Earth System Science Education Alliance: Online Professional Development for K-12 Teachers

Theresa G. Schwerin — Associate Director, Education, Institute for Global Environmental Strategies (IGES), 1600 Wilson Blvd., Suite 901, Arlington, VA 22044, theresa_schwerin@strategies.org

James Botti — K-16 PBL Consortium, jimbotti@comcast.net

Claudia Dauksys — Institute for Global Environmental Strategies (IGES), 1600 Wilson Blvd., Suite 901, Arlington, VA 22044, claudia_dauksys@strategies.org

Russanne Low — Director of Strategic Partnerships, UCAR/DLESE, FL4, Room 3316, PO Box 3000, Boulder, CO 80307-3000, rlow@ucar.edu

Robert Myers — Executive Director, Challenger Space Center, 21170 North 83rd Ave., Peoria, AZ 85382, bmyers@azchallenger.net

William Slattery — Department of Geological Sciences, Wright State University, Dayton, OH 45435-0001, william.slattery@wright.edu

ABSTRACT

Colleges and universities across the U.S. are offering online Earth system science courses for K-12 teachers through NASA's ESSEA program. The three available courses-for teachers of grades K-4, 5-8, and 9-12-are delivered online and feature student-centered, knowledge-building virtual communities. The courses were developed for NASA within the Center for Educational Technologies (CET) at Wheeling Jesuit University. The Institute for Global Environmental Strategies (IGES) and CET managed ESSEA through NASA funding. Twenty participating colleges, universities, and education organizations were competitively selected to receive funding and training for running the courses and continuing support from IGES and CET. From 2000-2006, 1,707 teachers from across the U.S. completed a semester or quarter long ESSEA course from one of the participating institutions. Pre- and post-course surveys, follow-up surveys, and case studies with course participants show that the courses have had a significant impact on teachers' content knowledge, attitudes and practices. ESSEA has also shown that the courses are capable of being sustained beyond the original NASA funding. Seventeen of the participating schools report that they will continue offering the courses and many have developed new programs that incorporate the courses or foster continued Earth system science education opportunities for teachers.

INTRODUCTION

The Earth System Science Education Alliance (ESSEA) is a NASA-funded program that was designed to:

- strengthen K-12 educators' understanding of Earth system science,
- demonstrate the ability to deliver exceptional K-12 teacher professional development over the Internet to a national audience in great need of such training, and
- create an infrastructure capable of sustaining Earth system science teacher professional development after the initial NASA support had ended.

The Institute for Global Environmental Strategies (IGES) and the Center for Education Technologies (CET) at Wheeling Jesuit University managed ESSEA through funding from 2000-2005 from NASA's Earth science education program.

The program is based on three online graduate-level courses - for K-4, 5-8, and 9-12 teachers. The courses were developed within the Center for Educational Technologies at Wheeling Jesuit University (WJU), and were piloted at WJU during the mid-1990s, before being rolled out for implementation through ESSEA at colleges and universities across the U.S. beginning in 2000.

Participating colleges, universities and other education organizations were selected to offer the ESSEA courses through a request for proposals that was released annually by IGES in 2000, 2001, and 2002. Institutions were evaluated and selected based on the following criteria:

- The proposing team's capabilities and expertise in K-12 teacher education and professional development; Earth system science; and online instruction.
- Evidence of long-term commitment to offering the ESSEA courses beyond the three-year funding, as well as potential scale-ability for offering the courses.
- Capability to recruit and retain teacher participants in the courses, including the organizations' ability to recruit teachers who serve minority, disadvantaged and underrepresented populations.
- Ability to participate in the program-wide evaluation and plans for any additional activities to meet local evaluation needs.
- A reasonable and realistic budget was presented. Consideration was also given to the extent that leveraging existing programs, products and other resources was presented in the proposal.

All participating colleges, universities and education organizations were required to provide either three semester hours of graduate credits or the equivalent quarter hour or continuing education units for teachers successfully completing an ESSEA course. The majority of ESSEA organizations were colleges or universities; three were non-profit education organizations that worked with colleges or universities of record to provide credits for teachers. These included the Gulf of Maine Aquarium (accreditation from University of Southern Maine); WestEd (accreditation from Weber State University), and Mid-continent Research for Education

Figure 1. ESSEA Institutions. This map shows the 20 institutions that were selected to offer online Earth system science courses for teachers. Minority-Serving Institutions (MSI) are noted with dark dots.

and Learning (McREL, accreditation from Colorado School of Mines).

Proposals were selected using both mail and panel review, including reviewers with expertise in Earth system science, teacher professional development, and online instruction. IGES made the final selection, with NASA concurrence. Figure 1 shows institutions that were selected to participate in ESSEA.

Each participating institution received total funding of $45,000 over three years. Funding was also provided for up to two representatives from each organization to attend an initial four-day training workshop, which provided instruction in how to run the course. Two representatives from each institution were required to attend an annual program review, where they reported on their progress and challenges, as well as learned about new resources, programs, and approaches to Earth system science education.

STRUCTURE OF THE COURSE

The three ESSEA courses share numerous design similarities. All three are 16-weeks in duration, including a three-week introduction to inquiry and Earth systems science analysis through teamwork. This startup time is followed by four three-week cycles. Each week contains individual and group activities, action and reflection, independent and collaborative tasks. These juxtapositions create the need to consolidate understanding and present it to others or reflect on it in a private journal or discussion space. The last week of each course is for an individual final project.

Four main areas greet course participants on the home page of each course:

- *Introduction* provides a general overview of the course, briefly summarizes the collaborative methodology, goals, expectations for participation, and provides "getting started" resources on Earth system science, inquiry and other topics. This section is designed to provide a common understanding of the "operating procedures" of the course, so participants have a structure to begin with, which requires participation and rigorous thinking. This section includes an overview of grading and assessment to make the criteria for success clear and accessible.

- *Guide* provides resources and tips for students to be successful in an online learning community, e.g., "Joining the Community", "Knowing Your Facilitator," "How to Sit in the Front," and "Learning in an Online Community" are examples of resources available in this section.

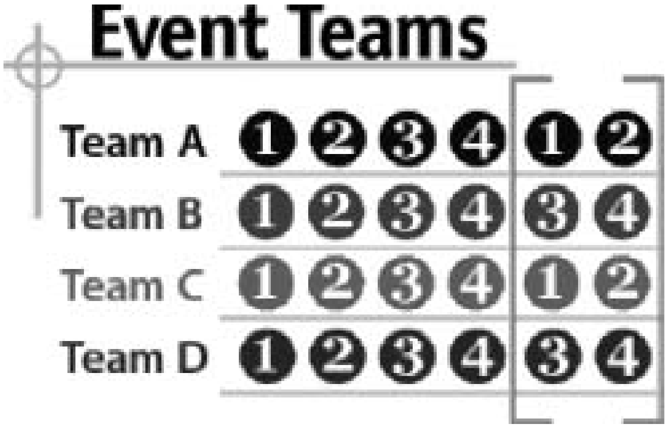
- *Weekly Course Outline* is a week-by-week outline for the 16 weeks, which shows the theme, goals, and specific assignments and requirements for each week.

- *Classroom* is where participants link to the "virtual spaces" of the courses that are used for discussion and collaboration with other participants and the instructor, including threaded discussions, posting assignments and resources, and reflection space. All course communication, except private emails, takes place in the virtual spaces found in the Classroom section.

The design of the courses built in explicit learning experiences focusing on theory, modeling, practice, feedback and coaching. These elements are considered essential when designing in-service education (Joyce and Showers,1980). The design framework also contains elements that are patterned after the first three National Research Council professional development standards summarized as learning science, learning to teach science and learning to learn (AAAS, 1996). Research suggests that teacher professional development programs that convey complex skills must contain modeling to be successful (Jeanpierre, et al., 2005; Joyce and Showers, 1980; and Reitzug, 2002). In the courses, instructors model what teachers are expected to do in their own classrooms. Teachers learn Earth system science content in a learner-centered way, exactly as they will have their own students learn content. Reflective learning and metacognition is addressed through pre-activity journaling asking teachers to state their own theories or beliefs, knowledge and goals for their own increased understandings. Post-activity journal entries ensure that teachers see and reflect upon what they have learned and how they learned it. Each course also provides opportunities for teachers to create original classroom applications of the content they have learned.

Each course provides "spaces" that define, support, and refine participant roles and tasks, and include areas for whole class discussion and collection of resources and activities, small group discussion spaces and individual reflection space. Discussion roles that occur within the personal journals and learning spaces are carefully scaffolded to promote the modes of thought required for each task. Scaffolding is a process in which students are given more support until they can apply new skills and strategies independently (Rosenshine and Meister, 1992).

The online environment supports the development and maintenance of a learning community in some



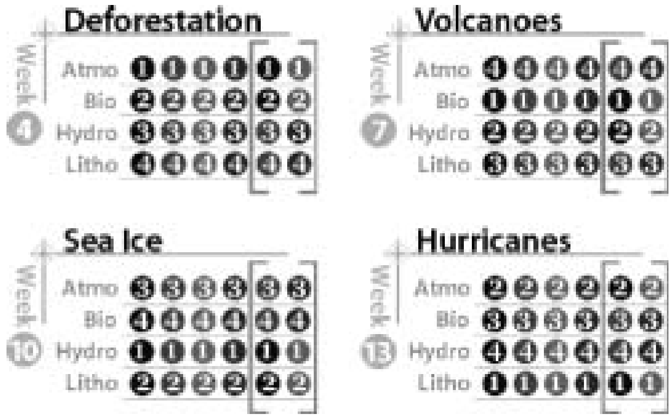


Figure 2. Event Teams. Each event team (Team A, B, C, and D) is composed of experts – at least one from each sphere team (e.g., in this week, those assigned number 1 are atmosphere experts, number 2 are biosphere experts, number 3 are hydrosphere experts, and number 4 are lithosphere experts). The umbers in parentheses show how the teams would be formed with six, rather than four, members.

Figure 3. Rotation through Sphere Teams. Each participant becomes "experts" on different spheres of the Earth system during weeks 4, 7, 10, and 13 of the course. For example, students assigned the number 1, work on the atmosphere expert team during week 4, they work on the biosphere team in week 7, the hydrosphere team in week 10, and the lithosphere team in week 13.

interesting ways. Commitment and involvement are intensified by the public nature of the text-based environment. Reflection is facilitated by the asynchronous threaded public discussions and an online private journal. Self-regulation comes through feedback from and interaction with other team members. Content and resources are provided in the week-by-week course outline, and a resource space grows with participants' suggestions.

A significant feature of the instructional design of the courses is the provision for learning to take place through dialogue between class participants and the faculty facilitator in asynchronous chat strands. Empirical evidence points to the importance of interaction in online education for both more effective learning and increased student course satisfaction (Su et al., 2005; Zirkin and Sumler, 1995; and Moore, 1992).

The following sections provide an overview of each of the courses. The courses can also be viewed online at: http://www.strategies.org/essea.

K-4 COURSE

The K-4 ESSEA course was designed to engage teachers in inquiry for the dual purposes of having them learn Earth system science and as a model for how to engage their students with Earth system science. Each week's activities are designed to use the strengths of K-4 teachers, while extending their skill and knowledge to new areas. K-4 students need short, focused activities to engage their attention (AAAS, 1993). These activities need to reveal student thinking so as to give the teacher the opportunity to coach students and plan additional activities to evolve their understanding. Although the Earth system science topics considered in each cycle are different (Land, Living Things, Water, and Air), the framework for every learning cycle is the same.

Design - Week 1 - The goal of the first week of each cycle is to give teachers a new perspective on their students as they are engaged in activities. What are their theories or beliefs? What satisfies them, or qualifies as true? By shifting the teachers' focus to understanding student thinking, they can be the "thinking coach" while the students inquire into content. The National Science Education Standards (AAAS, 1996) suggests a substantive change in how science is taught. Much current professional development emphasizes traditional lectures with the usual focus on technical training about teaching. Instead, suggests the NSES, "…professional development must include experiences that engage prospective and practicing teachers in active learning that builds their knowledge, understanding, and ability" (p. 56). Teachers must experience science and the way it is learned in accordance with the standards if teachers expect to use them with students. As stated in the NSES, "Simply put, preservice programs and professional development activities for practicing teachers must model good science teaching as described in the teaching standards…" (p. 56).

Design - Week 2 - The goal of the second week of each cycle is to have teachers experience inquiry with coaching. They are guided by their own questions as well as some essential questions provided to them. Examples of essential questions are: How do rocks change? Where does soil come from? How does soil help plants grow? What happens to plants when they die? How do Earthworms affect the soil? Teachers are asked to state what they know, what they believe, and what their own private beliefs are. They then use print and Internet resources to research the answers to the questions, alone and then in teams, to build their own Earth system science content understandings. Their findings are then posted for all participants to see, share and comment upon.

Design - Week 3 - The third week of each cycle has teachers apply what they have learned to their classrooms through designing lessons that incorporate the content and methodology they have learned in the first two weeks. They reflect, create, give each other feedback and present their lessons for evaluation with a rubric that was applied in the first week of the cycle. To prepare teachers to function in an inquiry environment, the NSES standards state that college faculty must develop courses based on investigations. Engaging in collaborative work allows teaches to experience inquiry methods, along with its rewards and challenges. Loucks-Horsley, et al., 1998, state that the same principles guiding reform for students' learning should also provide guidance for teacher professional development. Teachers teach as they are taught. Therefore, teacher education should be based on "active learning, focusing on fewer ideas more deeply, and learning collaboratively…" (p. xix), which are effective practices for K-12 student learning. Their model includes individual teacher reflection, a focus on learning or improvement, mechanisms for feedback and sharing, and opportunities for interaction. They also recommend a climate of trust and collegiality, a long-term commitment to interaction and skill building in coaching and mentoring. Week 3 is designed to extend the collegiality from learning together to applying what they have learned to their own classrooms.

MIDDLE SCHOOL COURSE

The middle school course uses the "jigsaw" cooperative learning technique (Aronson and Patnoe, 1997) and asks teachers to develop Earth system science models or analyses for different contexts or events: volcanoes, sea ice, deforestation, and hurricanes. Each person is responsible for learning a different part of the whole picture. In this course learners jigsaw between a "Sphere Group" where all team members are studying the same sphere (e.g., atmosphere) and an "Event Team" (e.g., hurricanes), which includes members from all four Sphere Groups (i.e., atmosphere, biosphere, lithosphere, and hydrosphere). Course participants are randomly assigned a letter (A, B, C, D) and a number (1, 2, 3, 4). This letter and number stay with each student for the remainder of the course. The letter indicates what Event Team they are a part of, and the number indicates what Sphere Group they are a part of. Figure 2 illustrates the organization of event teams.

Participants work together with the members of their Sphere Group during the "Sphere Study" of each three-week cycle. The three-week cycles begin in Week 4 and end in Week 15. Weeks 4, 7, 10, and 13 are the Sphere Study weeks. Figure 3 shows, based on assigned number, the rotation of the Sphere Groups through each of the spheres and the events.

As a member of the Sphere Group, each learner becomes an expert in the relationship of individual spheres to an Earth event. Then as a sphere expert, they will contribute their knowledge to their Event Team.

Learners work with the Event Team again in Weeks 5, 8, 11, 14, which are the Event Study weeks of the three-week cycles. The Event Team members synthesize the knowledge contributed by each individual sphere expert and conduct an Earth system science analysis of the event.

The three goals of the Middle School course are: Earth system thinking, event analysis and classroom applications. The event analysis is a common goal of each team and leads to the formation of the jigsaw expert groups, followed by the development of a classroom application. Being part of two groups invites multiple perspectives, interdependence in data gathering from individual expertise and expert groups, and negotiation in developing a rigorous analysis. The implications for course methodology are to:

- define the team task
- provide a model of an Earth system science analysis of an event
- plan repeated experiences for teams to do Earth system science analyses
- plan to provide feedback on analyses
- develop guidelines for evaluating Earth system science diagrams (rubrics)

The complex task is provided by the very nature of the Earth system science content. By viewing Earth as a system, in which the land, water, air and living things are interdependent and co-evolving, students learn each of the areas in the context of the others, as well as applied to familiar settings and events. Event teams are asked to create an Earth system diagram supported by a description for each of four events.

THE 9-12 COURSE

In the course for high school teachers, participants also collaborate in learning teams of four-six teachers and cycle through four three-week units, each unit providing an environmental context for developing deep understanding of the biogeochemical linkages between each of the Earth system spheres. Each unit culminates in designing a related lesson plan for participants to use in their own classrooms.

As in the K-4 and 5-8 course, the 9-12 course was designed to support creation of Earth system knowledge through reflection, analysis and self-discovery, familiarize participants with system analysis and provide a suite of techniques that can be employed to facilitate student analysis of simple systems in a classroom context, and engage teacher participants as learners in inquiry-guided instruction and problem-based learning. The last outcome is one of the most significant contributions of the ESSEA course, because teachers are now being asked to teach science in ways very different from those they typically encountered in their own science education. Experiencing the effectiveness of the inquiry approach in a teacher's own learning has been demonstrated to be a powerful motivator to emphasize inquiry in their own classrooms (Loucks-Horsley and others 2003).

Through the cyclic and iterative design of the curriculum, participants have the opportunity to develop and internalize a step-wise approach to system analysis that can be generalized to a variety of contexts. In the first three cycles, the context is assigned: Coral Reefs (oceanic), Tropical Forests (terrestrial), and Ozone (atmospheric). The fourth cycle, Global Change, served as the culminating activity, and provided participants the opportunity to apply the analytical techniques, system thinking, and problem-based learning approaches honed in the first three units to a topic of their own choice.

The pedagogic approach thus engages teachers in a strategy that could also be employed in their own classroom to scaffold their students in the development of system thinking skills.

Week	Dialogue Topics	Resulting Criteria
3	Allowing gifted children to teach other children Controlling correct knowledge v.s open exploration Hands-on learning for academically weak students	1. Peer Discussion (new topics)
6	Increased responsibility for student in learning process How to challenge all levels of students Heterogeneous classrooms	1. Peer discussion (enhanced) 2. Heterogeneous student distribution (new topics) 3. Students assuming teaching roles (new topic)
9	Students take charge of lesson. Role reversal Student has role of teacher Student has role of assessor	1. Peer discussion (enhanced) 2. Heterogeneous student distribution (enhanced topic) 3. Students assuming teaching roles (enhanced topic) 4. Students assuming assessor roles (new topic)

Table 1. Dialogue and criteria development regarding responsibility and role of students as learners.

EVALUATION AND FINDINGS

ESSEA's objectives were three-fold: Increase teachers Earth system science content knowledge, demonstrate the ability to deliver K-12 teacher professional development over the Internet to a national audience, and create an infrastructure capable of sustaining the program beyond NASA funding.

Through pre- and post-course surveys, follow-up surveys, and case studies with course participants we can see how the courses impacted teacher learning and Earth system science comprehension. This section provides a summary of the results of three studies: 1) a case study of ESSEA teachers in Ohio, Pennsylvania and West Virginia; 2) participants in a K-4 ESSEA Course Offering at Wright State University; and 3) participants in a Middle School Course Offering at the University of Nebraska, Omaha.

The program's effectiveness in delivering teacher professional development and sustainability beyond the initial NASA funding was tracked through annual reports and surveys of ESSEA institutions. This information included enrollment and retention statistics, descriptions of they implemented the courses and any unique approaches, and plans for the future.

Case Study - Ohio, Pennsylvania and West Virginia - K-12 teachers from Ohio, Pennsylvania, and West Virginia were subjects of a case study on their ESSEA experience. Teachers completing the courses reported them to be rigorous experiences, changing both the way they teach, and the way their students learn. The following paragraphs summarize some of the key findings of this case study (Prince, 2005).

Effect on Students - Students are more engaged with the content and with each other when teachers use inquiry methods they learned and experienced in ESSEA courses. Teachers particularly noted how students who were not normally engaged became enthusiastic participants. "Students who don't always do well got more involved in this because I think it catches their interest." Another teacher describes one student who "has a rough life, and he struggles with reading. He does not do any work for anybody else. But when he comes to science, then that kid tries every day and it's amazing to me."

Effect on Teacher Knowledge - All the teachers report gaining a profound understanding of Earth system science so that it permeates their teaching. A high school math teacher relates that not only has he learned much about Earth science, he is also able to use that knowledge in other classes. "For example, in my trigonometry class, we have a lot of questions about the atmosphere, space travel, and the Earth and determining distances on the Earth." Another teacher reflects, "Overall, I feel that I don't just have opinions, but I have educated myself enough to carry on an intelligent conversation about the coral reefs and their importance. Before, I would never have felt this comfortable teaching about this ecosystem but now am excited to do so."

Effect on Teacher Pedagogy - One teacher describes how participating in inquiry herself during the course helped her to slowly understand what it means for students to construct their own knowledge. "And I have kids that don't necessarily succeed in other classes, that have difficulty, that struggle, that don't want to be there, that come to my class and love it… and beg me to stay and learn more. And part of that is because I saw the way that that course was designed. I saw how we had to be responsible for our own learning and looking up the information and doing things."

Effect on Curriculum and the School Community - Each teacher had insights into how to make the curriculum more interesting, relevant, and engaging so students meet the standards. One teacher has revised all his course content to use problem-based learning and a systems approach. Another reported, "I've struggled the past several years with the idea of making our state required study of oceanography into a year long unit encompassing all seven state required units. ESS is a way for me to make this goal happen. Also, I can include relative units covering the lithosphere and hydrosphere from the previous grade (information my students are expected to know for the two year test at the end of fifth grade)." A teacher who facilitated the course for her district reports, "They stop me in the hall and want to know when we are going to offer it again. They want to learn more."

Assessment of an ESSEA K-4 Course Offering at Wright State University - Pre- and Post-course survey questions are built into each of the three ESSEA on-line Earth system science courses. Participants are asked about issues relating to their use of technology, their Earth system science content knowledge and classroom pedagogy. In addition to those built in assessment tools the on-line discussions of teachers taking the K-4 course were assessed to determine the changes in participant's ideas regarding their student's role in learning. The

Score	Question
1.55	How would you describe your content knowledge about Earth System Science today?
1.45	How much did the course affect your Earth System Science content knowledge?
1.64	How important was building Earth System Science models in learning content?
1.09	How important was learning through inquiry in learning content?
1.27	Course content could be immediately applied to your classroom?
1.27	Collaboration with other teachers was important?
1.36	How much your increased knowledge affected your students' content knowlege?

Table 2. Cognitive and Affective Domain Factors Impacting Continued Classroom Use of Earth System Science Content and Course Pedagogy. Scale (1-4, 1=very good; 4=Poor)

structure of the ESSEA course for K-4 teachers invites them to work individually and in teams to build their own Earth system content knowledge and pedagogical understandings of how their students learn. The theme "Teacher as Researcher" (weeks 3, 6 and 9) give teachers a chance to reflect and interact among themselves to build the teaching criteria necessary for building effective Earth system science concepts in their K-4 students. Discourse analysis of on-line discussions among participants (Prince et al., 2002; Slattery and Niekamp, 2002) revealed changes in teachers' attitudes about the responsibility and roles that children play in science learning. Table 1 provides examples of key dialogue topics and resulting criteria developed in weeks 3, 6 and 9.

These discussions eventually culminated in tangible modifications in teachers' attitudes that were observed in the changes and additions to the list of criteria for concept-building lessons that is built collaboratively and posted at the end of Weeks 3, 6 and 9. To substantiate the change in teachers' attitudes toward children in regard to their roles as students, several aspects of these data are noted. The number of criteria that relate to issues of roles of students expands. Week 3 offers one such criterion, Peer Discussion. Week 6 offers three, two of which are new (Heterogeneous Student Distribution, and Students Assuming Teaching Roles). Week 9 adds one more, Students Assuming Assessor Roles.

One of the hallmarks for effective professional development is the long-term change that occurs as a result of the learning experience. To determine the effectiveness of the ESSEA on-line K-4 teacher course, 14 participants in one ESSEA course section offered at Wright State University were contacted one year after the course (Myers, et al., 2003) to determine if the course contributed to lasting changes in teaching and learning in participant's classrooms.

A year after completing the ESSEA in-line course, participants felt strongly that they had retained a great deal of Earth System science content knowledge, that their increased content knowledge directly impacted their student's Earth System science understandings and that the content could be immediately applied to their own classrooms. Their responses are summarized in Table 2.

Assessment of Middle School Course offerings at University of Nebraska at Omaha - The University of Nebraska at Omaha (UNO) began offering the ESSEA courses during the Fall 2003 semester. The ESSEA middle school course was their most popular course with good student enrollment (e.g., in spring 2006, enrollment in UNO ESSEA courses totaled 64 students) and course completion numbers. The pre- and post-comparisons examined here are taken from UNO graduate participants' (N=50) enrolled in the ESSEA middle school courses taught by the same two instructors over a three-year period.

During the first and last weeks of the middle school course, participants completed a pre- and post-course survey. Pre- and post-course comparisons provide information on several aspects of the course design and its affect on the participant perceptions of ESS knowledge gains and attitude changes relative to pre- and post-course expectations. These surveys present the opportunity to examine participant benefits from ESSEA courses as documented empirically and descriptively. Paired samples t-tests were used to test for significant difference between pre- and post-test means to participant responses to survey question, "How would you describe your content knowledge about Earth system science?" In addition to the t-tests for paired samples, efficacy of the course experience can be seen by comparing participants' pre- and post-course responses to the following questions:

- What are your expectations for this course? (pre-survey)
- Were your expectations for this course met? (post-survey)

Increase in Knowledge - The fifty participants taking part in the UNO ESSEA Middle school course were asked to rate the change in their understanding of Earth system science on a scale of 1 to 4 (1 = lowest, 4 = highest) on the pre- and post-course survey. The t-tests for paired samples statistical test were used to determine if the scores of the same participants in this study differed under pre- and post-conditions. In this instance, these changes over time t-test was used to determine if participant perceptions of their ESS knowledge had changed as a result of taking the course.

Average changes reported indicate fairly substantial change. Participants perceived the considerable change in their knowledge of Earth system science. There was a significant improvement in mean score over time. The difference between samples means (meanpre =1.68 and meanpost = 2.88) was highly significant (paired t test; $t = 12.12$, df 49, $P < 0.01$).

Expectation Results - What were participants' expectations? Did the course meet them? Pre-course survey responses were fairly evenly divided between: 1) no expectations; 2) wanting to improve in using the Internet or computer for learning and teaching; and 3) wanting to learn more about Earth system science and how to teach it. Post-course survey responses indicate more than 90% of the people who finished the course had their expectations fulfilled and more. The range of post-course survey responses from the fifty University of

Nebraska at Omaha Middle school course participants is represented by the comments quoted below:

> I knew this course was going to give me access to NASA information, but it far exceeded my expectations. It taught me a whole new method of teaching about the spheres that truly relates one sphere to another.
>
> Yes, and then some! This course was exactly a tool in developing my knowledge of Earth Science. I have obtained so many wonderful lessons throughout this course which I will be able to use in my classroom!
>
> Absolutely! I enjoy earth science (rocks, volcanoes, etc.) but this class went into so much more. I learned more out of this class than any other class I have taken. I'm also going to be able to use more of my assignments from this class than any other class.
>
> I think my expectations for the course were exceeded. I never thought I would learn so much about Earth system science or the Internet. I can do so many more activities with my students because of my comfort level with the Internet. I also found that this course will help almost any teacher become better.
>
> More than met my expectations. Not only did I increase my knowledge base greatly, but I learned so much from the discussions with the other teachers. Lessons other teachers use, lessons similar to ones I use with new "twists" better ways to do things I am already doing.
>
> Yes, I can't believe how much knowledge I have gained from this class. I was so involved with the content each week. I also learned a lot from the other students.
>
> My expectations were exceeded by this course. The content that I learned and the things I am able to take back to my classroom are awesome!
>
> Gave me a working knowledge of Earth systems and how they interact. Made me more comfortable in teaching Earth Science concepts and gave me new ways to teach "old" material/concepts!

The pre- and post-comparisons of the UNO ESSEA middle school participants' expectations and perceptions of Earth system science content knowledge indicate that the course design was successful in meeting and exceeding the expectations of the course participants and accomplishing the course goal of increasing the participants' knowledge of Earth system science.

Effective Approach for Delivering Professional Development - The ESSEA program proved an effective infrastructure for delivering teacher professional development for both in-service and pre-service teachers. From spring 2000-spring 2006, 1,707 educators successfully completed a 16-week ESSEA course, reflecting an overall completion rate of 89%. Approximately 75% of educators completing the courses have been K-12 teachers; the other 25% including pre-service teachers, or other educators, including science supervisors, special education teachers, and informal science instructors.

SUSTAINABILITY

The program is also proving to be sustainable beyond the initial NASA investment. During spring 2006, participating ESSEA institutions were polled regarding their future plans in offering the courses. The majority of participating institutions (17 out of 20) stated that they plan to continue offering the ESSEA courses, with several universities reporting they have developed new programs that incorporate the ESSEA courses or foster continued Earth system science education opportunities for teachers. The open-ended instructional architecture of the courses lends them to these multiple contexts.
The following are just a few examples:

- Hampton University, a historically black college in Virginia, has incorporated the ESSEA course into the curriculum for undergraduates, and non-science majors who are interested in education. It is also being field tested as a beginning elective for a new minor in atmospheric science - called SEA (Sea Earth Air), supported by an NSF grant.
- At Western Kentucky University, the ESSEA High School course is now a required elective for a new Masters-level degree program in environmental science education. Also, a new geology major track in Earth & space science education for secondary teachers was developed in which an ESSEA course will be taken for required elective credit. Having the ESSEA courses in this track allows geology majors seeking teacher certification to be exposed to ESS concepts.
- The ESSEA course is an integral part of Wright State University's Department of Geological Sciences Master of Science in Teaching program. Wright State is also using the ESSEA middle school course as the foundation for a required course for pre-service teachers seeking Ohio middle school licensure with a science emphasis.
- At the Elizabeth City State University, a historically black college in North Carolina, the ESSEA course (ELEM 635 Earth System Science for Elementary/Middle Grades Teachers) is a popular elective course in their masters degree program in Elementary Education. ECSU has expanded and enriched the course by adding a hydrology workshop for which the students are required to come to campus. Some middle school teachers who have completed the course have agreed to serve as 'facilitators' in rural school divisions to develop teacher workshops to share Earth system science concepts and hands-on activities learned from the ESSEA course.
- San Jose State University is working to make the ESSEA course a required course as part of its Masters degree program in Natural Science that is part of the Science Education Program. The MA - Natural Science is directed at secondary school science teachers and others involved in science education.
- The University of Minnesota employed the 9-12 course as a capstone course for a cohort of in-service teachers who were enrolled in the University's summer

program providing certification for Earth science teachers teaching out of licensure. The program, funded by the Department of Education's Math Science Partnership program, consisted of 9 credits of traditional face-to-face coursework (lectures, labs, and fieldwork) in the Earth and space sciences during the summer.

CHALLENGES FOR THE FUTURE

A challenge for all teacher professional development programs is demonstrating and assessing their impact on student learning and comprehension, which is the ultimate goal of such programs. The resources available for evaluation of ESSEA were limited to identifying and assessing changes in teachers' knowledge, attitudes, and practices, which were then projected to impact their students. Beginning in 2007, the No Child Left Behind Act of 2001 requires each state to administer standards-based science tests each year, with students tested at least once in grade spans 3-4, 6-9, and 9-12. This requirement may provide opportunities for quantitatively assessing student performance of teachers who participate in ESSEA-like courses. Direct observation and case studies of students would also provide data regarding the impact of teacher professional development on their students' performance.

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