Disseminating Successful Undergraduate Science Curriculum Adaptation and Implementation Strategies and CCLI Grant-Writing Techniques: Regional Workshops Led by Successful Innovators and Experienced Investigators, Evaluating Faculty Change Processes and Assessing Student Understanding of STEM Concepts

James M. Haynes, State University of New York, Brockport, NY; Michele M. Hluchy, Alfred University, Alfred, NY; and Mark R. Connolly, University of Wisconsin, Madison, WI

Background

This CCLI National Dissemination (ND) project builds on a 25-year history of undergraduate teaching, research, curriculum development, and faculty enhancement activities that use environmental problem-solving to teach science. In conjunction with support for 10 projects from NSF DUE (Instructional Laboratory Improvement [ILI], Course and Curriculum Development [CCD], Undergraduate Faculty Enhancement [UFE], and CCLI Adaptation and Implementation [A&I]), with which we made curricular changes at our institutions, we have developed an effective national model for science education that melds classroom instruction, field and laboratory techniques, and cooperative learning that addresses environmental problems in college communities. Our multidisciplinary approach to science education uses environmental impact analysis as a theme to tie together the complex array of scientific concepts and theories, sampling and classification skills, research and analytical techniques, and mathematical and communication skills students need to address environmental and other scientific problems. We have found that focusing on environmental impact statements (EIS) in a format derived from the National Environmental Policy Act (NEPA) offers a broad-based, pedagogically sound, and accessible way to introduce undergraduate students and faculty to applied environmental problem-solving at the same time we are teaching how science in any discipline is done (Haynes et al., 1983; Hluchy et al., 1996; Haynes, 1998).

Eight DUE-UFE workshops in the 1990s provided a national testing ground for our approach and demonstrated cooperative learning and addressing real environmental problems as effective teaching strategies to stimulate the interest of undergraduates in science. Creative faculty across the nation, in disciplines ranging from earth sciences and biology to chemistry and engineering to geography and sociology, have adapted and implemented our approach in their courses and programs. Using two major themes (Stressed Stream Analysis, Great Lakes Ecosystem Dynamics), over 100 UFE faculty and many of their undergraduates have learned environmental analysis concepts and state-of-the-art techniques while they worked in teams to collect data needed to prepare environmental impact statements for real problems in their communities (Haynes et al., 1983; Haynes, 1998). Over 90% of UFE project alumni developed and implemented new curricula at their institutions, and many wrote successful proposals to funding agencies to support their innovations (Haynes, 1998).

Our approach also works well for non–environmental science majors. Working with a multidisciplinary team on a real problem allows students from a variety of majors, especially in the social and natural sciences, to bring their disciplinary backgrounds and approaches to bear on a common problem and, in particular, gives non-science majors access to and hands-on experience with science in a less threatening way than they encounter in traditional lecture and laboratory settings. We created hands-on experiences doing real science (i.e., for a real, field-based problem, the results cannot be known in advance). We have used the model successfully for undergraduate and graduate courses (Haynes et al., 1983), secondary science teachers (Dilcher, 1989), and undergraduate teaching faculty (Haynes, 1998). Our UFE alumni from across the nation have applied aspects of the model to all levels of the educational system (K-16 students, pre-service and in-service teachers, science and non-science majors).

We chose themes of Stressed Stream Analysis (SSA) and Great Lakes Ecosystem Dynamics (GLED) for our UFE programs because those topics allowed us to demonstrate new, ecologically based approaches to pollution control and to build spreadsheet models to explore the movements of pollutants in ecological systems. In a cooperative-learning context, teams of students or of UFE faculty from many disciplines (mostly biology, chemistry, geology, and engineering) conducted environmental analyses of a stressed stream receiving a new pollution source or modeled the effects on biomagnification of dredging a polluted harbor. Program participants returned to their home campuses and showed undergraduate students at all levels diverse but related developments in the following: 1) Great Lakes ecosystem science (e.g., cascading trophic dynamics, particle size spectra to analyze food webs, ecological impacts of exotic species); 2) sampling, instrumentation, and methods for water quality analysis (e.g., automated sampling and data transmission of stream discharge and water quality, processing of environmental samples with liquid sample autoanalyzers, electron-capture detector gas chromatography and mass spectrometry for polychlorinated biphenyl congeners, atomic absorption and graphite furnace spectrophotometry for metals, enzyme-linked immunosorbent assays for organic pollutants); 3) habitat and ecological evaluation procedures (e.g., habitat suitability index models, indexes of biotic integrity using fish and stream invertebrates, geographic information technology to visualize changes in riparian landscapes over time and space); 4) pollution effects on biological communities (e.g., microbial indicators of water quality, chemically induced deformities in aquatic insects, "endocrine disrupting" and other effects of persistent organic pollutants, electrophoresis to detect reduced genetic heterozygosity); 5) using spreadsheets to model chemical fate and transport in ecosystems (e.g., building simple models from scratch to explore system properties, using more sophisticated models to assess key factors influencing transport, fate, and bioaccumulation of pollutants); and 6) environmental impact analysis (e.g., NEPA model for impact analysis, techniques for scoping a project, impact identification and ranking, permitting regulations, and public hearings). In both the SSA and GLED programs, individual participants drew lots for typical stakeholder roles, and they delivered testimony at a mock public permit hearing to decide whether or not the project they had worked on should be permitted. Obviously, not all of the topics and techniques listed above were used in each 3-week UFE workshop, but participants used a coherent and integrated set to address the problem we presented to them.

At the end of each technical module in a UFE workshop, participants engaged in half-day discussions on how to adapt and implement our strategies and techniques into their curricula. At the 1994 UFE/GLED workshop, several participants, one of who was co-author Hluchy, presented an informal session on their successes and failures in writing proposals to funding agencies for curriculum development and implementation. That session was so well received that co-author Haynes made it a formal unit, presented by co-author Hluchy, in four subsequent workshops. One year after each UFE workshop, the participants gathered for a 3-day meeting to present the results of their curricula and other innovations during the previous academic year.

CCLI ND Workshops Project

Our CCLI ND project is delivering 20 workshops from 2001 to 2006 and has created a website (www.envsci-ed.brockport.edu) that contains the teaching innovations of the UFE program participants, technical and teaching materials presented at the UFE workshops, and other information useful to undergraduate science faculty interested in our approach. We are working with 15 regional leaders across the nation (UFE alumni who created new undergraduate science curricula and successfully wrote curriculum development proposals to DUE or other external funding sources) to deliver three five-day workshops each summer. Co-authors Hluchy and Haynes are also leading five two-day workshops in conjunction with scientific society national meetings (to date, American Chemical Society, Geological Society of America, and Society of Environmental Toxicology and Chemistry).

The goals of our CCLI ND workshops are to help teachers of undergraduate science students address these questions: 1) How can environmental problems in the campus or larger community be used to stimulate your students' interest in science? 2) What new theoretical and practical techniques are science faculties using to address ecological and environmental issues in their classes? 3) How can you find out what your students are actually learning? 4) How can you adapt workshop ideas in your teaching and implement change at your institution? 5) How can you write competitive proposals for external funding to support your efforts to improve student learning?

The schedule for the typical five-day regional workshop for this project follows. The schedule for a typical two-day workshop at a professional society meeting includes most of the activities on days 1 and 2 below and the grant-writing module.

Day 1:	**Introductions and Background**
3:30–4:30	The NSF CCLI-ND Program (Haynes) Introductions Regional workshop leader Grant-writing expert (Hluchy) WCER (Wisconsin Center for Education Research) presenter/evaluator (Connolly, Daffinrud [see below]) Participants (school, department, reasons for attending)
4:30–5:00	Gallery walk (getting a sense of participants' ideas about teaching)
6:30–7:15	EIS/problem-solving approach to teaching (Haynes)
7:15–8:30	Project CD/website tour (Haynes)
8:30–8:45	Complete end-of-day feedback form (Connolly)
Day 2:	**Stressed Stream Analysis or Chemical Fate and Transport Modeling Exercise**
8:30–9:45	Background and techniques for model exercise (Haynes)
10:00–12:00	Model exercise using spreadsheets (work in teams of four)
1:00–3:00	Complete exercise and report/discuss results
3:15–4:15	Develop implications (pros/cons) and uses of previous NSF/UFE program concepts and techniques for participants' pedagogical situations
6:00–7:15	Introduction to workshop-specific project/techniques: e.g., Performing Rapid, Onsite Assessments of the Impacts of Non-Point Source Pollution on River Ecosystems (topic in 2002 at Coastal Carolina University [CCU], Conway, SC)
7:15–8:45	Practice techniques: In situ probes for measurement of temperature, dissolved oxygen, total dissolved solids, chlorophyll, and turbidity. Colorimetric methods for true color, phosphate, and nitrate analyses. Indexx method for Enterococcus analysis (techniques taught at CCU workshop)
8:45–9:00	Complete end-of-day feedback form (Connolly)
Day 3:	**Model Field/Lab Investigation, Environmental Analysis, and Pedagogical Implications**
8:00–12:30	Data collection at field sites
1:30–3:30	Analyses of field samples in laboratory
3:45–5:00	Analyses of laboratory data
6:30–7:15	Prepare mini-environmental assessment (on non-point source pollution versus location in river system at CCU workshop)
7:15–8:45	Participants relate the day's techniques (pros/cons) to their pedagogical situations, 30 minutes in groups, 60 minutes report out)
8:45–9:00	Complete end-of-day feedback form (Connolly)
Day 4:	**Techniques and Tools for Assessment of Student Learning**
8:30–10:00	How to sustain innovations at your institution: finding solutions to barriers (Connolly)
10:15–12:00	Overview of assessment and introduction to inquiry-based, formative classroom assessment techniques related to principles emerging from the learning sciences (Daffinrud)
1:00–2:45	Introduction to the Field-Tested Learning Assessment Guide (FLAG) website and guided exploration of selected Classroom Assessment Techniques (CATs) (Daffinrud)
3:00–4:30	Guided exploration of the Student Assessment of Learning Gains (SALG) instrument (Daffinrud)
4:30–6:00	Grant writing strategies and tips, part 1 (Hluchy)
8:30–8:45	Complete end-of-day feedback form (Haynes)
Day 5:	**Grant Writing Strategies/Techniques and Post-Workshop Evaluations**
8:30–10:00	Grant writing strategies and tips, part 2 (Hluchy)
10:15–12:00	Small groups develop a proposal outline (60 minutes) and report out (45 minutes)
1:00–1:15	Complete end-of-day feedback form using online SALG instrument
1:15–3:15	Individuals complete end-of-workshop evaluation instrument

3:15–4:45 Focus group and wrap-up to reflect on the effects of the workshop on participants (Connolly)

4:45–5:15 Wrap-up discussion (all)

In the year after a workshop, each participant is asked to adapt and implement curricula in ways consistent with our strategies and techniques, to prepare a grant proposal to support his or her activities, and to file a report for inclusion on the project website.

The success by UFE alumni in adapting and implementing our ideas (94%) and funding their ideas (59%) are the bases for our current CCLI ND project. Our initial goal was to create and support active regional centers (or "communities of practice") for curricular adaptation and implementation, through which participating faculty can 1) learn about recent curricular innovations, involving problem-based and cooperative-learning techniques, in undergraduate science education; 2) learn how to write successful curriculum adaptation and implementation proposals to external agencies; and 3) receive follow-up guidance from the PIs and regional readers to bring curriculum adaptation, funding, and implementation ideas to fruition to enhance undergraduate science education at their institutions. Our proposal was approved for funding but, perhaps not surprising to other investigators involved in DUE projects, the reviewers commented that our assessment component was weak. We discussed this issue with our program officer and ultimately teamed with education researchers from the University of Wisconsin–Madison to develop a comprehensive longitudinal study of the effectiveness of our workshop in terms of faculty change and student learning.

Workshops Evaluation and Assessment of Student Learning Projects

Dr. Susan B. Millar and co-author Connolly from the Wisconsin Center for Education Research, and Ms. Susan M. Daffinrud of the University of Wisconsin's LEAD (Learning through Evaluation, Adaptation, and Dissemination) Center, joined the regional workshop project team. As workshop instructors, they created and now present two workshop units designed to 1) develop faculty capacity to use and modify new assessment instruments to gather better data on student learning and 2) effectively manage the challenges of undertaking significant pedagogical and curricular changes in their courses. As evaluators, they analyze data collected before, during, and after each workshop to assess the impact of the workshop on participants' teaching practices and grant-proposal writing. They also gather formative feedback during the workshops that workshop PIs and presenters use to improve the format, content, and delivery of their units and the "climate" of the workshops.

The Wisconsin evaluators also designed data-gathering instruments and collected baseline data during the summer 2002 and 2003 workshops for a long-term study of the effects of the workshops. This study entails twin studies of 1) the development of faculty capacity resulting from workshop participation and subsequent activities and 2) improvements in the quality and type of student learning resulting from the expected improvements in faculty capacity. Two divisions in the Directorate of Education and Human Resources provided this supplement to our original funding: DUE and REC.

In addition, Dr. Millar and Dr. Richard Iuli (University of Rochester) received funding from the Assessment of Student Achievement program in DUE to assess learning by students of faculty who attend our workshops. Based on type of institution, stage of career, discipline, and gender, 16 "critical case" faculty were selected from nearly 100 regional workshop participants in 2002 and 2003. In an ideal world, we would like to compare learning among students taking the same course taught by the same instructor, but with two approaches, with one using techniques demonstrated in our regional workshops. Unfortunately, it is impossible to conduct such experiments because they cannot be set up before workshop participants are exposed to our methods. However, by conducting pre- and post-instruction interviews of the same students, the study should support valid inferences about effects of teaching approach on quality of student learning. The regional workshop participant, in conjunction with the researchers, will develop a "master concept map" that will serve as a guide for the student interviews so that researchers can determine how well "novice" students understand concepts in relation to the understanding of "master" teachers. This process will also help the teacher to clarify course goals and objectives; identify and clearly explicate essential concepts, principles, and skills that they wish students to learn; and align assessment of student learning with student performance objectives of the teacher. University of Rochester researchers will conduct face-to-face interviews, pre- and post-instruction, with 10 students from a course taught by each of the 16 critical case faculty. Using faculty-created concept maps, the researchers will assess student understanding of STEM ideas presented in each course.

These activities, particularly developing an effective system to assess whether or not student learning in STEM disciplines improves after exposing teaching faculty to the concepts and methods presented in the regional workshops, are a direct response to the only reviewer criticisms of the original CCLI-ND proposal. Collectively, the three projects enable us to integrate assessment, evaluation, and curriculum to more effectively facilitate student learning of STEM content and processes. In addition, for the first time, data are being collected on the actual effectiveness of workshops like ours on faculty as teachers and students as learners.

Preliminary Results

It is clear from end-of-day and end-of-workshop surveys that the activities we provide for participants at the regional and scientific society workshops are very well received. After leaving our workshops, follow-up by participants on their good intentions for modifying their concept and practice of teaching has been more problematic. In part, this is because many of the people who attend our workshops are innovative teachers who have already experimented with pedagogic practices like the ones we demonstrate. Despite repeated attempts, with few exceptions, we have failed to get substantial responses to requests for reports on workshop-related activities by participants. The results to date are very disappointing in comparison to the 94% reporting rate by participants in earlier UFE programs. We speculate that the initial three-week, in-depth experience of UFE participants promoted greater comfort with the strategies and techniques we presented and that the three-day meeting a year later to present results of their workshop-related activities stimulated productivity and accountability. At this point, we are midway through the workshop delivery component of the project, but the evaluation of faculty change and assessment of student learning components are in their early stages. Based on our critical case studies, more definitive information on the effectiveness of workshops in promoting faculty change and improving student learning will be available in 2006.

Acknowledgments

Without the major efforts of our nine regional workshop leaders to date, this project would not be possible. They are Daniel Buckley, University of Maine–Farmington, Farmington, ME; Assad Panah, University of Pittsburgh–Bradford, Bradford, PA; Frank Romano, Jacksonville State University, Jacksonville, AL; Virginia Urbanik and Laura Meder, Danville University, Danville, VA; Susan Libes, Coastal Carolina University, Conway, SC; Stephen Spigarelli, Bemidji State University, Bemidji, MN; Timothy Knight, Ouachita Baptist University, Arkadelphia, AR; Craig Thompson, Western Wyoming Community College, Rock Springs, WY; and Catherine Rainwater, Our Lady of the Lake University, San Antonio, TX.

BIBLIOGRAPHY

Dilcher, R. C. 1989. Environmental impacts analysis techniques for secondary schools. Final Report. NSF Teacher Enhancement and Informal Science Education/Local and Regional Teacher Development Program. Brockport, NY: State University of New York.

Haynes, J. M. 1998. Stressed stream analysis: addressing real environmental problems in local communities to stimulate undergraduate science faculty and students. *J Coll Sci Teach* 28: 43–51.

Haynes, J. M., G. W. Thorburn, and J. E. Gannon. 1983. Environmental assessments: melding classroom instruction with problem-solving experience. *J Coll Sci Teach* 12:394–398.

Hluchy, M. M, J. F. Booker, and G. L. Godshalk. 1996. Writing an environmental impact statement: a way to link social and natural sciences in geoscience education (Abstract). GSA Abstracts with Programs. Annual Meeting, Geological Society of America. 28: A400–A401.