4.1 EARTH SYSTEM SCIENCE EDUCATION THROUGH THE EARTH SYSTEM SCIENCE EDUCATION ALLIANCE

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1. INTRODUCTION

The Earth System Science Education Alliance (ESSEA) is a successful teacher professional development program enhancing teachers' environmental literacy and ability to teach Earth system science. This program is ideally positioned to leverage its 40 university consortium in geoscience literacy by increasing ESS understanding and use of data, information, and programs.

ESSEA is supporting colleges and universities in teacher preparation and professional development for pre-service and in-service K-12 teachers. This NSF-funded program is building and expanding on the successful ESSEA program that was NASA-funded and implemented by the Institute for Global Environmental Strategies (IGES) from 2000-2005.

The Institute for Global Environmental Strategies (IGES) is enhancing and building on this foundation by: 1) Using the ESSEA online courses as a model to introduce newly upgraded Earth System Science undergraduate and graduate courses for teachers; 2) Introducing extensive use of data and existing Earth system educational materials to support the teacher courses; and 3) Disseminating model teaching practices and program success through annual conferences, continuing support, and presentations at geoscience and education conferences.

2. BACKGROUIND

Instructional Design of the ESSEA Courses

The design of the ESSEA 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, 1996; Loucks-Horsely, 2003). 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 (NRC, 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 are embedded throughout the course, using techniques such as 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.

ESSEA Elementary Course

The goal of the Earth System Science K-4 course is to prepare teachers to engage students in activities that reveal what they understand, and then to evolve their understanding through more collaborative hands-on/minds-on activities. The course is 16 weeks including four modules: Land, Air, Water and Living Things. It is structured as a collaborative, inquiry-based environment that models group investigation (Sharan & Sharan, 1976, 1992) and is held in an electronic environment where K-4 teachers can study Earth system science. As a result of research, interaction, hands-on activities, reading and reflection, teachers will: develop action research skills for assessing student knowledge; develop criteria for activities that enhance student learning; increase their knowledge; learn to collaborate with other course participants as designers of Earth science lessons; and create a unit plan for incorporation into their classroom instruction.

ESSEA Middle and High School Courses

A typical ESSEA course for middle-high school teachers is 12-16 weeks and includes 3-4 modules on Earth system science topics, which are selected by the course instructor. Examples of current ESSEA course modules that are available to faculty

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are: Black Carbon (Soot), Brazilian Deforestation, Coral Reefs, El Niño, Galveston Hurricane of 1900, Global Warming, Permafrost and the Changing Arctic, Hurricane Katrina, Ice Sheets, Mt. Pinatubo, Stratospheric Ozone, The Camanchaca: Fog in the Earth system, Yucatan Impact, Is the Answer Blowing in the Wind? (wind energy) and the Barnett Shale (oil exploration in urban areas).

The courses are designed to deepen teachers' content knowledge within an inquiry environment through reflection, analysis and self-discovery. They familiarize participants with Earth system analyses and provide a suite of techniques that can be employed to facilitate student learning. Each of these methods takes teachers out of the role of "middle man" (i.e., the deliverer of content) and creates a student-centered classroom.

When faculty set up their ESSEA course, they select the inquiry strategy that they will use; the course software sets the course up with instructions and assignments specific to each of these inquiry strategies. Problem-based learning, cooperative learning (Jigsaw), and Group Investigation methodologies are available to faculty members.

- Problem-based learning (PBL) is designed to "simultaneously develop both problem solving strategies and disciplinary knowledge bases and skills by placing students in the active role of problem-solvers confronted with an ill-structured problem that mirrors real-world problems." PBL models are generally characterized by the following steps: 1) the presentation of a problem to a small group of students, 2) discussion of the problem among the students which produces tentative explanations of the problem, and 3) an attempt to solve the problem.

  Problem presentation involves presenting students with an ill-structured problem in which they can find personal relevance. Ill-structured or "messy" problems are defined as: a) more information than is initially available is needed to understand the problem, b) the problem definition changes as new information is added to the situation, c) many perspectives can be used to interpret information, and d) no absolutely "right" answer exists. When students work to solve ill-structured problems, they are working toward learning generalized procedures for problem solving that will transfer to new situations (University of Delaware, 1999). The

- Jigsaw is a cooperative learning technique that creates "experts" on a certain topic within a classroom. A group of four to six students is broken down into different roles so that each student learns one aspect of the learning situation. For example, each of the students studying the impact of deforestation in a group of four could be assigned to determine the impacts on the atmosphere, hydrosphere, lithosphere or biosphere. This collaborative inquiry method supports the flow of energy toward new levels of understanding as members "jigsaw." Each person is responsible for learning a different part of the whole picture and in a sense creates positive interdependence, a key aspect of cooperative learning. (Aronson and Patnoe, 1997; Aronson, 2008)

- Group Investigation is a pedagogy for engaging and guiding students' involvement in learning. Students become active learners shaping events in their classroom. By communicating and cooperating in planning and carrying out their topic of investigation, they can achieve more than they would as individuals. The final result of the group's work reflects each member's contribution, but it is intellectually richer than work done individually by the same students.

Teacher participants in ESSEA courses are engaged as learners in inquiry-guided instruction. This 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, et al, 2003).

The pedagogic approach of ESSEA thus engages teachers in a strategy that can be directly employed in their own classroom to scaffold their students in the development of systems thinking skills. This is the same strategy that IGES uses when designing new Earth system science modules and courses.

Each module is designed to take three weeks in a normal university semester. Over 20 modules are currently available, so courses can be built around a class's particular needs. Current ESSEA modules cover topics that range from El Nino and coral reefs to Brazilian deforestation and California wildfires. Each module is divided into three cycles with four assignments to be completed for each module. Individual assignments include examining prior knowledge and developing a lesson plan, while group assignments include researching the topic and developing an Earth system science analysis. Each module is designed to show how events do not occur in isolation and consists of three cycles. In the first cycle, a teacher will begin by reading a scenario and then explore his or her own beliefs of what is happening in the Earth system, sharing

these ideas with teammates. In cycle two, the teachers investigate the issue and build a knowledge base. In cycle three, the teachers build their own lesson plan based upon what they have learned.

Earth system science education has a history of support from both NASA and the National Science Foundation beginning in the early 1990s. Over 75 colleges and universities have participated in the various Earth system science programs (Earth system science education for the 21st century, 2007). Through the NASA-sponsored Classroom of the Future modules designed for students at the K-12 level were developed (Classroom of the future, 2007; Exploring the Environment, 2007). The current program can be found at: esseacourses.strategies.org.

3. ESSEA MODULES

In addition to the modules that are currently available, approximately 20 are in various stages of development. Among the new modules are a series of modules that address climate change. These include such topics as climate on geologic time scales, climate change during the Holocene, the Little Ice Age, and the role of methane in climate change.

4. ENDEAVOR SCIENCE TEACHING CERTIFICATE (ESTCP)

During 2008 NASA announced the Endeavor Science Teaching Certificate Program. Implemented by US Satellite Labs with Columbia University Teachers College, selected K-12 teachers will complete a series of 5 online courses and action research based on NASA content and educational materials. This program prepares teachers to use mathematics and science using NASA related contexts. In-service teachers can work toward a certificate in math and science instruction; pre-service teachers can complete a certification. Both groups may use one ESSEA course toward the 15 credit hour program. (See: http://www.nasa.gov/offices/education/programs/descriptions/Endeavor_Science_Teaching_Certificate_Project.html).

5. ESSEA AT SEATTLE PACIFIC UNIVERSITY

In the past year, two Earth system science courses for in-service teachers have been offered by Seattle Pacific University. Fourteen teachers have completed a course for either three or five graduate academic credits (quarter credits). In the first course, in addition to an introductory module that introduces the concepts of Earth system science analysis and problem-based learning (PBL), modules that were completed included Global Climate Change; Brazilian deforestation; Mount Pinatubo; and Earth system science data and analysis. There was some attrition for the first course. Of 11 teachers who initially enrolled, eight completed the course. The main issue for those who did not complete the course appeared to be with the Internet technology. The second course was offered during August, 2008. Although there was a lot of interest, six teachers enrolled and completed the course. Topics this time included Living Things and Stratospheric ozone in addition to the introductory module.

For each module, teachers are required to prepare a problem-based lesson plan. Some examples follow.

- Global climate change – students, working in groups of four are asked to prepare a proposal for a city to host the Olympic Games in 2020. They must consider how climate change may affect sphere-to-sphere interactions.

- Brazilian deforestation – students are asked to examine sphere-to-sphere interactions in the Amazon biome and how these interactions may be affected by deforestation.

- Living things – fourth grade students study the life cycle and habitat of Coho salmon and how events in the habitat may affect the salmon life cycle.

Teachers who completed the ESSEA courses at Seattle Pacific University were enthusiastic. Comments after implementing a module with their students include:

- "…thrilled with how much thinking the students were doing."

- "…all the students were engaged."

- "…all the students could authentically contribute."

The one issue that occasionally arose during the course was that not all group members were contributing equally.

6. RECRUITING AT SEATTLE PACIIC UNIVERSITY

Through a partnership with the Seattle Public Schools, course faculty advertised through fliers and presentations to individual high school science departments. Fliers were also sent to other school districts in the area. Individual science teachers at various private schools were contacted by e-mail. The most effective way to reach teachers, however, proved to be through the Washington Science

Teachers association. Recruiting for all universities that are members of ESSEA is included on the ESSEA courses web site.

7. SUMMARY

Courses through ESSEA appear to be an effective way of providing professional development to teachers in the area of Earth system science. At Seattle Pacific University, three courses were scheduled between January 2008 and August 2009. By the Fall Quarter, 2009. There are also plans to have an Earth system science course available for pre-service teachers pursuing their degrees at SPU. Other universities that offer ESSEA courses can be found on the ESSEA web site. Many of these universities offer totally online courses.

The ESSEA program is funded through October, 2009.

8. REFERENCES

Classroom of the Future, 2007. online at: http://www.cotf.edu.

Earth system science education for the 21st century, 2007. online at: http://esse21.usra.edu/ESSE21/.

ESSEA, 2007. online at: http://esseacourses.strategies.org.

Exploring the Environment, 2007. online at: http://www.cotf.edu/ete.

Jeanpierre, B., Oberhauser, K., and Freeman, C., 2005, Characteristics of professional development that effect change in secondary science teachers' classroom practices, Journal of Research in Science Teaching, V. 42(6), p. 668-690.

Joyce, B., and Showers, B., 1980, Improving In-service Training: The Messages of Research, Educational Leadership, V. 37(5), p. 379-385.

Joyce, B., & Showers, B. (1996). *The evolution of peer coaching.* Educational Leadership, 53(6), 12-18.

Loucks-Horsley, S., Love, N., Stiles, K., Mundry, S., and Hewson, P., (2003), Designing Professional Development for Teachers of Science and Mathematics, Thousand Oaks, California, Corwin Press, 408 p.

National Research Council 1996, National Standards for Science Education.

Reitzug, U.C., (2002), Professional Development, In: Molnar, A., editor, School Reform Proposals: The Research Evidence, Tempe, Arizona, Information Age Publishing, p 289-316.

Sharan, S., & Sharan, Y. (1976). Small group teaching. Englewood Cliffs, NJ: Educational Technology Publications.

Sharan, S., & Sharan, Y. (1992). Group investigation: Expanding cooperative learning. New York: Teacher's College Press.