taking courses in content areas than on taking courses in education. This is not surprising given that secondary teachers are asked to teach discipline-specific topics. However, these same secondary

teachers also indicated that their pre-service training was better in subject matter than in *any* aspect of teaching (data from The K-12 Teaching Task Force, 2001). These data and the recommendations for the reform of teaching clearly indicate a need for high quality courses in teaching for secondary teachers.

Current Initiatives for Science Education Reform

State of Maine and University of Maine System Initiatives

The Maine Math and Science Alliance (MMSA, 2003), a non-profit organization founded in 1992, is committed to the reform of science education in Maine following the recommendations of the National Science Education Standards (NRC, 1995) and the Benchmarks for Science Literacy (AAAS, 1993), as well as the mandates of the Maine *Learning Results* (Maine Department of Education, 1997). In addition to offering grants to school systems in Maine which are attempting to institute reforms, MMSA offers myriad professional development opportunities for science teachers. These opportunities “are designed to be more connected, transformative, learning experiences that focus on deep understandings about science content, pedagogy, and the nature of learners.”

The MMSA is a participant in the Maine Mathematics and Science Teaching Excellence Collaborative, along with three campuses (University of Maine, University of Southern Maine, and University of Maine at Farmington) of the University of Maine System, (MMSTEC, 2003). MMSTEC was formed with support from the U.S. National Science Foundation’s Division of Undergraduate Education Collaboratives for Excellence in Teacher Preparation (CETP) and is committed to increasing the number of qualified science teachers in Maine and improving the quality of the teacher education programs on the three campuses. In addition to offering scholarships to undergraduates

potentially interested in becoming teachers, MMSTEC holds annual conferences, workshops, and meetings where teachers share their reform efforts and how they have evaluated their effectiveness. The MMSA provides resources and expertise to the MMSTEC activities and assists them in utilizing the findings of education research.

The University of Maine received a three-year grant from the National Science Foundation in 2001 (renewed in 2003) for Graduate Teaching Fellows in K-12 Education (University of Maine, 2003). These awards place top graduate students and upper-level undergraduates in science, mathematics and technology programs into K-12 classrooms in the vicinity of the University of Maine campus, bringing content refreshment and professional development to the participating teachers. Through their exposure to K-12 education, some of these advanced students may become interested in pursuing careers in teaching.

National Initiatives

Tertiary institutions nationwide are beginning to address the needs of science teachers. Pedagogical reform has entered introductory science courses, through which most future teachers pass. Harris (2002, 2001) provides a concise summary of recommendations for making courses more student-centered and interactive, although there are problems and disincentives to faculty associated with their implementation. Harris's suggested reforms may help all students, including pre-service teachers, learn the content more thoroughly than is typical in courses taught more didactically. Other efforts (Gosselin and Macklem-Hurst, 2002; Hansen et al., 2003; Buck, 2003) are specifically designed to benefit teachers and include targeted content enrichment, field or research experiences, and developing research partnerships, although some may span these

categories. Attempts to measure the effectiveness of these efforts in the short-term (Gosselin and Macklem-Hurst, 2002; Huntoon et al., 2001) and long-term (Slater et al., 1999) indicate that they hold promise as means for positively influencing K-12 science education either through improving teacher content knowledge, pedagogy, or attitudes toward science.

Content Reform

From the perspective of content, the NSES and Maine *Learning Results* are better known for their lists of student learning standards than they are for teaching and professional development standards and recommendations. Standards associated with the earth sciences are strongly represented in the NSES and less so in the *Learning Results*. One particularly challenging aspect of standards-based education is the need to cover all of the content material closely linked with the learning standards prior to their statewide assessment. In Maine, mastery of the *Learning Results* standards is assessed during the 4th, 8th and 11th grades using the Maine Educational Assessment (MEA) (Maine Department of Education On-line, 2003). This poses a problem for secondary schools whose traditional curricula may expose students to only two discipline-specific courses—typically one life science and one physical or earth science—prior to the onset of the MEA testing during 11th grade. This leaves a significant number of the standards uncovered. One strategy for resolving this, which has been adopted at schools across the state, is to fundamentally change the science curricula from traditional, discipline-specific courses to integrated courses for the 9th and 10th grade years. An integrated study of the earth provides an effective context in which to learn concepts from all of the scientific disciplines, making it easier for science curricula to be aligned with the learning

standards, and providing students with learning experiences that link with the world around them. However, most science teachers have only discipline-specific courses in their backgrounds. Similar to the need for high quality education courses that integrate content and instructional learning, this integrated view of the scientific disciplines may require the modification of content courses offered as professional development opportunities for science teachers, as well as of typical undergraduate science courses frequented by pre-service science teachers. Given the emphasis on improving science literacy for all students, the effectiveness of all programs designed to improve teaching and learning should be assessed.

Measuring the Effectiveness of Instruction

The assessment of educational programs typically involves a blend of qualitative and quantitative methods. Two types of assessment instruments prevalent in the literature are distractor-driven multiple choice tests and Likert-scale surveys. Common to the development of these types of instruments are the extensive qualitative methods used to demonstrate their validity and reliability.

Many of the conceptual tests in science education research use valid and reliable multiple choice questions. Sadler (1998) made a strong case for the use of reliable and valid multiple-choice assessments of student conceptual understanding. He contended that the use of distractor-driven multiple choice assessments may be used to demonstrate the degree of development of conceptual understanding as students progress through their education. Further, by knowing which alternative concept a student believes in at a particular time, one can predict the next step in development and therefore tailor instructional activities accordingly. However, the development of such instruments is not

easy. Zeilik (2003) describes the ten years he and others spent in the development of the Astronomy Diagnostics Test (Collaboration for Astronomy Education Research, 2003) and its use as a measure of pedagogical effectiveness. Validation of the instrument involved many experienced astronomy instructors, student focus groups, and clinical interviews.

Although sometimes debatable as to what is being assessed, student performance on diagnostic instruments is indicative of the effectiveness of classroom instruction (Hestenes et al., 1992; Huffman and Heller, 1995; Hestenes and Halloun, 1995; Heller and Huffman, 1995). Heller and Huffman (1995) cautioned about the degree to which high scores on the Force Concept Inventory (Halloun and Hestenes et al., 2003) are indicative of students possessing a universal force concept. However, higher scores on valid and reliable assessments represent better understanding than do lower scores.

An important feature of the Force Concept Inventory and the Astronomy Diagnostics Test is the use of more than one question per concept. This approach limits the influence that context-dependency has on the answers selected by students. Palmer (1998) demonstrated that incorrect answers to multiple-choice questions may be inappropriately labeled as misconceptions if only a single question (representing a single context) is asked for each concept. However, Licht and Thijs (1990) and Halloun and Hestenes (1985) showed that context-dependency for specific topics diminishes with student age. Therefore, interpreting these incorrect answers as misconceptions may be appropriate with older or more advanced students.

The scientific rigor of the studies cited above is rare in earth science. Shea (1999) emphasized this point in a review of abstracts for rigorous education research designs.

Of the 146 education-related abstracts he found, “virtually none” passed his criterion of “real education research,” although 16 contained elements of some education research methods. This void is probably due to the infancy of the field of earth science education research and the lack of field-tested instruments for measuring student understanding of earth science concepts. The Assessment of Student Achievement in Higher Education Program in the Division of Undergraduate Education at the National Science Foundation (NSF) is funding the development of a valid and reliable geosciences concept test to be available for the fall of 2003 (Geological Society of America, 2003). It will be used by post-secondary instructors to make curricular and pedagogical decisions as well as to measure the effectiveness of the classroom instruction. This advance may allow education research in the earth sciences to become more widespread, following the precedents in physics (Mechanics Diagnostics Test [Halloun and Hestenes, 1985] and the Force Concept Inventory [Halloun and Hestenes, 2003]); astronomy (Astronomy Diagnostics Test [Collaboration for Astronomy Education Research, 2003] and the Moon Concept Inventory [Kansas State University, 2003]); and biology (Conceptual Inventory of Natural Selection [Anderson et al., 2002]; Diffusion and Osmosis Diagnostic Test [Odom and Barrows, 1995]). Additionally, other disciplines have conducted education research (Brickhouse et al., 2000 and Ryder et al., 1999) and created instruments (Biology Self-Efficacy Scale [Baldwin et al, 1999]; Survey of Attitudes toward Astronomy [Zeilik, 2003]; Maryland Physics Expectations Survey [University of Maryland, 2003]; Views about Science Surveys [Hestenes et al., 2003]) that are designed to measure the effectiveness of instruction for improving student confidence in particular courses, and the influence of instruction on student beliefs about the nature of science.

The earth sciences are behind the other sciences, but the development of a valid and reliable instrument should initiate more widespread evaluation.

Summary

The reforms necessary to realize the vision of the national and state science standards and other recommendations require that science teachers begin to teach science and assess success differently. Teachers and future teachers must have experience in the practice of science, an integrated understanding of scientific content and how to teach it, and the skills to accurately assess the effectiveness of their instruction. It follows that teacher education and professional development programs must deliver different opportunities than they traditionally have, and model the “best practices” they are teaching.

Chapter 2

EARTH SYSTEMS SCIENCE FOR TEACHERS

Introduction

The University of Maine has responded to recent recommendations for the education and professional development of secondary science and mathematics teachers (NRC, 1995) by instituting a new Master of Science in Teaching (MST) program. This program, offered through the Center for Science and Mathematics Education Research (the Center), benefits (1) teachers who would like to strengthen their knowledge of the subjects they teach while earning a Master's Degree, (2) recent graduates who have majored in mathematics, science, or engineering and are interested in pursuing a career in teaching, and (3) established scientists, engineers, or mathematicians who are interested in making a career change into secondary teaching.

Core courses in the MST utilize and demonstrate the value of findings from education research in the construction of innovative science pedagogies. These courses, rich in discipline-specific content and research-based pedagogies, are offered in mathematics and science departments at the University of Maine. The "Earth Systems Science for Teachers" course was designed to be one of these core courses and is offered through the Department of Earth Sciences.

Course Design

Relevant Background Information

I was awarded a graduate research assistantship from the Center to help the Department of Earth Sciences design, implement, and assess the course "Earth Systems Science for Teachers" that it would offer in the MST curriculum (Appendix A). Essential

to this task was my background as a secondary science teacher, my interest in curriculum and pedagogical reform, and my desire to support teachers' professional development.

My initial vision of the course involved the integration of needs of secondary science teachers, including content enrichment, and exposure to and practice with innovative methods in curriculum design, pedagogy, and assessment. In my experience, professional development opportunities were almost always interesting and relevant to some aspect of science or teaching, but rarely were they directly transferable to my classroom or applicable to my immediate needs as a teacher. In essence, the experiences were typically too theoretical. The teaching profession is too time-consuming for teachers to be able to develop classroom applications from everything they experience during professional development programs. Consequently, a major goal for the course was to "practice what we preach" and model the use of research-based strategies for answering important instructional questions, in addition to helping the students in the course (herein called "participants") develop the knowledge and skills necessary to answer those questions for themselves as quickly and directly as possible. Examples of these instructional questions included:

- How does one decide what concepts to teach and how does one prioritize them?
(Curriculum Design)
- How are these concepts collected into a coherent program? (Curriculum Design)
- How does one decide how to teach those concepts? (Pedagogy)
- Are the students sufficiently prepared for this program? (Education Research)
- Did the instruction develop the intended student understanding? (Assessment and Education Research)

The initial vision of the course was also shaped by a document created by the Maine Mathematics and Science Teaching Excellence Collaborative (MMSTEC, 2000), outlining the five major attributes of effective classrooms. The course would be designed to exemplify and teach these attributes, and would be characterized as:

- Having all students engaged in learning;
- A community of learners;
- Managing and monitoring student learning, frequently and purposefully;
- Focusing on fundamental concepts in the Earth Sciences and the relationships among them; and
- Emphasizing pedagogical procedures specific to teaching science.

The Design Process

Two Earth Sciences faculty, whose expertise and experiences complemented one another, were recruited to help instruct the course. Dr. Stephen A. Norton's area of expertise is aquatic geochemistry, and he has many years of experience teaching introductory geology courses and an interest in teacher education. Dr. Kirk Maasch is a climate modeler with expertise in Earth's energy budget and ocean-atmosphere interactions. Dr. Molly Schaufler's offer to help with the instructional topics of the course was welcomed. Schaufler was a post-doctoral fellow in Earth Sciences, has expertise in ecology, and an extensive background in education as a secondary science teacher and outreach educator supporting the professional development of teachers.

I shared my vision for the course with the instructors and collectively we agreed that integrating scientific and instructional topics would create a truly meaningful course for the participants. However, such a course would necessarily devote less time to

content or instructional topics than a traditional course. Thus our first planning meetings considered what the most important objectives for the course would be.

Two lists were created based on the vision described above. A list of: (1) ESS topics relevant to secondary level science curricula; and (2) instructional topics directly related to decisions that teachers have to make every day. Subsequent iterations of these lists (Table 1) were used to draft the course’s primary objectives and content outcomes (Appendix A), which reflected our broad goal that participants be able to use the earth system as a context for the in-depth instruction of some fundamental laws of nature using innovative and research-based instructional activities.

Table 1: Course Topics

Class Meeting Number	Earth Systems Science Topic	Instructional Topic
2	The Earth System	The “Backward Planning” Concept and Identifying Desired Learning Outcomes
3	Radiation and Temperature	Determining acceptable evidence of learning using traditional assessments
4	Atmospheric Circulation	Determining acceptable evidence of learning using performance assessments
5	Oceanic Circulation	Planning the learning experiences—A review of the recommendations for science education
6	Plate Tectonics	A model for an inquiry-based activity
7	The Rock Cycle	Adapting traditional laboratory activities to become more student-centered and scientifically-valid
8	Chemical Evolution of the Oceans and Atmosphere	Creating inquiry-based projects and evaluation rubrics
9	The Hydrologic Cycle	Assessing prerequisite knowledge
10	The Carbon Cycle	The use of pre- and post-assessments
11	Modern Climate	Using Student Interviews—Prepare Interviews
12	Humans and the Environment	Using Student Interviews—Conduct Interviews

Having stated the course objectives and outcomes at the outset, the four instructors designed the course following the general recommendations of the “Backward Planning” model (Appendix B) promoted by Wiggins and McTighe (1998). This model allows for the seamless integration of curriculum design decisions with those involving pedagogy and assessment. Thus decisions regarding the assessment of the outcomes preceded those of pedagogy.

We met weekly throughout the summer of 2002 to design the course. First, we created an assessment program for the course that would (1) model strategies associated with our instructional objectives, and (2) provide a mechanism for determining the knowledge and skills competencies of the participants. Wiggins and McTighe (1998) promote the use of performance assessments for the most essential course outcomes. As such, we decided that the primary assessment for the course would be a semester-long project in which each participant would create a unit of instruction exhibiting the application of the ESS content and instructional goals of the course (Appendix C). These projects and the presentation of them (which included the facilitation of an inquiry-based activity) accounted for 70 of the course’s 120 total points.

Less essential course outcomes may be assessed through the use of more traditional, formal or informal, assessments (Wiggins and McTighe, 1998). The course had many less essential outcomes, including:

- Developing facilitation skills, for discussions and teaching-through-inquiry;
- Modifying traditional laboratories and tests to make them more scientifically valid and to require higher-order thinking skills;

- Becoming familiar with national and state learning standards for secondary sciences; and
- Developing accurate conceptual understanding of ESS topics.

The second most significant assessment in the course would be participation.

Participants would be responsible for coming to class prepared, facilitating and participating in discussions, and working collaboratively on all assignments.

Typically participation, although expected in courses, is a minor factor in determining student grades. In this course, the role of participation was explicit (i.e., the course is a “community of learners”). We emphasized the importance of participation through the collaborative generation of a grading rubric and by having 30 of the course’s 120 total points devoted to participation. Other miscellaneous assignments associated with the course accounted for the remaining 20 points.

Wiggins and McTighe (1998) contend that decisions regarding pedagogy must follow those associated with assessment. As the course’s assessment package was defined, the nature of how the course had to be taught became apparent. The participants had to perform at the end of the semester in a manner that demonstrated the depth of their knowledge and the extent of development of their instructional skills. As such, a large portion of each class session had to be devoted to the development of instructional skills in the context of ESS content knowledge. To that end, the participants would work collaboratively: (1) to construct their understanding of the ESS content, using peer-facilitated discussions; and (2) to develop their instructional skills and ESS-based classroom materials. The objective associated with this format was to immediately

transfer ESS content knowledge into instructional knowledge or materials that could be used directly in a classroom (Appendix D).

An additional component of the course, integral to all aspects of the MST program, was to use education research instruments as a means for establishing the effectiveness of instruction. The participants in the course had to demonstrate the use of these techniques in their performance assessments. The instructors for the course would model an education research protocol in the course using the participants as subjects. A survey, administered at the end of the course, would provide data on the perceived value of the instructional components of the course. Multiple choice assessments of two types would be developed for the ESS topics: an assessment of pre-requisite knowledge, and assessments of conceptual understanding. These assessments would provide data on the degree of preparedness of the participants for the course concepts and on the gain in conceptual understanding developed during the course.

To create these multiple choice assessments, we reviewed the NSES and the Maine *Learning Results* as they related to the ESS topics previously selected for their centrality to Earth Science and relevancy to secondary curricula. The instructors' weekly meetings became devoted largely to discussing the individual topics at length, to carefully define both the broad and focused concepts integral to each, as well as any underlying pre-requisite concepts necessary to understand them. These concepts were used to create the pre-requisite knowledge assessment and the pre- and post-instruction assessments for the course. The broader concepts were used as the basis for the course assessment and the more focused concepts were used to create the weekly ESS topic assessments. Although our use of the data generated by these assessments would be primarily limited to

classroom use, we secured permission from the University of Maine Institutional Review Board for the Protection of Human Subjects so that we could make the findings public (Appendix E).

Course Description

There were fifteen three-hour class meetings. Reserving the first for logistics, pre-assessments and introductory information, and the last three for project presentations, left 11 class meetings for the development of student understanding and skills. These 11 class meetings contained approximately an hour of ESS topic discussion for content enrichment (nine of which were participant-led discussions), an hour of workshop devoted to an instructional topic, and an hour workshop on the development of classroom materials.

The participants facilitated the ESS content discussions each week instead of the faculty. On the first day of class the participants randomly drew the ESS topics they would facilitate later in the semester. Each participant was then given the list of specific concepts, generated during our planning discussions, for their topic. This list provided a basis for their required interaction with one of the faculty during the week prior to their facilitation. During the facilitations, faculty maintained the technical accuracy of the discussion and kept discussion moving such that we would reach near-completion of coverage by the end of the hour. Two of the 11 ESS discussions were facilitated by the instructors as there were nine participants in the course.

The weekly schedule included the assessment of each ESS topic. These assessments were administered before and after each class session using the university's access to the on-line WebCT program (WebCT, 2003). This program allowed the

assessments to be an integral part of the course without sacrificing the already severely limited class time. The WebCT program provided access to assessment documents at the same time each week and for the instructors to be able to monitor when each participant took each assessment and how long they spent taking it. Participants:

- were limited to one try for each assessment;
- were allowed 15 minutes for each assessment;
- were not allowed to return to previous questions; and
- had knowledge only of how many questions were answered correctly (but not which questions).

The participants were required to log-on to the program once each week, between noon on Wednesday and midnight on Sunday, to take an assessment that was a combination of the post-assessment for the previous week's ESS topic and the pre-assessment for the subsequent week's ESS topic.

The final three class meetings were devoted to project presentations, described below. Each participant was allotted 30 to 60 minutes to share with the class the unit developed for the project; the decisions made during the construction of the unit; and to have all of us participate, as students, in the inquiry-based activity developed as part of the unit.

Participant responsibilities for the course included the weekly content and instructional readings and assignments, active participation in the discussions and group work, the semester project, and all of the education research assessments. The instructors' responsibilities during class varied. The faculty whose expertise most closely matched the upcoming week's ESS topic assisted the participant in preparing for the

facilitation. During the hour of participant-facilitated discussion the faculty member was responsible for the technical accuracy of the discussion and its pace. During the second and third hours, I facilitated the instructional activities while the other instructors joined the small groups to provide input and direction as needed. I formatted the assessments and posted them to the WebCT site. (See Appendix A for the complete course description.)

Participants were recruited to the course from the University as well as the portion of Maine from which people might be able to travel for a mid-week evening class. Flyers about the course were mailed to the principals and/or science department chairs of the secondary schools in our region of the state. A course description with contact information was posted on the Maine Math and Science Alliance's web-based list-serve and a poster-presentation describing the course was given at the Center/MMSTEC jointly-sponsored summer conference, which drew teachers from across the state (CSMER, 2002). Several academic advisors in the College of Education and Human Development promoted the course as an option to appropriate undergraduate students. Our class was piloted during the fall semester of 2002. We had a diverse group of nine participants (Appendix F).

Because of the integration of pedagogy and assessment in the course, the Maine Department of Education accepted the course as meeting the criteria for a 'methods in science' education course and a course in 'educational assessment' for (re)certification. Participants in the course used both options. One participant used the course as an elective in a Master of Science (in Environmental Education) program and one of the

undergraduate participants majoring in secondary science education was allowed to take this course in place of the required secondary science methods course.

Education Research Questions and Methods

Our goals were to teach classroom-level education research techniques and demonstrate their value to the participants in our course. We posed the following research questions:

- (1) Do the participants possess the prerequisite knowledge and skills they will need to be successful in our course?
- (2) What is the short-term influence of instruction on participants' understandings of specific concepts related to the weekly ESS topics in the course?
- (3) What is the influence of instruction on participants' understandings of the course's broad ESS concepts?
- (4) Are the participants able to apply the course's curriculum design, and pedagogical and assessment strategies in the development of ESS instructional units?
- (5) At the end of the course, what are the participants' beliefs and attitudes about the curriculum design, pedagogy and assessment strategies studied in the course?
- (6) Six months after the course, have those beliefs and attitudes persisted and have they influenced the instructional practices of the participants?

We created multiple choice assessments for the first three questions knowing that they can develop insights into participant understanding if carefully constructed (Sadler, 1998). The development of these assessments was completed prior to the first class session. To make each of them as valid and reliable as possible, we tried to mimic the method and structure of some published assessments from other disciplines (Zeilik,

2003). Many papers have documented the use of qualitative studies, particularly interviews, as a key step in the generation of multiple choice assessments (e.g., Zeilik, 2003; Geological Society of America, 2003). For the assessments associated with the first two questions (prerequisite knowledge [Appendix G] and the ESS topic assessments [Appendix H], respectively) we didn't have time to conduct interviews and had to rely on the experience of the two faculty to provide distracting answers that were common in their courses, plausible, and internally consistent. For the third question, we created a pre-instruction assessment that probed the course's more general concepts using short answer questions and administered it on the first day of class. Then, overnight, many of those short-answer questions were converted to multiple-choice (in most cases, with a few true/false) questions using the incorrect responses from the short answer version as distractors wherever possible. The participants were given the multiple-choice version as the pre-instruction course assessment (Appendix I) prior to the second class session and again as the post-instruction course assessment during the last week of the semester. On the first day of class, each participant took:

- The assessment of prerequisite knowledge;
- The pre-instruction assessment for the general ESS course concepts (short-answer version);
- The pre-instruction assessment for the first ESS topic; and
- The pre-instruction assessment for their assigned facilitation topic.

In total these assessments contained 30 multiple-choice and 20 short answer questions.

Data for the fourth research question came from the semester projects, a form of performance task in which the participants were to apply the instructional strategies

discussed in class to the design of an instructional ESS unit. A qualitative analysis of the participant projects and presentations was conducted to search for examples of, and explicit statements about, the instructional practices we had taught.

Surveys were created to provide data relevant to the fifth and sixth research questions. During the final week of the semester, participants completed an end-of-the-course survey (Appendix F) containing questions about beliefs and attitudes as well as important feedback about the course. Six months after the completion of the course, in May of 2003, a follow-up survey (Appendix J) was sent to all of the participants to investigate their teaching during the spring semester. These surveys were not anonymous, possibly sacrificing a degree of openness in the criticism, but did allow for the alignment of surveys with content assessments.

Results and Interpretation

Prerequisite Knowledge

Assessing prerequisite knowledge is something that most instructors do informally through conversations with individual students (or classes), or by reflecting on successes and failures of courses or material they have taught in the past. Formalizing this process makes the subtleties of student understanding more apparent, and is particularly important when a course draws students from a variety of backgrounds. Identifying which students hold at least some level of understanding of prerequisite concepts informs the instructor which students need to be helped (and for which topics that help may be necessary) and may markedly influence the way particular topics are taught.

For K-12 teachers, effective assessment of learning standards for their students at every level may eventually remove the need for the assessment of prerequisite

knowledge. If, for instance, a ninth grade teacher of a required course knows that the students, simply by their presence in the class, have all mastered the eighth grade learning standards relevant to the course, solid content and pedagogical decisions may be made in the absence of a specific assessment of prerequisite knowledge. However, standards-based education in Maine has not yet reached the level of maturity for this to be appropriate. Students are still advanced from grade to grade without meeting all the standards. The depth of understanding necessary to meet the standards varies from school to school. Students transferring from school to school may experience dramatically different curricula.

At tertiary institutions, instructors typically identify prerequisite courses, but the use of this strategy raises the same instructional problem of not knowing how well the students understand the concepts covered in those courses. The courses commonly listed as prerequisite are introductory level courses with high student enrollments. Courses of this type are commonly taught in the traditional manner (lectures, possibly with laboratory and/or recitation sessions). Commonly the students do not develop a deep and enduring understanding of the concepts (Hake, 1998). Instructors who list such courses as prerequisites for their courses are forced to view the depth and breadth of understanding of all students as being the same. Given the importance of these assumptions, and that we hoped to draw a diverse group of pre- and in-service teachers to the course, modeling the use of and utilizing the data from an assessment of prerequisite knowledge was an important addition to the classroom-level education research in our class.

Our assessment of prerequisite knowledge contained 20 multiple-choice and true/false questions covering a range of fundamental scientific concepts and skills (Appendix G). The questions, to a large extent, were not posed in the context of ESS but were instead rather generic applications of the knowledge and skills. Generation of the questions in this manner largely removed contextual understanding and application (which we hoped to teach during the course) from the demonstration of basic understanding. Our questions covered topics such as mass, volume, density, energy, unit conversions, graphical analysis, and simple applications of Newtonian motion. The results (Table 2) indicate that the majority of the participants were in possession of the fundamental knowledge and skills we thought necessary for success in the course. Two topics arose as potential areas of concern—the difference between heat and temperature and some applications of Newton’s Second Law. We recognized that one participant might have difficulty in the course due to a weaker background than the others and monitoring that participant’s progress was particularly important.

Table 2: Prerequisite Knowledge Assessment

Participant Code #	# Correct (of 20)	% Correct
D81	11	55
E76	19	95
G56	20	100
K29	19	95
L34	18	90
R16	20	100
T53	20	100
W91	16	80
Z12	19	95
AVERAGE	18	90

Earth Systems Science Content Knowledge

Traditional assessments used in courses to generate grades may be meaningful gauges of student understanding. These assessments, whether they are examinations, laboratory exercises, or projects, allow instructors to determine the extent of the knowledge and skills possessed by students. The understanding demonstrated by these assessments, which typically follow instruction, is a combination of what was learned during the instruction in the course and the students' knowledge acquired prior to the course. Therefore the use of only these assessments makes it difficult to gauge the effectiveness of the instruction. This dilemma is partly resolved through the use of assessments given both prior to and following instruction. If the assessments are valid and reliable, their use quantifies learning gains attributable to the classroom instruction. The degree of effectiveness of curricula, can then be used to guide reform efforts.

Our second, third and fourth research questions focused on measuring the effectiveness of our course. For the ESS concepts we created assessments to be administered before and following instruction (Appendices H and I). Two statistical measures were applied to the results of these assessments, a dependent-samples t-test ($p = 0.05$, one-tailed) and average normalized gain. Average normalized gain, $\langle g \rangle$, is a ratio of the average change in participant scores from pre-test to post-test compared to the maximum possible improvement:

$$\langle g \rangle = (\text{average post-test} - \text{average pre-test}) / (100 - \text{average pre-test})$$

The $\langle g \rangle$ for each of the course's 11 ESS topics are in Table 3. There is much variation among these $\langle g \rangle$. Their distribution averaged 0.37 with a markedly negative skew.

Eight of eleven were statistically insignificant. These $\langle g \rangle$ resulted from the pedagogical

Table 3: Learning Gains by Weekly ESS Topic

Topic	Pre-Test Average (%)	<g>	Significant?
Atmospheric Circulation	66	0.79	yes
Carbon Cycle	79	0.24	no
Chemical Evolution of the Oceans and Atmosphere	71	0.07	no
The Earth System	73	0.22	no
The Hydrologic Cycle	64	0.67	(barely) no
Humans and the Environment	75	0.44	no
Modern Climate	89	0.18	no
Oceanic Circulation	89	0.18	no
Plate Tectonics	84	0.88	yes
The Rock Cycle	79	-0.29	no
Radiation and Temperature	68	0.56	yes
Mean	76	0.42	
Median	75	0.44	
SD	9	0.35	

decisions made during the planning of the course. The participants were to take ownership of the content by having to facilitate the weekly discussions, and having to work through pedagogical and assessment issues in the context of those weekly topics. The facilitations varied tremendously in strategy and effectiveness and were strongly influenced by the knowledge held by the facilitators and participants, as well as the care taken by all the participants to complete the reading assignments carefully. The participants' perceptions of the effectiveness of this pedagogical strategy varied as well, but seven of nine indicated that it should be kept as an integral component of the course, possibly with some modification, the next time the course is offered. Some of the low <g>, particularly in the latter portions of the course, may result from time spent discussing the linkages among the weekly topics. The discussions of linkages were valuable, emphasizing the nature of the earth as a system, the central theme of the course. However, these discussions took time away from getting to the level of detail we hoped

for in some of the ESS topic discussions. The low $\langle g \rangle$ for the evolution of the oceans and atmosphere topic is likely attributable to an incorrect reading for the topic. The discussion was still very informative, but lacked the detail and participation common to many of the others.

Average normalized gains are a useful mechanism for assessing the effectiveness of instruction. However, analyzing instruction using $\langle g \rangle$ without consideration of the pre-test averages limits their usefulness. For instance, two of the very respectable average normalized gains shown on Table 3 are 0.78 and 0.85 for the topics of atmospheric circulation and plate tectonics, respectively. In the absence of knowing the pre-test averages for these topics one could be led to believe that the learning for these two topics was similar. However, the reality is that they are quite different: the $\langle g \rangle$ of 0.78 for atmospheric circulation represents a 26% average gain, while the $\langle g \rangle$ of 0.85 for plate tectonics is an average gain of only 14%. This difference is due to markedly different pre-test averages.

The pre-test averages for the 11 EES topics are interesting. The questions on these eleven assessments targeted the concepts most central to the topics, and were written to probe those concepts at the depth to which we hoped the participants would learn them. The pre-test averages were quite high. With a mean of 76% and a standard deviation of only 9% it appears that our participants were particularly knowledgeable about these topics. This is likely given that eight of the nine participants had strong Earth Science backgrounds and we were, in some respects, teaching a refresher course. Also, the questions may not have tested the concepts to the depth or degree of difficulty we

intended. It will take repeated iterations of the course before we generate a sample size large enough to discriminate among different explanations.

The $\langle g \rangle$ for the more general ESS concepts, as determined by the pre- and post instruction assessment for the whole course, was statistically significant at 0.45 with a pre-test average of 63%. The data for each question on this course assessment clearly indicate that our pedagogical methods for the course, which allowed for dramatically different depths of content discussion and instructional work, didn't work equally well for all of the concepts. However, a statistically significant $\langle g \rangle$ of 0.45 may still be indicative of substantial improvement in participant understanding.

The grand average of pre-test scores for the 11 weekly ESS topic assessments was 76%. This was higher than the pre-test average (63%) for the more general course assessment. I would have predicted that the pre-course assessment, with its more general questions, would have been easier than the topical assessments, which had somewhat more specific questions. Three possible explanations for this result are: (1) the intent of making the questions on the ESS topic assessments more specific than those on the course assessment was not realized; (2) participants do better when they know they are focusing on a single topic; or (3) the better success on the ESS topical assessments, which were given throughout the semester, may be in part due to the learning that has occurred during the course. If this latter explanation were true one would expect a positive trend in the ESS topical pre-test scores over the course of the semester. This trend exists, but it is very slight and not significant.

The $\langle g \rangle$ for the general course assessment was higher than that of the average performance on the weekly assessments, and it had a lower pre-test score. The higher

<g> of the course assessment, measuring the course's overarching concepts over a longer period, indicate that the understanding and application of concepts in the context of ESS was something that we were successful at influencing. The lower average <g> of the weekly assessments reflects the limited influence we had at enriching the depth of content knowledge.

Instructional Topics and Attitudes

The fourth research question, “can the participants demonstrate that they have learned and can apply the course's concepts?” is a question typically posed by instructors. To answer it we sought specific evidence in the performance assessment of the application of the instructional topics. This evidence was largely in the form of the presence of documents (e.g., an assessment of prerequisite knowledge) with supporting language describing why and how they were created, and possibly the anticipated value of them. Table 4 shows the number of participants whose projects explicitly contained evidence of applying the course's instructional topics, and the number of participants whose attempts were completely successful. The criteria for determining successful application were:

- Is the list of outcomes appropriate and complete, and are the outcomes truly essential?
- Do the performance assessments ask the students to apply their understanding in a context not previously used in instruction and are there ways for individual strengths to be used successfully?

- Do the inquiry-based activities exhibit characteristics of scientific inquiry, such as problem formulation, hypothesis testing, observation and data collection, data reduction and analysis, and the communication of findings?
- Do the performance assessments and inquiry-based activities align with the unit's essential outcomes?
- Do the assessments of prerequisite knowledge use appropriate questions to probe the knowledge and skills necessary for students to possess at the beginning of the unit?
- Do the pre- and post-instruction assessments contain good questions that are aligned with the unit's stated outcomes?
- Do the interview questions probe the accuracy and depth of student understanding, or do they remain factual and/or superficial?

Table 4: Participants Demonstrating Instructional Elements in their Projects

Instructional Element	Number of Participants Demonstrating	
	Explicit Attempt	Marked Success
Backward Planning	9	6
Performance Assessments	9	4
Inquiry-based Learning Activities	9	5
Assessment of Prerequisite Knowledge	8	6
Use of Pre- and Post-Instructional Assessments	9	5
Use of Student Interviews	9	6

The fifth and sixth research questions, probing the attitudes and beliefs about the instructional practices we were teaching, arose during the delivery of the course when it became apparent that such data would be valuable. We had neglected to administer a pre-instruction assessment of instructional attitudes/beliefs or practices. This realization

forced the revision of the end-of-course survey we were planning to use and prompted the creation of a follow-up survey to be administered six months later, after the in-service participants may have had the opportunity to implement some of what they had learned in the course.

The results of the end-of-course survey (Appendix F) indicate that the course had a positive influence on the instructional attitudes and practices of the participants. Self-reporting at the end of a course may have been influenced by efforts to make the instructors feel a particular way about what they've accomplished or may represent somewhat superficial feelings if the participants don't take the time to thoroughly reflect on their experiences in the course. Even so, the participants who took the time to answer our open-ended questions, almost without exception, expressed positive sentiments about the various aspects of the course.

The mean scores on the 1-5 Likert scale questions, asking about the degree to which the course influenced the participants' knowledge of the various aspects of the course, ranged from 3.3 to 3.6 (where 1 = weakly and 5 = strongly) and the ranges spanned the entire scale (though there were very few 1s and 5s). The individual responses on these questions quite clearly demonstrated the diverse participant backgrounds. For example, one participant, a practicing middle school teacher, had taken courses in assessment and science pedagogy and as such this course was really a refresher and didn't strongly influence existing knowledge of those topics. Another participant had never taken an education course and his knowledge was strongly influenced in all areas except the ESS concepts. So the results from these scales are positive, but tentative and strongly population dependent.

The two survey questions asking about the participants' use of knowledge and skills from the course in their current teaching and future teaching plans also provide reassuring but tentative results because the questions may have been poorly constructed. Participants recording for the first question an instructional strategy they've already tried, may have then omitted that strategy from the second question (i.e., "If I have already recorded my adoption of performance assessments, why would I say that I'll be adding them in the future?"). Evidence of this poor question construction came from a conversation with one of the participants. Needless to say, these results indicate that at the end of the course many of the participants were likely to transfer many of the instructional strategies we taught in the class into their secondary classrooms.

There was almost unanimous participant opinion that: (1) the course contributed to their understanding of instruction more so than had other education courses, and (2) all components of the course (possibly with the exception of the use of the WebCT assessments) should be included when we teach the course again. Most of the participants, at some point in the semester, expressed a desire for us to "slow down" and spend more time on the ESS content and instructional topics. We may not have met the participants' needs in this area to the degree we had hoped (see the comment at the end of Appendix F).

The sixth research question related to the implementation of the ESS content and instructional practices we had taught and the sustainability of attitudes developed in our course. Six months after the end of the semester, near the end of the public school year, we sent the follow-up survey (Appendix J) to all of the participants. Only four of the nine participants replied (one pre-service teacher and three in-service teachers).

However, the information was very favorable and provides strong evidence that at least some of our participants believe in the value and effectiveness of the strategies we taught and are implementing them to varying degrees.

One participant said, “As I approach each unit (or part of a unit) I find myself asking what is it I want the students to know and how it fits with both the National Standards and Learning Results.” This is consistent with the *backward planning* model. This same participant explicitly discussed the course’s instructional topics, the transformation of “canned” laboratory activities into inquiry-driven activities, the use of activities as performance assessments, and attempts to construct test questions that are less concrete and more directed toward the synthesis and application of understanding. “There is no way I would have even attempted to do this unit were it not for the [discussion of it] in the course.” Further, the teacher adopted the “integration of systems” as a course theme, a suggested strategy we emphasized, but stated that “this probably would have happened without the course but was certainly accelerated and emphasized by taking the course.” Lastly, the same teacher refers to the use of pre- and post-testing “a few times” and the use of “as many inquiry-based activities as possible”, but struggles with aspects of both.

A second participant reported the following: teaching a topic as a result of content knowledge and confidence gained through the course; being positively influenced to continue using the earth system as the integrated context for much of his teaching; using backward planning for one unit and desiring to use it more as time permitted; using only informal (conversational) assessments of student prerequisite knowledge; not using pre- and post-testing; using inquiry-based activities all the time, but with difficulties in

“designing the experiences skillfully enough so that they bring the student’s brain face-to-face with concepts via data and observations,” and; the frequent use of performance assessments.

Secondary science teachers know that there are strong recommendations to teach using inquiry-based activities. A third participant (a middle school teacher who had previously taken many education courses) makes reference to this prior knowledge in responses on the six-month survey, “Before beginning the course I strongly believed in providing students with hands-on, relevant, inquiry-based experiences. I would say that this course helped me re-focus on that belief. Completing the course did not result in any radical changes in my teaching style, although it did encourage me to use more inquiry-based projects....and to take the step of having students work with real data sets.” Statements such as these suggest that the course strengthened the prior beliefs held by participants, perhaps to the extent that classroom practices were then influenced.

The limited data from this six-month-later survey establishes that many of the instructional topics we taught in class are being implemented in secondary science classrooms. Due to the absence of a pre-instruction survey, it is unclear how these classroom teachers would have been teaching had they not taken the course. Nonetheless, many of our strategies and much of our content are being professionally used by our participants.

Limitations of the Findings

Several factors limit our ability to make generalizations based on these results.

1. We had a small number of participants ($n = 9$) taking the assessments. The influence of such a small sample on the power of statistical manipulations is very

dramatic. One's confidence in the applicability of the dependent-samples t-test is quite low when just one participant's responses can alter the significance.

2. The assessments were administered, in part, using the on-line WebCT program with which some participants had problems (failing internet connections and improper use of the program). These problems lowered the sample size to below nine for some of the questions.
3. The instruments we used (both the assessments for ESS content knowledge and the two surveys), though carefully created with input from all of us over many hours, weren't specifically or rigorously evaluated for reliability and validity prior to their use. We know of problems with certain questions, with the implication that there are likely to be others.

Conclusions and Implications for Future Implementation

Many of the documents associated with the reform of science education either explicitly state or imply that the current professional development needs of science teachers are more different now than they have ever been (NRC, 1995). It is now recognized that teachers need specific skills to be able to teach in a manner that develops in their students a deep and enduring understanding of scientific concepts, and develops the students' skills associated with the practice of science. And teachers must now appreciate the value of and possess the skills for accurate assessment of the effectiveness of their instruction. Our course integrated research-based curriculum design, pedagogy and assessment with content refreshment to help teachers teach more effectively.

Assessment results and anecdotal evidence indicate that the participants:

1. Valued their experiences in this course;

2. Acquired the knowledge and skills necessary to approach their teaching differently; and
3. Acquired the ability to use classroom-level education research to assess the effectiveness of what they try.

The design and implementation of the course are aligned with the goals of the new MST program at the University of Maine. The use of education research in the course enabled the participants to appreciate its value and practice skills associated with its implementation.

Teachers have been urged to do classroom-level education research since 1945 (American Council on Education), yet it is only slowly becoming common practice. Statistically, such research will always be encumbered with small sample sizes and poor controls. But, for the teachers doing the research, the results are informative because the teachers are knowledgeable about how the materials were taught, the students' strengths and weaknesses, and the local influences the school and community have on student learning. A teacher possessing this relevant information will be able to estimate the effectiveness of the instructional approaches used. Although the composition of the next group of students may be markedly different, there is a basis for planning instructional revisions. The education research we conducted forms the beginning of what we hope to be a broader effort in the Department of Earth Sciences to take a hard look at the learning that is occurring in the courses offered.

Prior to offering the course a second time we will improve it in several ways.

1. Several of the participants and instructors felt that we tried to do too much in the course. We set out to teach a course in the design, instruction, and assessment of

secondary-level Earth science content. As such, it resembled a survey course in that it didn't go into detail in any one aspect of EES or instruction. This was intentional, but also frustrating for the participants and instructors. There needs to be a tighter link between the ESS content and instructional topics during the workshop hours each week. Doing so will allow for the continued development of ESS content knowledge while the skills associated with instruction are developed.

2. The difficulties that arose with the participant-led discussions included: variable levels of preparation, depth, and accuracy of treatment; a wide range of strategies, from hands-on activities to lectures; and varying degrees of interjection from the instructors. These variations had a large impact on the depth of understanding of the targeted ESS concepts. These difficulties have not swayed our belief that participant-led discussions are excellent forums for learning, as well as a means for creating student-centered learning environments. The next time the course is offered we hope to reduce these variations by more carefully modeling the desired type of facilitation and developing guidelines and rubrics for the facilitators to use.
3. The semester project was an appropriate performance assessment for the course. We were very impressed with what the participants produced. In the future we will spread the project work over the course of the semester and align work on the project with the weekly instructional topics. That way, (a) the participants may take advantage of fresh information by transferring it directly from class to their

projects, and (b) we may monitor the generation of the projects using milestones as a means for providing feedback to the participants (Polman, 2000).

4. Continued work with our education research instruments is also warranted. The questions on the course assessment were not as tightly aligned with the eleven ESS topics as they should have been. The multiple choice version of the course assessment was created very quickly (overnight) and was based on the short answer version administered during the first class meeting. In the rapid creation of this assessment the eleven ESS topics did not receive equal treatment. Our next version of the course assessment will have two questions about each of the topics, and all true/false questions will be recast as multiple choice questions.
5. A pre-instruction survey of beliefs and attitudes about science education will be created. The addition of this instrument will help to more finely gauge the effectiveness and appropriateness of our instruction.
6. An interesting and valuable result of the course was the impact it had on the two Earth Sciences faculty. Both of them regularly make comments regarding how much more they are now thinking about the instruction of the other courses they teach. The importance of this from the perspective of pre-service teachers can not be understated as both of the faculty teach introductory-level Earth Science courses in which many education majors enroll. In light of this development, I hope that other Earth Sciences faculty will rotate through the instruction of our course as a means for increasing instructional awareness.

The design and implementation of this course are transferable to other disciplines.

All of the instructional components of the course are research-based and representative of

both quality science and science education. Presumably the ESS content could be replaced with content from any other scientific discipline. Departments across our university may find this model appropriate for creating professional development courses for secondary teachers in their disciplines.

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APPENDICES

Appendix A

EARTH SYSTEMS SCIENCE FOR TEACHERS

Instructors:

- Prof. Steve Norton, 314 BGSC, 581-2156, norton@maine.edu
- Assoc. Prof. Kirk Maasch, 125 BGSC, 581-2197, kirk@iceage.umeqs.maine.edu
- Jeff Owen, 205a BGSC, 581-2028, jeffrey.owen@umit.maine.edu
- Molly Schauffler, 103 Environmental Sciences Lab, 581-2707, mschauff@maine.edu

Class Meeting Time/Location:

- Tuesday, 4:30-7:30pm, 100 BGSC, UMaine

Course Description:

This course will cover aspects of the Earth System's dynamics and develop the concepts and skills associated with teaching that material to middle and high school students. The scientific content of the course includes the study of Earth by following the flow of energy and the cycling of matter through its many systems. The pedagogic content of the course will help teachers develop the skills associated with assessing appropriate content and delivery levels, build fundamental background knowledge for their students, developing scientific content through student inquiry, and use education research to assess student learning. The course is designed primarily with the interests and needs of current 7-12 science teachers in mind, but may also be suitable for advanced undergraduate students and pre-service teachers.

Course Objectives:

- To understand the fundamentals of the Earth System and the interactions of its sub-systems.
- To develop the skills and tools necessary to teach those fundamentals to students of grades 7-12 using student-centered pedagogies.
- To develop the skills and tools necessary to accurately assess the true learning of those students.

Content Outcomes: Throughout this course students will develop an understanding of the following concepts as they apply to the Earth System:

- | | |
|------------------------------------|-------------------------------|
| • Systems and systems interactions | • Laws of radiation |
| • Law of conservation of matter | • Laws of Newtonian motion |
| • Law of conservation of energy | • Temporal and spatial scales |

Required Materials:

- Text: Hamblin, W.K., Christiansen, E.H., *Earth's Dynamic Systems*, 9th Ed., Prentice Hall, 2001.
- Text: Anthes, R.A., *Meteorology*, 7th Ed., Prentice Hall, 1997.
- Optional Text: Wiggins, G., McTighe, J., *Understanding by Design*, Association for Supervision and Curriculum Development, 1998.

Class Sessions:

The class sessions for the semester will initially be divided into three parts. The first hour will consist of a student-led discussion of the Earth Science topic from the assigned readings. This will be your opportunity to have your understanding verified and your uncertainties clarified. Your goal for the end of this hour is to be confident that you understand that topic to the depth discussed by the student group. For this goal to be realized it is absolutely essential that all students carefully complete the reading ahead of time and fully participate in the discussion.

Following the hour of class discussion, the second hour will be spent developing the skills and tools used to discover what to teach and how to teach it in the way that leads to the best possible student understanding. Often working in small groups, we'll go through the process of unit design as recommended by some of the pre-eminent pedagogical researchers. Additionally, we'll create some useable classroom tools that you as a teacher will be able to transfer to your own classrooms. Some of the research tools we'll create and use will include:

- Student Interviews
- Assessments of prior knowledge
- Pre-/Post-instruction conceptual assessments
- Performance assessments

The third hour of each class will be spent working in groups focused on how to teach that day's Earth Science topic to students. Sometimes innovative curricula will be modeled during this time and on other days the students will work to develop activities for their students that are student-centered and scientifically valid.

Evaluation: The students in this course will be evaluated in multiple areas:

1. Class Participation—Students will be expected to fully participate in all aspects of the course including being informed participants (based on the readings) in the discussions, and active participants in all group work and task completions. This participation will be monitored in every class meeting, so please consider attendance to be mandatory. (If you must miss a class, please notify one of the instructors ahead of time and the work to be completed will be mailed to you either by e-mail or snail mail.)
2. Assignments—All assignments must be completed in a timely and thoughtful manner. Some of these will be in-class assignments and some will be to take home and complete things we've started during class.
3. Pre- and Post-Instruction Assessments—Students will complete pre- and post-instruction assessments for the course as well as weekly for each topic area that is covered.
4. Semester Project—Every student will complete a project based on one of the Case Study Topics (or another approved topic) and present the work during class at the end of the semester. Details about this project will be forthcoming. The general nature of it is to have every student create a mini-unit (appropriate for students in their current or future classrooms) that incorporates a systems approach to the Earth Science content into a student-centered pedagogy and accurately assesses the learning of the students.

Daily Schedule:

Day 1—Sept. 3

- Introductions
- Expectations and the Syllabus
- Themes—The Nature of Science and Systems Interactions
- **Content**—The Universe and Solar System
 - Guiding Questions:
 - How old is the universe and what evidence is there for its expansion?
 - How old is the Solar System?
 - Why is the Solar System structured as it is and what maintains it that way?
 - Readings
 - None
- **Pedagogical/Education Research Topic**
 - Completing the Course Pre-Instruction Assessments
 - Readings
 - None

Day 2—Sept. 10

- **Content**—The Earth System (Prof. Maasch)
 - Guiding Questions:
 - How old is the Earth?
 - What is the structure of the Earth (solid and fluid)?
 - How old are Earth's various parts?
 - What interactions exist among the various parts?
 - Readings
 - *Earth's Dynamic Systems*—Ch. 1
- **Pedagogical/Education Research Topic**
 - The "Backward Planning" concept
 - Identifying the desired learning outcomes
 - Readings
 - Wiggins and McTighe—Introduction and Ch. 1

Day 3—Sept. 17

- **Content**—Radiation and Temperature (Prof. Maasch)
 - Guiding Questions:
 - What determines the global average surface temperature on Earth and why is it relatively constant?
 - Why are the low latitudes warm and the high latitudes cold?
 - Readings
 - *Earth's Dynamic Systems*—pp. 206-214
 - *Meteorology*—Chapters 1 & 3
- **Pedagogical/Education Research Topic**
 - Determining acceptable evidence using traditional assessments
 - Readings
 - Handout—Writing Examination Questions

Day 4—Sept. 24

- **Content**—Atmospheric Circulation (Prof. Maasch)
 - Guiding Questions:
 - Why does the wind blow?
 - Why does it get colder as you go up in altitude?
 - Readings
 - *Earth's Dynamic Systems*—pp.215-218
 - *Meteorology*—Chapters 4 & 5
- **Pedagogical/Education Research Topic**
 - Determining acceptable evidence using performance assessments
 - Readings
 - Handout—Performance Assessments

Day 5—Oct. 1

- **Content**—Ocean Circulation (Prof. Maasch)
 - Guiding Questions:
 - How do we know the oceans circulate and why do they circulate?
 - What drives the tides and what influences their local magnitude?
 - What other systems are influenced by ocean circulation?
 - Readings
 - *Earth's Dynamic Systems*—pp.218-228
- **Pedagogical/Education Research Topic**
 - Planning the learning experiences—A review of the recommendations for science education
 - Readings
 - NSES—Science TEACHING standards

Day 6—Oct. 8

- **Content**—Plate Tectonics (Prof. Norton)
 - Guiding Questions:
 - What evidence is there that the continents have not always been in their current positions?
 - What evidence is there that the ocean basins are dynamic in size and shape?
 - Where do mountains come from and go?
 - What systems are influenced by the process of plate tectonics?
 - Readings
 - *Earth's Dynamic Systems*—Chapters 17-21. Read these as carefully as time allows focusing primarily on the visual and tabular material and their captions.
- **Pedagogical/Education Research Topic**
 - A model for an inquiry activity
 - Readings
 - TBA

Day 7—Oct. 22

- **Content**—The Rock Cycle (Prof. Norton)
 - Guiding Questions:
 - What evidence is there that the rock cycle is a cycle?
 - What drives the cycle?
 - How does this system interact with other systems?
 - Readings
 - *Earth's Dynamic Systems*—Chapters 4-7. Read these as carefully as time allows focusing primarily on the visual and tabular material and their captions.
- **Pedagogical/Education Research Topic**
 - Adapting traditional laboratory activities to become more student-centered and scientifically-valid
 - Readings
 - Bring to class (hardcopy!) a Rock Cycle-related laboratory activity used in your school or that is appropriate for the grade level you think you may teach.

Day 8—Oct. 29

- **Content**—Chemical Evolution of the Oceans and Atmosphere (Prof. Norton)
 - Guiding Questions:
 - What are the controls on the chemistry of the modern oceans and atmosphere?
 - Have these controls been constant through time?
 - What evidence is there for/against their change?
 - Readings
 - *Earth's Dynamic Systems*—Chapter 9 (206-220), Chapter 10
- **Pedagogical/Education Research Topic**
 - Creating projects and rubrics
 - Readings
 - Excerpts from *Designing Project-Based Science: Connecting Learners Through Guided Inquiry*

Day 9—Nov. 5

- **Content**—The Hydrologic Cycle (Prof. Norton)
 - Guiding Questions:
 - How do we know this is a cycle?
 - What drives the cycle?
 - How does this cycle interact with other systems?
 - Readings
 - *Earth's Dynamic Systems*— Chs. 12, 13, 14, & pp. 211-218
- **Pedagogical/Education Research Topic**
 - Assessing prerequisite knowledge
 - Readings
 - TBA

Day 10—Nov. 12

- **Content**—The Carbon Cycle (Prof. Norton)
 - Guiding Questions:
 - How do we know this is a cycle?
 - What drives the cycle?
 - How does this cycle interact with other systems?
 - Readings
 - *Earth's Dynamic Systems*—Reread Chapters 9 (pp. 206-209) and 10 (pp. 242-248).
- **Pedagogical/Education Research Topic**
 - Pre- and Post Assessments
 - Readings
 - TBA

Day 11—Nov. 19

- **Content**—Modern Climate (Prof. Maasch)
 - Guiding Questions:
 - What is climate?
 - What determines the distribution of the modern climatic zones?
 - Is the modern climate dynamic? What evidence is there for/against change?
 - What systems interactions involve the climate?
 - Readings
 - *Earth's Dynamic Systems*—pp. 228-234
 - *Meteorology*—Chapters 7 & 8
- **Pedagogical/Education Research Topic**
 - Student Interviews—Prepare questions
 - Readings
 - TBA

Day 12—Nov. 26

- **Content**—Humans and the Environment (Profs. Maasch and Norton)
 - Guiding Questions:
 - Do humans influence the Earth's climate?
 - Can humans change the answers to any of the questions posed for the topics discussed earlier in the course?
 - Readings
 - TBA
- **Pedagogical/Education Research Topic**
 - Student Interviews—Conduct the interview(s)
 - Readings—None

Day 13—Dec. 3 Student Project Presentations**Day 14—Dec. 10 Student Project Presentations****Day 15—Dec. 17 Student Project Presentation**

Sample Case Study Topics for the Semester Project (other topics by permission):

- Atmospheric Topics
 - Monsoons
 - Hurricanes and Tornadoes
- Hydrologic Topics
 - Floods
 - Mudslides
- Tectonic Topics
 - Earthquakes
 - Volcanoes
- Anthropogenic Topics
 - Acid Rain
 - Ozone Depletion
 - Water Contamination
 - Waste Disposal (solid, radioactive, or sewage)
 - Greenhouse Effect

Appendix B

INTERPRETATION OF THE *BACKWARD PLANNING* MODEL

(adapted from Wiggins and McTighe, 1998)

The backward planning model promoted by Wiggins and McTighe allows for the seamless integration of curriculum design decisions with those of pedagogy and assessment. Our application of the model, far reduced from authors' more thorough suggestion, may be represented by the following "steps" a teacher might consider when planning her/his instruction:

1. Decide upon the broad topic for the unit.
2. Identify the specific learning outcomes for the students to achieve by the end of the unit. To do this, refer to national and state learning standards, issues of local importance and content strengths (yours and others) locally available.
3. Prioritize those learning outcomes into three levels—**essential**, **important** and **"good to know."**
4. Plan your assessments of the learning outcomes based on their priority: for those outcomes deemed **essential**, consider some form of performance assessment; for those that are **important**, allow yourself to use assessments constructed such that students are forced to articulate their understanding and apply (or synthesize, etc.) it; and for those that are **"good to know,"** feel free to use more informal assessments, such as homework assignments, discussions and conversations.
5. Plan your instruction of the learning outcomes based on how they will be ultimately assessed. **Essential** outcomes must be learned using activities and projects that fully develop deep and enduring understanding—such activities are characterized as

being hands-on/minds-on, inquiry-based, student-centered, and use direct observations and real data. **Important** outcomes may use traditional, but possibly modified, activities—web quests, laboratories (modified to require student hypothesis testing and reflection), debates, etc. “**Good to know**” outcomes may still be taught using traditional methods, such as lecture/discussion or “canned” laboratories.

Note—The decreasing “rigor” evident in the assessment and pedagogy sections, as one moves from essential through “good to know” outcomes, is one way for instruction to reflect the prioritization of learning outcomes. However, decreasing rigor may not be appropriate as the sole factor in determining one’s instruction. Consider, too, the amount of time necessary to teach to the desired level of depth: in this light, a very good but quick inquiry-based activity may work for an outcome at any of the levels.

Additional Note—You’ll notice that “available resources” are not listed as a determining factor in the decision making process. This is intentional and exemplifies the philosophy that one may find the means to teach in the manner in which one believes—where there’s a will, there’s a way.

Appendix C

SEMESTER PROJECT DESCRIPTION

Project Description

During this semester, students in this course will practice constructing the components of a student-centered, research-based teaching program. This project asks the student to model all of these components for a single Earth systems unit of study. In a sense this is a performance assessment—you'll have practiced the parts, now demonstrate that you understand them and know how to use them together in a cohesive educational package.

Required Components—those that are starred (*) must be **conducted** during the presentation:

- Pre-Assessment—containing:
 - An assessment of the prerequisite knowledge necessary for the unit.
 - A pre-assessment for the “unit”.
 - *A pre-assessment for the lesson/activity.
- Unit Description—that:
 - States the essential questions targeted by the unit.
 - Describes the series of lessons contained in the unit.
 - Describes the range of assessments used in the unit.
- *A Sample Lesson/Activity from the Unit—that:
 - Addresses an essential question.
 - Is inquiry-based or driven by hypothesis-testing and real data or direct observations.
 - Is student-centered and requires student-to-student communication.
 - Is linked to both content and process Learning Results and/or National Standards
- Unit Assessment—that is:
 - A performance assessment.
 - Multi-brained, educative and meaningful.
 - Linked to both content and process Learning Results and/or National Standards
- Post-Assessment—containing:
 - A unit post-assessment.
 - *A lesson/activity post-assessment. (This will be given to everyone to fill out at home. In addition to the post-assessment questions it should ask for specific feedback on each part of your presentation.)
- Interpretation and impressions of the Student Interview

Other Requirements

- Time Limits—your presentation, including the three components conducted with the class, must fall between 30 and 60 minutes.
- Format—variable, but keep in mind the pedagogical goals of the course and at some point you should clearly articulate your application of the “backward planning” that led you through the entire design of your unit.
- The individual components of the project must form a cohesive whole.
- The presentation must be clear, concise and well-articulated.
- The documents must be “classroom handout” quality—clear, concise and without grammatical or spelling errors—and appropriate for the academic level of your current or future classroom.
- All parts of the project must be submitted on hard copy and on a 3.5” floppy disk. The entire electronic version will be made available to all class participants following the presentation.
- Only your disk and a rubric with comments will be returned to you.

Appendix D

TYPICAL CLASS SESSION

4:30-4:45	Welcome, announcements, and discussion of printed summary from previous week.
4:45-5:45	Participant-Facilitated Discussion on the ESS topic “Radiation and Temperature.” (Everyone was responsible for having completed the content reading.) One participant facilitated the discussion of the interactions of solar radiation with the Earth System as they relate to atmospheric temperature. Support for the facilitator was provided by one of the faculty.
5:45-5:55	Break
5:55-6:45	<ol style="list-style-type: none">1. Study the provided lists of national and state learning standards associated with Radiation and Temperature. (Everyone was responsible for having completed the pedagogical reading.) Work in small groups to prioritize them using the strategy recommended in the reading. (Curriculum Design skill development)2. The reading suggests that traditional tests are appropriate for use for less essential learning outcomes. However, these tests are typically constructed of questions requiring only “low level” thinking. Working in groups, study the Radiation and Temperature test provided by Dr. Maasch from his Atmospheres course. Following the suggestions from the reading, re-write some of the questions such that they require the application of “higher order” thinking skills. (Assessment skill development)
6:45-7:30	Work in small groups to design learning activities that might lead to deep and enduring understanding of concepts fundamental to Radiation and Temperature. (Development of activities and ideas directly transferable to secondary classrooms.)

Appendix E

HUMAN SUBJECTS RESEARCH PROPOSAL

August 27, 2002

To: College of Natural Sciences, Forestry, and Agriculture, Protection of Human Subjects Review Board

1. Summary of the Proposal

We propose to collect data regarding what the students in GES602 (086) and GES221 (086) know about general science and geology topics prior to the start of the course and again at the end of the course (see attached syllabus and sample assessment). Further, on a weekly basis we will assess their knowledge of the subject material before and after treatment in class. These assessments will be used to provide insight into the effectiveness of our pedagogical style as well as providing the participating pre- and in-service teachers with skills for their own development of assessment tools for their own courses and students.

2. Personnel

- Jeffrey Owen - BA in biology from the University of Maine (1988), 12 years experience as a high school science teacher and is a second-year student in the Center for Science and Mathematics Education Research.
- Dr. Molly Schaffler, NSF Post-doctoral Fellow, Department of Earth Sciences
- Dr. Kirk Maasch - Assoc. Professor of Earth Sciences and Climate Change Institute
- Dr. Stephen A. Norton - Professor of Earth Sciences and Climate Change Institute

3. Subject Recruitment

The subjects will be the students enrolled in GES602 (086) and GES221 (086) and will consist primarily of pre- and in-service grade 7-12 teachers.

4. Informed Consent

Students will be informed in the first class as to how we anticipate using the data provided by the assessments. We will then obtain written consent from the individual students to use their data.

5. Confidentiality

Individual assessments will be available to the individual students and all hardcopies of the data will be returned to the students at the end of the course. Electronic data will be stored on the Earth Sciences server accessible only to the above listed personnel and will be deleted after five years. The collective data will be accessible only to the above listed personnel. If the data are published, all identifying references will be removed.

6. Risks to Subjects

The assessments will be short answer and multiple-choice questions typical of many introductory courses at the University of Maine (see attached sample assessment). Because there is no risk associated with assessments of these types and the collective data will be anonymous, there are no risks to the subjects.

7. Benefits

The pre- and post-instruction assessment style in this course will allow for two things:

- A. Feedback to the personnel listed above for improving teaching effectiveness, and
- B. Teaching the skills for assessing student learning to the students in the course for use with their own students.

INFORMED CONSENT

For Participation in a Research Study

You are invited to participate in a research project being conducted by Jeffrey C. Owen, a graduate student working with the Earth Sciences Department at the University of Maine. The purposes of this research are to determine the effectiveness of the pedagogy used in GES602/221 and to begin the development of an ongoing education research program in the Earth Sciences Department.

What Will You Be Asked to Do?

If you agree to participate in this project, you will be asked to provide some demographic information and to allow Jeff to analyze and publish the data provided by the assessments used in the course. Participation will not require any of your time or effort beyond that required by the course.

Risks

There are no foreseeable risks to you in participating in this study.

Benefits

By participating, you'll benefit the education community by helping to shed light on the link between pedagogy and student learning in content-based teacher education courses. You will also receive a copy of the final analysis when it is available.

Confidentiality

Your name will not be used on any of the documents. A code number will be used to protect your identity and the key linking your name to the code number will be destroyed when the analysis is complete. The instructors of the course (Stephen Norton, Kirk Maasch, Molly Schauffler, and Jeff Owen) will be the only individuals with access to the data. All hardcopies of the data will be returned to you at the end of the course. The coded data (now anonymous) will be kept for five years, then destroyed.

Voluntary

Participation in this study is voluntary. If you choose to take part in this study, you may stop at any time. Not participating in the study will have no effect on your success in the course. Because the data for the study are in the form of responses on the course's regular assessments, non-participation will simply mean that the results of your assessments will be kept out of the study's database.

Contact Information

If you have any questions about this study, please contact me at:

Jeff Owen
205a Bryand Global Sciences Center
University of Maine
Orono, ME 04469-5790
581-2028
jeffrey.owen@umit.maine.edu

If you have any questions about your rights as a research participant, please contact Gayle Anderson, Assistant to the University of Maine's Protection of Human Subjects Review Board, at 581-1498 (or e-mail gayle.anderson@umit.maine.edu)

Informed Consent

Your signature below indicates that you have read and understand the above information and that you agree to participate in the study. You will receive a copy of this form.

Signature

Date

Appendix F

END-OF-THE-COURSE SURVEY RESULTS

Number of Students **9**

Female:Male **3:6**

Age **Mean = 30 Range = 20-42**

Education Background

- Years of Undergraduate work **Mean = 4 Range = 2.5-4.5**
- Degree or Expected Degree **B.S. = 7 B.A. = 2**
- Advanced Degree(s) **M.S. = 2 M.Ed. = 1**
- Number of college-level science courses you've taken (estimate if necessary)
Mean = 20 Range = 8-30
- Number of education courses you've taken, not including this one (estimate if necessary)
Mean = 6 Range = 0-14

For in-service teachers:

- Years in teaching **Mean = 6 Range = 2-14**
- Subjects taught **Earth Science (4), Ecology (1), Physical Science (3), Astronomy (1), Physics (3), Biology (1), Life Science (2), Chemistry (1), Environmental Science (1)**
- Grades taught **Middle School = 1 High School = 5**

For pre-service teachers and non-teachers:

- Current job/profession **Student (3), Astronomy Educator at Planetarium (1)**
- Plans for teaching or education outreach
 - In Maine? **Yes (2) No (2)**
 - Grade level(s)/ages **Middle School = 2 High School = 2**
 - Subject(s)/concentrations **Earth Science (2), Natural Science (1) Math/Science (1)**

What other, non-teaching (non-classroom) experiences have you had in the sciences over the past ten years that have (or will have) an influence on your ability to teach science?

Research (2) Outreach Education (1) Park Ranger (1)
Aquaculture (1)

Why did you take this course? What specific goals did you have?

Nine Respondents:

Improve Earth Science content knowledge (3)
Improve pedagogical knowledge and teaching skills (8)
Improve ability to teach standards in Earth Science context (2)
Required (1)
Interest (2)

To what degree has this course:

- Influenced your knowledge of Earth Science content? Please circle a number:

1 2 3 4 5
weakly strongly **Mean = 3.4**

- Influenced your knowledge of science pedagogy? Please circle a number:

1 2 3 4 5
weakly strongly **Mean = 3.6**

- Influenced your knowledge of curriculum design? Please circle a number:

1 2 3 4 5

weakly strongly Mean = 3.3

- Influenced your knowledge of student assessment and its uses? Please circle a number:

1 2 3 4 5

weakly strongly Mean = 3.6

In-Service Teachers: Are there any components of this course that you have already incorporated directly into your teaching or work? **Yes = 5** **No = 0**

- If yes, specifically which ones? **Five Respondents:**

Backward Planning	3
Inquiry-Based Activities	4
Performance Assessments	2
Assessment of Prerequisite Knowledge	2
Pre-/Post-Testing	2

Are there any components of this course that you will likely incorporate directly into your teaching or work in the future? **Yes = 9** **No = 0**

- If yes, specifically which ones? **Seven Respondents:**

Inquiry-based Projects or Activities	7
Backward Planning	5
Performance Assessments	3

Compare your perceived gain in understanding resulting from this course to that of:

- Other science content courses
Greater = 1
Greater on some topics = 3
Lesser = 4
- Other education courses
Much Greater = 4
Greater = 1
Lesser = 1 (had already taken courses that specifically dealt with each topic)
Can't Say = 2 (this was the first education course)

On-line Assessments—please circle one number for each bullet:

- How convenient was it for you to access the WebCT program every week?
1 2 3 4 5
very very
inconvenient convenient
Mean = 4.1
- How frequently did you experience problems with the WebCT program?
1 2 3 4 5
never very frequently
 (i.e., every week)
Mean = 2.4
- Generally speaking, how serious was your approach to taking the assessments?
1 2 3 4 5
not very
serious at all serious
Mean = 3.8

On the Pre-Tests, how frequently did you find yourself guessing?

- 1 2 3 4 5
never very frequently **Mean = 2.6**
(i.e., multiple times every week)
- How frequently did you find Post-Test questions that were not covered in either the readings or discussions?
1 2 3 4 5
never very frequently **Mean = 3.3**
(i.e., multiple times every week)

For each component of the course listed below, please comment on whether we should change it (and how) in the future or keep it essentially the same: **Eight Respondents:**

- Having a mix of classes devoted to pedagogy, curriculum design and assessment
Keep “as is” (4)
Change some (4) “...to allow more focused study of each”*
Discard (0)
- Student-led content discussions
Keep “as is” (4)
Change some (3) “...to help insure that the discussions are all thorough.”
Discard (1) “...because teachers are good didactic learners.”
- Project
Keep “as is” (4)
Change some (4)
Discard (0)
- On-line assessments
Keep “as is” (2)
Change some (4)
Discard (1)

To what degree did the course meet your goals? **Eight Respondents:**

Yes (4)
In Part (4)
No (0)

Inquiry-based activities should be used as much as possible, particularly for those learning outcomes deemed absolutely essential. Do you agree or disagree? Please explain. **Seven Respondents:**

Yes (3)
Yes, with care (3)
Yes, but still uncertain how (1)
No (0)

*** The implication of this was the single most common comment we heard during the semester. We tried to do a lot every class meeting and frequently had to cut off discussions or activities in order to move along. Unfortunately, the things that most frequently got cut off were the penetrating discussions of how to do the instructional activities.**

Appendix G

ASSESSMENT OF PREREQUISITE KNOWLEDGE

Please circle the most correct response:

1. Which statement best describes the mass of an object?
 - a. The amount of space an object takes up.
 - b. The amount of matter that is contained in an object.
 - c. The amount of matter and area an object occupies.
2. Which statement best describes the volume of an object?
 - a. The amount of matter in an object.
 - b. The amount of space an object occupies.
 - c. The amount an object weighs.
3. Which body has the most kinetic energy?
 - a. A ball at rest on the ground.
 - b. A person walking down the street.
 - c. An elephant standing at the top of a tall building.
4. Which body has the most potential energy?
 - a. A ball at rest on the ground.
 - b. A person walking down the street.
 - c. An elephant standing at the top of a tall building.
5. Which statement best describes density?
 - a. A comparison of the length and height of an object.
 - b. A comparison of the mass and volume of an object.
 - c. A comparison of the area and height of an object.
6. The quantity that tells us how warm or cold an object is with respect to some standard is:
 - a. energy
 - b. temperature
 - c. calorie

7. Which statement best describes heat?
- a. The temperature of an object.
 - b. The energy lost or gained by an object.
 - c. The total energy of an object.
8. The amount of water a submerged object displaces is representative of the object's:
- a. mass
 - b. volume
 - c. density
9. If a runner completes a 10 km road race in 45 minutes, what is her rate in miles per hour? 1 km is equal to 0.62 miles
- a. 8.3 miles/hour
 - b. 13.3 miles/hour
 - c. 16.1 miles/hour
10. If the same runner (problem 9) wanted to run a marathon (26.2 miles), what would her approximate time in hours be if her rate remained steady?
- a. 3.6 hours
 - b. 3.2 hours
 - c. 4.0 hours
11. The earth's age is approximately 4,500,000,000 years. It can best be expressed in number format as:
- a. $(4) * (500,000,000)$
 - b. (4.5×10^9)
 - c. $10^{4.5}$

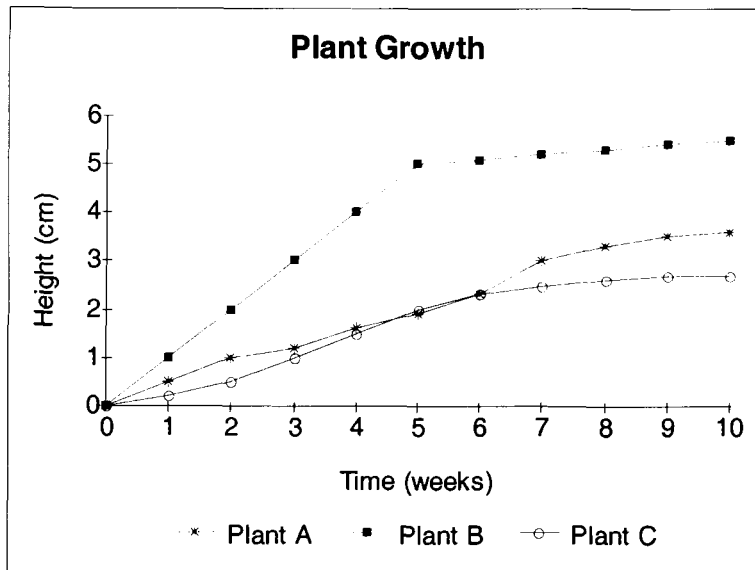


Figure 1

Refer to Figure 1 to answer questions 12-14

12. Which plant grew the most during the first 3 weeks?

- a. Plant A
- b. Plant B
- c. Plant C

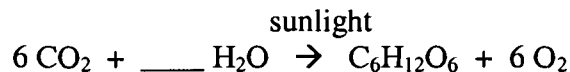
13. Which plant had the greatest growth between week 6 and 7?

- a. Plant A
- b. Plant B
- c. Plant C

14. Which plant grew the least over 10 weeks?

- a. Plant A
- b. Plant B
- c. Plant C

Using the following incomplete chemical equation, answer questions 15 and 16.



15. What number should occupy the blank to make the chemical equation balanced?

- a. 6
- b. 12
- c. 3

16. How many carbon atoms are there on the reactant (left) side of the equation?

- a. 1
- b. 12
- c. 6

17. Balancing chemical equations is an application of what Law of Conservation?

- a. Momentum
- b. Energy
- c. Matter

Use the following statement of Newton's 2nd Law of Motion to answer questions 18 – 20:

Newton's 2nd Law of Motion states: "whenever an unbalanced force acts on a body, it produces an acceleration that is directly proportional to the force and inversely proportional to the mass of the body." [Force = (Mass) * (Acceleration)]

Force in Newtons (N)

Mass in kilograms (kg)

Acceleration in meters per second per second (m/s^2)

18. If an object is accelerating at 5.5 m/s^2 and has a mass of 7.0 kg, what is the force applied to the object?

- a. 40.0 N
- b. 1.3 N
- c. 38.5 N

19. If an object is under a force of 23.2 N and has a mass of 0.5 kg, what is the acceleration of the object?

- a. 46.4 m/s²
- b. 11.6 m/s²
- c. 13.3 m/s²

20. If an object is traveling at a constant velocity of 20.0 m/s and has a mass of 12.0 kg, what is the value of the net force acting on the object to maintain the velocity?

- a. 240.0 N
- b. 1.7 N
- c. 0.0 N

Appendix H

PRE- AND POST-INSTRUCTION ESS TOPIC ASSESSMENTS

Atmospheric Circulation

1. A land-breeze is formed when:
 - a. the air temperature above the ocean is warmer than above the land.
 - b. the air pressure above the ocean is higher than above the land.
 - c. tidal currents draw warm air off the shore.

2. An unbalanced pressure gradient in the atmosphere will cause air to move from:
 - a. low pressure to high pressure
 - b. high pressure to low pressure
 - c. either high pressure to high pressure or low pressure to low pressure

3. The Coriolis Force is stronger at high latitudes because:
 - a. cold polar air deflects surface winds very easily creating cyclical wind patterns.
 - b. polar air is subject to higher pressure and exerts a force on the surface winds.
 - c. polar air is circulating more rapidly around a vertical axis than air at lower latitudes.

4. The Ideal Gas law states that:
 - a. the pressure, temperature, and viscosity of any fluid are related.
 - b. the density, volume, and viscosity of any fluid are related.
 - c. the density, temperature, and pressure of any fluid are related.

5. Hydrostatic Equilibrium is best described as:
 - a. a balanced relationship between hot and cold air masses.
 - b. a balance between vertical pressure gradient force in the atmosphere and gravity.
 - c. a balance between the density of the atmosphere and its pressure.

Carbon Cycle

1. In the past century, carbon dioxide levels have increased dramatically in the earth's atmosphere. Which statement best describes the situation?
 - a. The carbon in the atmosphere is not in a steady state with the biosphere.
 - b. The carbon in the atmosphere is in a steady state with the biosphere.
 - c. The carbon in the atmosphere is in equilibrium with the oceans.
2. Which of the following processes represents the greatest input to the atmospheric carbon reservoir?
 - a. fermentation
 - b. photosynthesis
 - c. respiration
3. Which of the following is the largest carbon reservoir at or near the earth's surface?
 - a. living biomass
 - b. limestone
 - c. fossil fuels
4. Which of the following carbon reservoirs has the longest residence time?
 - a. terrestrial living biomass
 - b. the Oceans
 - c. the Atmosphere
5. Plate tectonics interacts with the Carbon Cycle in what way?
 - a. It provides the return flux of carbon dioxide from metamorphosing rocks and volcanoes to the atmosphere.
 - b. It provides a short-term (less than 100 years) exchange of carbon dioxide between the earth's mantle and the atmosphere.
 - c. It provides a one-way flux to bury carbon that is bound in rocks in the earth's interior without letting it back into the atmosphere.

Chemical Evolution of Oceans/Atmosphere

1. The oceans are saturated with respect to calcium carbonate. Weathering of which of the following minerals will change the carbon dioxide in the atmosphere?
 - a. calcium carbonate
 - b. silicon dioxide
 - c. calcium silicate
2. The oceans are unsaturated with respect to nearly all minerals. This is most likely caused by:
 - a. biological and chemical processes removing dissolved material from the water.
 - b. the ocean waters not accumulating dissolved material for a sufficiently long period.
 - c. the water temperature at the equator being too high to allow for saturation.
3. The oxygenation of the earth's oceans and atmospheres can be explained through the:
 - a. evolution of the photosynthetic process.
 - b. release of bound oxygen from silicate minerals through chemical weathering.
 - c. photo-dissociation of water molecules by sunlight.
4. Which of the following gasses is likely to have been de-gassed from the earth's interior?
 - a. oxygen
 - b. hydrogen
 - c. carbon
5. Which of the following rocks gives us information about the oxygen state of the atmosphere?
 - a. an igneous rock such as granite
 - b. a fossiliferous limestone
 - c. ancient sand dune deposits

Earth System

1. The age of the earth is best determined by a radioactive isotope having a half-life of:
 - a. 5,370 years.
 - b. 1.3 billion years.
 - c. 0.5 million years.
2. The seasons of Earth are controlled by:
 - a. the earth's distance from the sun.
 - b. the solar output of the sun.
 - c. the angle of the earth's tilt.
3. The Earth System can best be characterized as:
 - a. a static and fairly uniform system with predictable components.
 - b. a dynamic system with fairly predictable components.
 - c. a dynamic system with components that are sometimes predictable.
4. Which of the following properties **does not** increase consistently from space to the core of the earth?
 - a. viscosity
 - b. density
 - c. temperature
5. A negative feedback in a system will cause:
 - a. the system to move toward equilibrium.
 - b. the system to move away from equilibrium.
 - c. the system to remain in an unbalanced state.

Humans and the Environment

1. The burning of fossil fuels most immediately involves:
 - a. a reservoir of the carbon cycle.
 - b. the short-term climate change.
 - c. the limestone reservoir of the rock cycle.
2. Strip mining creates an environmental hazard because it:
 - a. creates the potential for land subsidence.
 - b. exposes compounds produced in anaerobic conditions to weathering.
 - c. raises the pH, causing metal pollution in surface water.
3. Which of the following Earth systems could show the most rapid changes due to human activities?
 - a. the chemical composition of the biosphere
 - b. the chemical composition of the hydrosphere
 - c. the chemical composition of the atmosphere
4. World climate is known to have cooled from 1940 to 1970. The most plausible explanation for this is:
 - a. an increase in atmospheric carbon dioxide.
 - b. the depletion of oxygen due to the burning of fossil fuels.
 - c. an increase in emissions of particulate matter to the atmosphere.
5. The bull's eye for the emission of most air pollutants in the U.S. is the Ohio River valley. If you were to document this fact, where and at what frequency would you document the effects of these emissions on surface water chemistry?
 - a. annually in large streams draining agricultural land
 - b. monthly in headwater streams draining forestland
 - c. weekly in very deep lakes in the upper Midwest (for example, Lake Superior)

Hydrologic Cycle

1. As water changes states from solid to liquid to gas the following is true:
 - a. Energy must be released throughout the entire process.
 - b. Energy is absorbed throughout the entire process.
 - c. Heat is required but no energy is absorbed or released by the water.
2. Which freshwater reservoir contains the highest percentage of the earth's freshwater?
 - a. groundwater
 - b. lakes, ponds and rivers
 - c. glaciers/ice sheets
3. What is the best line of evidence suggesting that the hydrologic cycle is indeed a cycle?
 - a. The earth's ocean levels are not dropping.
 - b. The frequency of wet and dry periods is globally constant.
 - c. In past ice ages, the ocean levels increased as ice sheets grew in the Northern Hemisphere.
4. The main driving forces of the hydrologic cycle are solar input to the earth and
 - a. wind
 - b. evaporation
 - c. gravity
5. The density of water _____ when water changes from a solid to a liquid.
 - a. increases
 - b. remains constant
 - c. decreases

Modern Climate

1. A geographic region's _____ exerts the greatest influence over region's temperature.
 - a. longitude
 - b. latitude
 - c. proximity to an ocean
2. Which of the following **is not** evidence that Earth's climate has fluctuated over time?
 - a. Sedimentary rocks in Alaska indicate that the area was once at high latitude and warm.
 - b. Recent (last 100 years) journal entries and paintings that depict a cooler than present day average temperature in England.
 - c. The changing location of the continents over millions of years and the locations of modern day continents.
3. The best way to describe the climate of a region is by its:
 - a. position relative to the mountains and coastlines of its continent.
 - b. daily weather conditions over a month's time and the average number of severe storms.
 - c. average annual precipitation and temperatures for at least the past century.
4. It is difficult to forecast future changes in the global climate because:
 - a. it is a dynamic system that naturally fluctuates due to the influence of many factors.
 - b. humans have altered all components of the climate system and we can't predict the collective impact these changes will have.
 - c. our understanding of climate is in its infancy due to the lack of climate data prior to the 1800s.
5. Oceans moderate the climate of coastal regions because:
 - a. they influence the direction of upper atmospheric winds.
 - b. of the water's relatively high heat capacity.
 - c. the mixing of the freshwater and salt water alters the local balance of atmospheric and oceanic carbon.

Ocean Circulation

1. Surface circulation of the oceans is driven by:
 - a. the tidal flow of the water.
 - b. the Coriolis Force exerted on the water.
 - c. the earth's surface winds.
2. Tides and their magnitude are controlled by:
 - a. gravitational interactions of the earth, moon and the sun.
 - b. gravitational interactions of the earth and the moon.
 - c. gravitational interactions of the earth and the sun.
3. Which of the following is most responsible for influencing the quality and quantity of ocean fisheries?
 - a. local climate patterns
 - b. ocean upwelling
 - c. tidal patterns
4. Over the course of Earth's history, which of the following has had the greatest influence on the circulation of the oceans?
 - a. reversals of Earth's magnetic field
 - b. changes in the distribution of the continents
 - c. changes in solar insolation due to shifts in Earth's orbit
5. Deep ocean currents are most likely caused by:
 - a. differences in the salinity and temperature of water masses.
 - b. surface winds and other atmospheric disturbances.
 - c. differences in the pressure exerted on a water mass as it descends.

Plate Tectonics

1. At an oceanic rift zone, oceanic crust:
 - a. becomes younger as you move away from the rift.
 - b. becomes older as you move away from the rift.
 - c. is roughly the same age at all distances from the rift.
2. At a converging oceanic plate/continental plate boundary, the following events would occur:
 - a. Continental crust is subducted, creating a band of volcanoes above the subduction zone.
 - b. Both the oceanic crust and the continental crust will collide, without subduction, creating a massive mountain range.
 - c. Oceanic crust is subducted, creating a band of volcanoes above the subduction zone.
3. The plate tectonics model depends on:
 - a. a brittle upper mantle/crust.
 - b. a brittle lower mantle (asthenosphere).
 - c. a brittle continental crust.
4. The most plausible line of evidence that supports the Theory of Plate Tectonics includes:
 - a. magnetic anomalies, mantle convection, and large mountain ranges along transform boundaries.
 - b. fossil correlation, location of volcanoes and earthquakes, and a static seafloor.
 - c. continental shelf geometry, magnetic anomalies, and matching rocks from different continents.
5. With oceanic crust being constantly formed at a spreading center, how is the law of conservation of matter satisfied?
 - a. the weathering and erosion of continental coastlines
 - b. the subduction of oceanic crust
 - c. oceanic crust becoming continental crust at a convergent zone

Radiation & Temperature

1. In general, what can be said about the Electromagnetic Spectrum?
 - a. The energy of radiation increases as the wavelength increases.
 - b. The energy of radiation decreases as the wavelength increases.
 - c. The energy of radiation is independent of both its wavelength and frequency.
2. Heat that is transferred by conduction is accomplished by:
 - a. electromagnetic waves moving through the substance.
 - b. the circulation patterns present in the fluid.
 - c. direct contact between individual molecules.
3. If the earth's energy system is balanced, what must be true?
 - a. The energy received by the earth from the sun is balanced by the earth's own internal heat energy.
 - b. The earth is receiving from the sun the same amount of energy needed by all of the earth's systems.
 - c. The earth's surface is emitting as much energy as it receives.
4. The greenhouse effect on Earth occurs because some gases absorb outgoing radiation and re-emit _____ radiation back to the earth.
 - a. infrared
 - b. gamma
 - c. ultraviolet
5. Which of the following **is not** a true statement?
 - a. 50% of the radiation that enters the earth's atmosphere reaches the earth's surface.
 - b. 50% of the radiation is absorbed or reflected by the earth's by the atmosphere.
 - c. 50% of the radiation is reflected by the earth's surface.

The Rock Cycle

1. Which piece of evidence provides the strongest argument that there is a rock cycle?
 - a. The local stream is transporting a collection of boulders, pebbles, and sand.
 - b. The mountain near your house has a variety of rock types at the highest points.
 - c. Earthquakes seem to occur most frequently in particular areas.
2. Which type of weathering influences the exposed bedrock of an inter-tidal zone most?
 - a. chemical
 - b. biological
 - c. mechanical
3. Which of the following **is not** a correct statement describing the conversion of a sedimentary rock into a metamorphic rock?
 - a. Altering the rock's mineral composition using specific chemicals from the surrounding environment over a long period of time.
 - b. Mechanical weathering of the rock and subsequent re-deposition of the minerals.
 - c. Exposing the rock to elevated temperature and pressure.
4. Which of the following involves the smallest interaction with the rock cycle?
 - a. The hydrologic cycle involves sediment transfer and chemical weathering.
 - b. Biological interactions lead to the formation of sedimentary rock on land.
 - c. The carbon cycle releases inorganic carbon into the oceans allowing the formation of coral reefs.
5. Which statement explains most strongly why the oceans are not saturated with dissolved material?
 - a. Biological and chemical activities in the oceans remove the dissolved material over time.
 - b. The constant input of freshwater from the atmosphere, land and ice to the oceans prevents the oceans from becoming saturated.
 - c. The oceans transport the dissolved material to the polar regions of the earth where it is deposited.

Appendix I

PRE- AND POST-INSTRUCTION COURSE ASSESSMENT

The correct response for each question is shown in ***bold/italics***.

1. The best evidence used to estimate the age of the earth by contemporary scientists is:
 - a. Fossil and stratigraphic records.
 - b. Radioactive elements found in rocks with a half-life in the billions of years.***
 - c. Radioactive carbon-14 dating of ancient rocks.

Answer Option	Pre-Course Frequencies	Post-Course Frequencies
a	.125	0.000
<i>b</i>	<i>.750</i>	<i>1.000</i>
c	.125	0.000

2. The tilt of the earth's axis remains constant with respect to Earth's orbit over the course of a year.
 - a. True***
 - b. False

Answer Option	Pre-Course Frequencies	Post-Course Frequencies
<i>a</i>	<i>.667</i>	<i>.444</i>
b	.333	.556

3. The path of the earth around the sun is slightly elliptical (nearly circular).
 - a. True***
 - b. False

Answer Option	Pre-Course Frequencies	Post-Course Frequencies
<i>a</i>	<i>.875</i>	<i>1.000</i>
b	.125	0.000

4. There is a net surplus of radiation energy at:
 - a. High latitudes.
 - b. Low latitudes***
 - c. Neither high nor low latitudes due to atmospheric circulation.

Answer Option	Pre-Course Frequencies	Post-Course Frequencies
a	.125	.111
<i>b</i>	<i>.625</i>	<i>.667</i>
c	.250	.222

5. When the energy of incoming solar radiation exceeds the energy released to space:
- The greenhouse effect causes the upper atmosphere to heat.
 - There is a net deficit of energy in the atmosphere.
 - The energy emitted from Earth increases.***

Answer Option	Pre-Course Frequencies	Post-Course Frequencies
a	.875	.556
b	0.000	0.000
c	.125	.444

6. The primary (first order) cause of large-scale wind is:
- The Coriolis Effect, a rotational effect that causes air to circulate.
 - Horizontal pressure gradients.
 - Differential heating of the earth's surface.***

Answer Option	Pre-Course Frequencies	Post-Course Frequencies
a	.125	0.000
b	0.000	0.000
c	.875	1.000

7. If an entire column of air is cooled, what happens to the density gradient from the bottom to the top?
- It increases***
 - It decreases
 - It remains constant

Answer Option	Pre-Course Frequencies	Post-Course Frequencies
a	.333	.444
b	0.000	.111
c	.667	.444

8. The surface waters of the oceans circulate because of water temperature gradients.
- True
 - False***

Answer Option	Pre-Course Frequencies	Post-Course Frequencies
a	.556	0.000
b	.444	1.000

9. Coastal upwelling in the ocean is driven by:
- Deep water being heated by geothermal energy causing the water's density to decrease.
 - Deep water currents rising up along continental shelves.
 - Deep water being pulled up as surface water is pushed away by the wind.***

Answer Option	Pre-Course Frequencies	Post-Course Frequencies
a	.111	0.000
b	.667	.111
c	.222	.889

10. A primary source of evidence for plate tectonics is the convective movements within the earth's mantle.
- True
 - False***

Answer Option	Pre-Course Frequencies	Post-Course Frequencies
a	.143	.111
b	.857	.889

11. Subduction occurs when continental crust is driven beneath the more dense, less mobile oceanic crust.
- True
 - False***

Answer Option	Pre-Course Frequencies	Post-Course Frequencies
a	.111	0.000
b	.889	1.000

12. The most plausible explanation for a marine fossil high in the bedrock of the alps is:
- Crustal uplift.***
 - Sea-level lowering.
 - Glacial rebound.

Answer Option	Pre-Course Frequencies	Post-Course Frequencies
a	.889	.889
b	.111	0.000
c	0.000	.111

13. If average global rainfall increases by 20%, global sea-level will:

- a. Rise.
- b. Lower.
- c. ***Remain constant.***

Answer Option	Pre-Course Frequencies	Post-Course Frequencies
a	.222	.111
b	0.000	0.000
c	.778	.889

14. Evaporation is an excellent example of the law of conservation of energy because the water molecules':

- a. ***Kinetic energy increases.***
- b. Temperature increases.
- c. Potential energy increases.

Answer Option	Pre-Course Frequencies	Post-Course Frequencies
a	.667	.778
b	0.000	0.000
c	.333	.222

15. It is possible to change a body's temperature without adding or removing heat.

- a. ***True***
- b. False

Answer Option	Pre-Course Frequencies	Post-Course Frequencies
a	.333	.222
b	.667	.778

16. In the absence of human activities, the pH of atmospheric precipitation in Maine would be:

- a. ***Slightly acidic.***
- b. Approximately neutral.
- c. Slightly basic.

Answer Option	Pre-Course Frequencies	Post-Course Frequencies
a	.875	<i>1.000</i>
b	.125	0.000
c	0.000	0.000

Appendix J

TEACHER SURVEY—SIX MONTHS LATER

I'm exceedingly interested in the degree to which your beliefs and/or instructional practices have been influenced by the course you took last fall. In other words, have any of the topics we covered been incorporated into classroom practice? The questions that follow are quite specific to what you've done with your classes this spring. However, if there are any topics/approaches that you haven't employed but that you believe are valuable, I'd like to hear those stories as well (i.e., what barriers have you encountered that are preventing you from transferring beliefs into practices?). Please be as specific as you can and if there are any documents that you could attach to show whatever it is you are describing I'd really like to see those, too.

1. Regarding your Earth Systems Science content knowledge—Are there any concepts that you taught this spring that you would either not have taught or would have taught with less confidence had you not taken GES602?
2. Has taking the course influenced your use of the Earth System as a scientifically integrated context in which to teach your units?
3. Have you employed any of the following? (Where possible, please comment on the degree to which you found the activity valuable.)
 - a. Backward Planning in order to determine the outcomes for a unit, prioritize those outcomes, and plan instructional activities that reflect that prioritization.
 - b. Assessments of Prerequisite content knowledge to determine the degree to which your students are prepared for a lesson or unit as you have designed it.
 - c. Pre- and Post-Assessments of content knowledge, used in combination, such that you can get an indication of the effectiveness of a particular lesson or unit.
 - d. Student Interviews where you have used detailed conversations with students to determine the true nature of their understandings.
 - e. Inquiry-based activities that allow students to confront their understandings of concepts through the interpretation of data and/or observations they've collected.
 - f. Performance Assessments at the ends of units such that students have some flexibility in demonstrating their understanding of the units' essential concepts.

BIOGRAPHY OF THE AUTHOR

Jeffrey C. Owen was born in Champagne, Illinois on January 23, 1966. He was raised in Orono, Maine, graduated from Orono High School in 1984, and, in 1988, graduated from The University of Maine with a Bachelor of Science (in Biology). Jeff was a secondary science teacher for twelve years before returning to The University of Maine as a full-time graduate student. He is a member of the National Association of Geoscience Teachers and in September of 2003 became the assistant director of the Center for Science and Mathematics Education Research at The University of Maine. He is a candidate for the Master of Science in Teaching degree from The University of Maine in December, 2003.