A. Project Summary

Disseminating Successful Undergraduate Science Curriculum Development, Adaptation and Implementation Strategies and CCLI Grant Writing Techniques:
Regional Workshops Led by Successful Innovators and Experienced Investigators

submitted by

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Eight NSF/DUE UFE workshops in the 1990s, involving 147 undergraduate faculty from Alaska to Florida and California to Maine, demonstrated cooperative learning and addressing real problems as effective teaching strategies to stimulate the interest of undergraduates in science. Using two major themes (Stressed Stream Analysis, Great Lakes Ecosystem Dynamics), UFE faculty and many undergraduates learned environmental analysis concepts and state-of-the-art techniques (e.g., biotic indices, electrophoresis, geographic information systems, automated water quality analysis, toxic organic chemical detection in environmental samples, spreadsheet modeling) and worked in teams to collect data needed to prepare environmental impact statements for real, local problems. This project will deliver 20 workshops to 400 faculty over a 5-year period. The PIs will work with regional leaders across the nation (UFE alumni who created new undergraduate science curricula and successfully wrote CCLI or related proposals to external funding sources) to prepare 3-day workshops for undergraduate faculty. During and after the workshops, the PIs and regional leaders will: 1) deliver fully documented summaries (with easily adaptable sample exercises) of the innovative teaching methods and curricula developed, 2) present strategies and methods to write successful proposals to external agencies that will allow participants to adapt and implement tested curricula, and 3) work with regional faculty to transform curricula and to submit proposals to support curricular change at their institutions. The results will be: 1) national dissemination (through workshops and creation of a web site) of already tested, successful teaching strategies and methods followed by further adaptations and innovations, and 2) successful UFE alumni role models sharing proven methods for writing grant proposals for curriculum development, adaptation and implementation.

B. Table of Contents in Detail

C. Project Description

1. Results from Prior NSF Support

This proposal builds on a 20-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 six projects from the NSF/DUE ILI (3), CCD (2) and CCLI A&I programs, with which we made curricular changes at our institutions (see section I.3), since 1990 we led eight NSF/DUE UFE workshops involving 147 college faculty from Alaska to Florida and California to Maine. We developed an effective national model for environmental science education that melds classroom instruction, field and laboratory techniques, cooperative learning, and addresses environmental problems in local communities. The model has been used successfully for undergraduate and graduate courses (Haynes *et al.* 1983), secondary science teachers (Dilcher 1989, DUE 8651532), and undergraduate teaching faculty (Haynes 1999, 1998b, 1997, 1996, 1995, 1994, 1993, 1991; DUE 9752783, 9653394, 9554722, 9455043, 9353978, 9255415, 9154284, 8954405; see section I.3 for details). Over 90% of our UFE alumni developed and implemented new curricula at their institutions, and many wrote successful proposals to funding agencies to support their innovations (see sections C.2.b.iv, I.1 and I.2).

Content modules for undergraduate faculty in five UFE-funded Great Lakes Ecosystem Dynamics programs included: 1) new developments in Great Lakes ecosystem science (e.g., cascading trophic dynamics, particle size spectra, effects of endocrine disrupting chemicals on wildlife and humans), 2) analytical instrumentation and biotechnology techniques for detecting environmental contaminants (e.g., electron-capture gas chromatography, mass spectroscopy, enzyme-linked immunosorbent assays/ELISA), 3) computer modeling using spreadsheets (e.g., mass balances of toxic chemicals, fish bioenergetics, biomagnification), and 4) writing an environmental impact statement (EIS) on the likely impacts on the food web of dredging PCB- contaminated sediments in a Great Lakes harbor.

Using the concept of Stressed Stream Analysis (Haynes 1998a), we expanded our approach from a Great Lakes regional to a national scale. Content modules for undergraduate faculty in three UFE-funded SSA programs included: 1) instrumentation, sampling and methods for water quality and hydrological

analysis of streams (e.g., liquid sample autoanalysers, atomic absorption and graphite furnace spectrophotometry, stream discharge), 2) habitat and ecological evaluation procedures (e.g., habitat suitability and biotic integrity models, biological assessments using stream invertebrate and microbiological indicators, GIS analysis of riparian landscapes), 3) pollution effects on biological communities (e.g., electrophoresis to detect reduced genetic heterozygosity, toxic chemical-induced deformities in aquatic insects), and 4) environmental impact analysis (e.g., NEPA model for impact analysis, techniques for scoping a project, impact identification and ranking, permitting, public hearings). The problem we presented participants was a doubling of capacity of a sewage treatment plant on a small stream to accommodate suburban growth and economic development (e.g., siting of a lead recycling plant in the watershed). Based on the participants' observations of effects of current sewage treatment discharges on water quality and on aquatic organisms, communities and habitats vs. upstream conditions, teams of participating faculty evaluated the likely impacts of doubled volumes of treated sewage effluent with increased lead content on the stream ecosystem and wrote EISs. 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.

At the end of each technical module in the UFE programs, 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 whom was PI 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 PI Haynes made it formal unit, presented by PI Hluchy, in subsequent UFE workshops (1995-1998). The success by UFE alumni (see section I.1) in adapting and implementing our ideas (94%) and funding their ideas (59%) is a major basis for this proposal that will share our strategies and techniques with 400 new faculty, create a web site, and disseminate our ideas nationally.

2. The Project

a. Overview, Goals and Objectives

The emphasis on dissemination by NSF in recent years (e.g., NSF 1998 and its predecessors) makes it clear that effective dissemination of successful curricular innovations is difficult to achieve. Our experience during the past 10 years supports this view. This proposal will disseminate for adaptation and implementation curricular materials that have already been developed and tested with NSF/DUE support. Our goal is to create and support active regional centers 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 implementaton ideas to fruition so as to enhance undergraduate science education at their institutions.

While creating, adapting, funding and implementing our own courses and conducting UFE programs, we and our UFE alumni created powerful curricular tools, using state-of-the-art laboratory and field techniques, for faculty to use to teach undergraduates how science is really done (learning and applying knowledge in a problem solving context, hands-on, teamwork) while students work to address real, local environmental problems. These models and tools have been compiled in eight UFE project reports on curriculum development ranging from 250 to 570 pages each. Some results have been published (Haynes 1998a, Haynes *et al*. 1983) or presented at professional meetings (see section I.3), but bulk, cost and time constraints make it difficult to disseminate this valuable information widely and effectively. The purpose of this project is three-fold: 1) expand our ability to infuse successful curricula across the nation by organizing 15 regional workshops and 5 workshops in conjunction with professional society meetings over a 5 year period beginning in January 2001, 2) employ successful former UFE program participants (see section C.2.b.iv) as regional workshop leaders, role models and mentors to show new faculty how to adapt and implement stimulating science curricula and how to write proposals to fund innovation, adaptation and implementation, and 3) create a web site and list-serve to make curricular adaptations easily available to interested parties across the nation. We will create 20

groups of 20 faculty from diverse scientific disciplines (e.g., biology, chemistry, earth sciences, environmental science/engineering) in geographically compact regions throughout the nation who can maintain easy contact with one another, their regional leader and the PIs, to achieve these objectives: 1) demonstrate environmental problem solving as an integrative, challenging, effective way for faculty to stimulate undergraduate science students, majors and non-majors, and 2) enhance the knowledge of faculty about new concepts and field/laboratory techniques available for contemporary environmental analysis and suitable for teaching undergraduates how science is done in a real world, problem solving context.

Planned activities to accomplish the goals of this project include: 1) work with 15 former UFE program participants as regional leaders to organize 3-day workshops for science faculty in their geographic regions, 2) organize five workshops for undergraduate science faculty attending discipline-based, national conferences (e.g., American Chemical Society, Geological Society of America, Ecological Society of America, Sigma Xi annual meetings), 3) present summaries to workshop participants, in written, electronic and oral formats, of teaching materials (including lab and field methods and key references) developed for previous UFE workshops and created by the PIs and regional leaders for their courses, 4) present, in written, electronic and oral formats, successful strategies and techniques used by the PIs and regional leaders to write successful curriculum development, adaptation and implementation proposals, 5) use "break-out" sessions to engage small groups of participants in "brainstorming" of ideas for curricular innovation at their institutions along with plans for writing proposals to external agencies to adapt and implement existing curricula, 6) provide time for individuals to develop their ideas and to consult individually with the PI/regional leader team before leaving the regional workshop, 7) engage in follow-up activities for continuing communication, including list-serves for each regional group and paper sessions at the next annual meeting of the professional societies where workshops are held, and 8) create a web site on which curricular innovation, adaptation and implementation supported by this and previous DUE-supported projects can be disseminated nationally.

It is clear from information presented in NSF (1996) that encouraging undergraduates to

enter science majors and retaining current science majors has become increasingly difficult using traditional methods of teaching science to modern students. The intent of this project is to share directly with 400 new faculty throughout the nation innovative teaching strategies and content modules that UFE participants and others have shown do excite students, majors and non-majors, traditional and non-traditional, about science. We believe working with teaching faculty one-on-one is the most effective way to widely disseminate, by chain reactions, innovations already created for further adaptation and implementation and to inspire new innovations. The proposed web site and list-serves will provide opportunities for an unlimited number of science faculty and teachers across the nation to access ideas and materials developed by past and future participants.

b. Detailed Project Description

i. <u>Pedagogical Context</u>: In the past 25 years, new approaches for teaching science have been widely discussed in the literature (cf. Johnston and Aldridge 1984, AAAS 1990, Emiliani 1991, Johnson *et al.* 1991, Mayer *et al.* 1992, NSF 1996, Hurd 1998). Indeed, there are numerous educators at all levels who are successfully implementing new techniques in their classrooms. However, most science courses are still taught in the traditional way, by faculty who present an assemblage of facts to students in a lecture setting, emphasizing content rather than process, within the context of a single scientific discipline (Johnston and Aldridge 1984). Most of these courses fail to capture students' interests and many fail to adequately prepare students for professional positions in science or for effective citizenship in their communities (Sigma Xi 1990). In order for science education to be effective, science must be taught as a process and method of inquiry that incorporates facts as they are needed (Sigma Xi 1987, Harrison 1989, Johnston and Aldridge 1984, Rutherford and Ahlgren 1990, Dunkhase and Penick 1990, Ortez 1994, NRC 1996, NSF 1996, Ehlers 1997). In other words, science should be taught as it is actually practiced (cf. AAAS 1989, Steen 1991, Wehmeier 1996, Ehlers 1997, Devlin 1998).

At the same time that educators are evaluating how they teach science, the nature of science is changing. It is becoming increasingly interdisciplinary and contemporary scientific research is commonly done by teams rather than by single researchers (Sigma Xi 1987, Rutherford and Ahlgren 1990, Hurd 1998). Unfortunately, a survey of scientists done by Sigma Xi, the Scientific Research Society, indicated

that lack of interdisciplinary training was "one of the most important scientific issues facing the scientific community today" (Sigma Xi 1987, p.11). The challenge for science educators, therefore, is to develop strategies for teaching science that are effective, capture students' interests, and reflect the way contemporary science is done.

One way to accomplish these goals is to teach science courses that revolve around a unifying theme or a relevant problem to be solved (cf. Rutherford and Ahlgren 1990, Steen 1991, Mayer *et al.* 1992, Marzano 1998). Proponents of this strategy argue that it will lead to greater success in engaging students' interest and a better understanding of the nature of science (cf. Mayer *et al.* 1992, AAAS 1990, Sanders 1994). It is important, however, that the unifying theme or problem should be relevant to the students and that the students be able to see connections to the "real world" (Penick and Crow 1989, Dunkhase and Penick 1990, Brennan 1996, Howard and Boone 1997, Hurd 1998). Unifying themes that have been suggested include environmental issues, public health, and earth system science (Steen 1991, Mayer *et al.* 1992, Ireton *et al.* 1996).

A second strategy, which can be successfully used in conjunction with a problem solving or unifying theme approach, is to organize students into teams or groups to work on specific tasks or research topics, so called "cooperative" or "group" learning. Advocates of cooperative learning contend that students learn more from group activities than from traditional lectures (AAAS 1990, Johnson *et al.* 1991, Howard and Boone 1997), that group efforts "demonstrate the dependence of the scientific enterprise on teamwork as well as on individuals" (AAAS 1990, p. xv), and that group approaches often de-emphasize competition and help students to realize that all group members can contribute to achieving a common goal (Rutherford and Ahlgren 1990, Johnson *et al.* 1991). Activities can range from group discussions to original research.

A third necessity for effective science teaching, which is usually not stressed in traditional science classes and which can be integrated into any number of teaching strategies, is to instruct students on how to communicate effectively in both written and oral formats (Rutherford and Ahlgren 1990). Written or oral presentations force students to think about and make sense of complex scientific concepts (Bonwell and Eison 1991, NRC 1997). Memorization of "facts" for recall on multiple-choice or short answer exams does not accomplish this. Communication of research results is an important part of doing science and students

should have the opportunity to develop and practice these skills as part of their science classes.

ii. <u>Scientific Context</u>: Although we and our UFE alumni have used a variety of approaches to demonstrate environmental problem solving as an effective way to teach undergraduates how to do science, Stressed Stream Analysis, a phrase we believe is original to our work (Makarewicz 1993), is a nationally applicable model that best demonstrates our approach. Stressed Stream Analysis is an integrative, comprehensive methodology to determine the environmental health of a stream. It is a technique that identifies the sources, extent, effects and severity of pollution or other disturbances in a watershed. It combines elements of the sciences of hydrology, chemistry, ecology, and organismal biology by using an integrated approach to analyze cause and effect relationships in disturbed stream ecosystems. The basic approach is to systematically evaluate sub-watersheds of a larger, disturbed watershed until the impacted sub-watersheds are identified. Within the impacted sub-watersheds, non-point and point sources of pollution are identified by chemical sampling (e.g., nutrients, metals, pesticides) above and below suspected sources. At this point, the extent, causes and types of pollution have been determined. The severity of the pollution within the impacted sub-watershed or the entire watershed can then be evaluated by spatial analysis of the quantity and quality of biological indicators, such as fish and invertebrates, and by biological examination of structural and functional changes in individual organisms and populations in affected communities. *Streams, and the opportunity to evaluate their environmental problems from the point of view of any scientific discipline, are available to virtually every undergraduate institution in the nation.*

A major rationale for the NSF's former UFE program was to bring faculty from predominately undergraduate teaching institutions up to date on contemporary research concepts and techniques relevant to undergraduate science curricula. Large portions of our UFE programs were devoted to showing our participants diverse, but related techniques that the research and management communities use to evaluate water quality problems in lakes and streams. Most water pollution regulations in the U.S. are based on water quality standards that limit the concentrations of chemical substances permitted in receiving waters. These standards typically are set using laboratory toxicity testing and calculated loading rates, but ignore issues of

biological or ecological integrity of aquatic ecosystems. For example, a stream where habitat has been degraded by channelization or flow fluctuations may meet strict water quality standards, yet have lost much of its aquatic biota due to the degraded habitat. Or, some chemicals at non-toxic, nearly undetectable levels in the environment may biomagnify and damage upper levels of a food web. Without sophisticated detection instruments and computer modeling techniques it is difficult to set reasonable water quality standards in such cases. Thus, excellent water quality does not ensure biological integrity (Karr *et al*. 1986). Although methods for measuring biological integrity and using computer models to inform management decisions have been widely reported in scientific literature for two decades (cf., Scavia and Robertson 1977, Karr 1981, Stewart *et al*. 1983, Thoman and Mueller 1987, Rodgers *et al*. 1987, Fausch *et al*. 1990), and their use by regulatory agencies is increasing (e.g., Bode *et al*. 1990, Ohio EPA 1987, Rudstam 1996), the teaching of these methods has not been widely incorporated into traditional curricula that prepare students for employment or help them understand the complex environmental science issues facing society today.

iii. <u>Linking Science and Pedagogy-Our Approach</u>: Over the past two decades, we have developed a multidisciplinary approach to science education that uses environmental impact analysis as a theme to tie together the complex array of sampling/classification skills, research/analytical techniques, scientific theories, and communication skills students need to address environmental problems. Although there are many types of environmental analyses (assessments, audits, technical reports, etc.), just as there are different strategies to facilitate science education, we have found that focusing on environmental impact statements (EISs) 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 1998a). 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. Our approach also works well for non-science majors. Working with a multidisciplinary team on a real problem allows students from a variety of majors (particularly the social and natural sciences) to bring their disciplinary backgrounds and approaches to bear on a problem and gives non-science majors access to and hands-on experience with science in a less threatening way than they encounter in traditional lecture/laboratory settings.

We chose themes of Stressed Stream Analysis and Great Lakes Ecosystem Dynamics 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. We used this approach with eight groups of undergraduate faculty, through 3-week summer workshops, and with undergraduate and graduate students in courses at our own institutions. In a cooperative learning context, teams of students or teams of UFE faculty from many disciplines (e.g., chemistry, biology, geology, geography, engineering, sociology) conducted environmental analyses of a stressed stream receiving a new pollution source or modeled the ecological effects of dredging a polluted harbor. UFE program participants returned to their home campuses and showed undergraduate students at all levels diverse but related developments in: 1) sampling, instrumentation, and methods for water quality analysis (e.g., automated processing of environmental samples with autoanalyzers, electron-capture gas chromatography, mass spectrometry, atomic absorption spectrophotometry, enzyme-linked immunosorbent assays), 2) habitat and ecological evaluation procedures (e.g., habitat suitability index models, indices of biotic integrity, geographic information technology to visualize changes in riparian landscapes over time and space); 3) 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); 4) using spreadsheets to model chemical fate and transport in ecosystems (e.g., building simple models from scratch to explore system properties, using sophisticated models to assess key factors influencing transport, fate and bioaccumulation of pollutants); and 5) environmental impact analysis (e.g., NEPA model for impact analysis, techniques for scoping a project, impact identification/ranking, permitting, and public hearings).

Before and after the "Neal Report" (NSB 1986), we created hands-on experiences, doing real science (for a real, field-based problem the results cannot be known in advance). Our UFE alumni have shown that the approaches we have developed are applicable throughout the nation for use at all levels in the educational system (K-16 students, pre-service and in-service teachers, science and non-science majors), but their efforts have been limited to less than 150 institutions and communities. Consistent with several of the recommendations in "Shaping the Future" (NSF 1996), what remains to be done is to develop effective ways to disseminate throughout the nation our innovative curricula and creative approaches to science teaching, and to show more faculty how they can adapt, fund and implement innovative curricula that will stimulate their students' interests in and knowledge of science. Our proposed series of 15 regional workshops and five short courses held in conjunction with national professional society meetings will share these strategies directly with 400 more faculty who teach science to undergraduates. The proposed web site and list-serves will be available to an unlimited number of science faculty and teachers.

iv. Regional Workshop Leaders: Many UFE alumni have adapted and implemented environmental problem solving techniques and cooperative learning strategies into their curricula and have successfully written grants to support their activities. Fifteen of them, discussed below, have agreed to lead the 15 proposed regional workshops. The information that follows comes from their UFE program reports (Haynes 1999, 1998b, 1997, 1996, 1995, 1994, 1993, 1991) and discussions while preparing this proposal. Professors Libes, Romano and Buckley will lead the first three workshops in the summer of 2001. A pool of standby workshop leaders can be found in section I.2.

Southeast and Mid-Atlantic Regions

South Carolina: Susan Libes, Professor and Chair, Marine Sciences and Chemistry, Coastal Carolina University, Conway, attended the 1996 UFE/GLED (Great Lakes Ecosystem Dynamics) program to update and expand her knowledge of environmental chemistry. She then wrote a successful NSF ILI proposal to purchase a modern GC-MS system, mercury analyzer for her atomic absorption spectrophotometer, and a variety of sample preparation instruments. She

tied the need for the proposed instrumentation to her post-UFE, revised "Environmental Chemistry" lab manual that uses environmental analysis of a campus development/wetland pollution problem, an approach learned in her UFE experience, to link the diverse analytical techniques her students are expected to master with a problem. Reviewers of the proposal commented favorably on the innovative EIS approach that linked these techniques together in a meaningful way for students and on the exportability of her techniques and approach to other institutions. Based on her UFE experiences, Dr. Libes also worked to integrate math and science teaching in the CCU School of Science by using spreadsheet modeling, and she successfully wrote two NSF ARIE (Awards for Integration of Research and Education at Baccalaureate Institutions) grants totaling nearly $1 million that renovated environmental chemistry labs and involved undergraduates in mentoring high school students doing environmental monitoring.

Alabama: Frank Romano, Professor, Biology, Jacksonville State University, attended the 1993 UFE/SSA (Stressed Stream Analysis) program. He then adapted our approach to develop a senior capstone course, "Advanced Topics for Biology", in which student teams conducted research and wrote an EIS for a hypothesized expansion of the city sewage treatment plant. Based on the very positive response to the EIS approach by senior majors, Dr. Romano revised the published lab manual for his introductory biology course (Romano, Higgenbotham & Bowen, "Freshman Biology: An Inquiry Approach", Kendall Hunt, 1994). He used cooperative learning "to combat a major issue that has developed at all college campuses in the U.S. The problem is that our core curriculum is supposed to enable students to 'become informed decision-makers and responsible citizens in solving the problems of one's communities (quotation from the 1993-1994 JSU catalog)'." While doing a series of integrated field and laboratory exercises, freshman pursue a semester-long "informed decision-making" assignment to develop arguments for or against a project in the community. Teams of students investigate the project, gather background data and formulate a position that each team presents in a mock public hearing. His students "use information gathered from outside sources, use information that is contained within the structure of the laboratory, use information gained from the lecture portion of the class, and put it all

together in [a problem solving] format. This is using information to make an informed decision!"

Dr. Romano also wrote several proposals, incorporating techniques he learned in the UFE program that involve undergraduates and local citizens in water quality monitoring and education programs. For example, the Georgia Environmental Foundation funded the "Chattooga River Basin Water Quality Monitoring and Environmental Education Project" to: 1) develop public school curricula based on the Chattooga River basin's resources, 2) conduct public forums on water quality and stewardship issues, 3) teach water quality analysis programs for local citizens and students, and 4) conduct a baseline water quality and trend analysis (biological and chemical) on the river.

Virginia: Sue Urbanik, Professor, Chemistry, Averett College, Danville, employed strategies and skills learned in the 1996 UFE/GLED program to upgrade the laboratory experience for students in her "Environmental Chemistry" course. For a development project on the local river, her class conducted a variety of new, theme-linked water quality analyses and prepared an EIS for the project. Some of the same techniques also have been incorporated into a new course, "Water Quality Assessment," co-taught with a biology colleague at the Humbolt Biological Station in Steuben, ME. Before attending our program, Dr. Urbanik had successfully secured NSF ILI funding to upgrade the environmental chemistry curriculum at Averett.

Northeast and Mid-Atlantic Region

Maine: Daniel Buckley, Professor, Natural Sciences, University of Maine-Farmington, used his 1995 UFE/SSA experience to create a new "Environmental Impact Assessment" course which became a required component of the new Environmental Science major he helped to develop. In the EIA course, students work in teams to analyze a local problem (e.g., tannery waste entering a stream), write an EIS, and recommend solutions. A mock "trial" to "decide" the issue concludes the course. Before and after his UFE experience, Dr. Buckley successfully wrote proposals to upgrade his "Aquatic Biology" and "Ecology" courses. Through the ILI program, the NSF funded two proposals: 1) "Field Experience in Limnological Sampling and Data Analysis" provided equipment to more accurately monitor water quality and enabled

development of a student research team approach to data collection and analysis, and 2) "GPS/GIS/Image Analysis Technology for Field Research in Bio-Environmental Science" allowed UMF to incorporate technologies for resource mapping and geographical information systems into ecology courses. Now, teams of students monitor lake water quality with modern instruments, map wetland change over time and, through service learning, share their data and analyses with local lake associations and Maine's Dept. of Environmental Protection.

New York: Karen Harpp, Assistant Professor, Geochemistry, Colgate University, Hamilton, had just finished her first year of college teaching when she participated in the 1996 UFE/GLED program. Since then she has been a whirlwind of creativity, adapting, funding and implementing our active learning and problem solving approaches into her chemistry and geology courses while she funded curriculum innovations and provided essential equipment for her courses. With support from the NSF ILI, ARIE and Career Grant programs and the Hewlett-Packard Company (total funding $650,000), she obtained GC-MS (gas chromatograph-mass spectrometer) and ICP (inductively coupled plasma-mass spectrometer) instruments.

Dr. Harpp completely changed the way all of her courses are taught. In Introductory Chemistry, students are presented with problems to solve that are related to everyday life--an inquiry-based approach. In attempting to find solutions, students "discover" that they need to master certain concepts and techniques, at which time Dr. Harpp provides the appropriate information through mini-lectures or relevant lab/field exercises. Analytical techniques are presented on a need-to-know basis as tools for solving problems, not as canned procedures that provide only context-free results. She uses this approach to avoid the high attrition rate of students in chemistry courses that "focus on mathematical and formulaic skills at the expense of investigative skills and practical illustrations of science."

Dr. Harpp also mentors teams of undergraduates who design and perform chemistry shows for local schools and community groups. Using "skits" to explain chemical concepts relevant to everyday life, she and her students dispel the image of science as inaccessible and irrelevant to non-scientists. Examples include explaining ELISA techniques learned in our UFE

program with "interpretive dancers" to illustrate binding of antigens and antibodies and the ticket taker on the "Hindenburg" who learns about the reactive properties of hydrogen and water! To advance her approach nationally, Dr. Harpp is an active participant in the Chemical Links Consortium that is attempting to change forever the way chemistry is currently taught. She also has been active in the Pew Middle States Consortium that is working to integrate mathematics into science curricula.

Pennsylvania: Jeff Erikson, Assistant Professor, Natural Sciences, Messiah College, Grantham, PA worked with colleagues to develop a "seamless approach to science" introductory course for freshmen intending to major in biology, chemistry, biochemistry, environmental science, dietetics or pre-professional health. The course has many objectives, including experiencing science as researchers do, using an interdisciplinary approach, enhancing critical thinking and analytical skills by addressing real world problems with hands-on projects, and helping students to see connections among the lecture, laboratory, scientific writing and oral presentation components of the scientific education process. Clearly, a well-conceived laboratory is critical to achieve the high expectations for this course. Based on Mr. Erikson's 1997 UFE/ SSA experiences, Messiah College chose a Stressed Stream Analysis approach in which students will characterize biological and chemical conditions of the campus stream in relation to nearby streams impacted by acid mine drainage and landfill leachate. Even the dietetics students are not left out. Field labs looking at fish stomach contents vs. available food supplies will be linked to data collection in the college cafeteria on student diets vs. menus. A lab project will look at vitamin C deficiency and fish growth and development. To support the new curriculum, Mr. Erikson and colleagues secured a $500,000 grant from Whittaker foundation to equip their laboratories in a new $11 million science building with the gear needed to sustain the SSA focus of the entire laboratory planned for the new introductory course for science majors.

Midwest and Great Lakes Region

Ohio: Paul Belanger, Professor, Environmental Management Program, Lake Erie College, Painesville, attended the 1997 UFE/SSA program to become familiar with current

technology and methods in aquatic ecology. He adapted his experiences in our program to biology and environmental management courses to help meet the goals and objectives outlined in his NSF Curriculum Development grant, "Trying Science, Undergraduate Curriculum Reform." The focus of the grant was to revise major and non-major science courses away from traditional passive lectures to a more active, hands-on approach. Specific objectives included: 1) focus on real-world problems using a collaborative approach, 2) utilize computer technology to solve problems, 3) work on problems requiring data collection outside of the classroom, and 4) practice skills using appropriate scientific tools. After his SSA experience, Dr. Belanger served on a DUE review panel for proposals submitted to the NSF Institution-wide Reform of Undergraduate SMET program and he secured funding for an ILI grant titled "Enhancing Undergraduate Curriculum Reform with an Interdisciplinary Computer Laboratory." The latter incorporated computer modeling and GIS technology throughout the LEC curriculum.

Based on his SSA experiences and NSF funding, Dr. Belanger created two new courses. "Trying Science: A Grand River Course" is an interdisciplinary course that meets a general education requirement for non-science majors. The Grand River and its watershed encompass most of the local county, and environmental impacts are severe. Teams of students investigate many aspects of the river, particularly hydrological and chemical issues, as part of group projects associated with the impact of urban development on river water quality. "Environmental Research and Problem Solving" is a capstone course for senior Environmental Management majors. In the latter half of the course, student teams produce an environmental impact analysis for an actual project in their county, construction of a bridge over the Grand River. The project is hotly debated in the local community and a real EIS is being prepared. Students visit the project site and speak with engineers and local/state officials. They become very interested in the process and want to compare their EISs to the one produced by "professionals."

Illinois: Timothy Bell, Associate Professor, Biological Sciences, Chicago State University, teaches at an institution attended predominately by African-American students. After his 1994 UFE/GLED experience, he and a colleague in the Chemistry/Physics Department

created a new course, "Environmental Impact Analysis" that has been taught four times. The course focuses on teaching students USEPA protocols for water and soil analysis using hands-on lab and field techniques in the context of preparing an EIS for a development project in the highly urban environment adjacent to the CSU campus that is highly degraded by past industrial activity (Calumet Basin). To provide equipment and supplies for the course, they successfully wrote a proposal to the USEPA Environmental Education Section and submitted a grant to the WMX Corporation to support the new Environmental Biology and Industrial Chemistry curriculum options at CSU. The major portions of the latter grant will provide Environmental Science Research Assistantships to encourage minority students to enter science careers and will provide equipment to support the new environmental science courses being developed at CSU as a result, in part, of Dr. Bell's UFE experience. Dr. Bell has much of value to share with faculty who teach at predominately minority-enrollment colleges and universities.

Minnesota: K. Ravichandran, Assistant Professor, Chemistry, Bemidji State University, attended the 1998 UFE/GLED program to learn applied problem solving techniques at the interface of environmental chemistry and biology. He then added units on organochlorine analysis and effects into his "Standard Methods of Water Analysis" course. In the laboratory part of the course, students collected water and sediment samples from lakes in northern Minnesota and analyzed for ions using wet chemistry techniques. As a class research project, students analyzed PCBs in lake sediments using commercially available immuno-assay test kits.

A major outcome of Dr. Ravichandran’s participation in our program was funding of a grant, “Incorporating Active Student Learning Experiments and Research Projects into Biology and Chemistry Laboratory Courses at BSU.” Based on techniques learned in the UFE program and supplies provided by the grant, quantitative aroclor-specific analyses of PCBs in lake sediments were carried out, using gas chromatography, by an undergraduate student as a senior honors thesis project. On completion, the student won the BSU best student research award.

Dr. Ravichandran and two students also modified and used our spreadsheet models to predict ion concentrations in Lake Bemidji. One student investigated the dynamics of metals in

the lake coming from a wastewater treatment plant. In the model, the student used field-determined concentrations of metals in the water column and in the sediments, along with several other parameters, to predict metal accumulations in the lake. The other student modeled phosphorus levels in two storm water detention basins.

Mid-South and Southwest Region

Arkansas: Timothy Knight, Professor and Chair, Biological Sciences, Ouachita Baptist University, Arkadelphia, used his 1995 UFE/SSA experience immediately upon returning from our program. A local lake association came to OBU complaining of water quality problems, especially aesthetically displeasing slimy green water. Adapting and implementing SSA strategies and techniques, Dr. Knight's "Biological Monitoring" class conducted a semester-long environmental assessment for the lake property owners on how to remediate their problems by addressing faulty septic systems and fertilizer applications to their lawns and golf course. As an active department chair, Dr. Knight has built curricula and facilities to modernize OBU's biology programs. In addition to several successful research contract proposals involving students in field research, he has written NSF EPSCOR and EPA Education proposals for curriculum development that were not funded, but are being revised for resubmission.

Missouri: After attending the 1995 workshop, Russell Robbins, Assistant Professor, Biology, Drury College, Springfield, incorporated UFE/SSA field/laboratory techniques and the cooperative learning/problem solving approach into an existing "Environmental Biology" course and a new "Environmental Impact Statements" course. In "Introductory Biology," he changed the traditional microscope use/measurement lab exercise (passive examination of the letter "e") into an exercise that addressed a real world problem (observing pollution-induced deformities in chironomid larvae). Also, he was the PD for an Eisenhower Grant that funded a 6 day workshop for in-service primary and secondary teachers, 'StreamLines '96: Increasing Science Literacy Through Watershed Monitoring". Dr. Robbins will provide a valuable link between teachers and undergraduate science educators.

Texas: Catherine Rainwater, Associate Professor, Biology, Our Lady of the Lake

University (all women, many Hispanic), San Antonio, used her 1997 UFE/SSA experience to upgrade lab and field exercises in her "Ecology" and "Limnology" courses. She is the PD for a grant from the U.S. Dept. of Education Minority Science Improvement Program ("Development of a Bachelor's Degree in Environmental Science") that is supporting curriculum development and equipment purchases at OLLU, is a major participant in a successful Dept. of Defense HBCU/MI (Historically Black Colleges and Universities/Minority Institution) Infrastructure Support Program grant ("Instrumentation for a Computer-based Laboratory to Modernize Data Acquisition and Analysis in Biology"), and is preparing to resubmit a CCLI A&I proposal ("Equipment to Enhance Studies of Limnology and Ecology in a Small Urban Lake") to NSF.

Rocky Mountain and Pacific Region

California: Michel Boudrias, Assistant Professor, Marine Sciences, University of San Diego adapted many of the techniques he learned in the 1997 UFE/SSA program for estuarine environments. His research on patterns in the structure and composition of benthic invertebrate communities along a gradient of eutrophication in a bay of the Baha Peninsula of Mexico led to creation of an upper division honors course. In “Pollution in the Sand,” for 3 weeks in the summer undergraduates study effects of lead and nutrient pollution from a fish cannery on benthic invertebrates. The course is designed around an integrated plan to collect water chemistry (metals, nutrients) data, habitat and sediment characteristics, and benthic invertebrates. Each undergraduate (chemistry, marine science and biology majors) learns how to collect, analyze or identify physical, chemical and biological samples, then teams of students develop research projects and use the methods learned. A grant from the Packard Foundation obtained by Dr. Boudrias provided support for the course.

Dr. Boudrias also redesigned benthic ecology laboratories for two upper division courses, Biological Oceanography (majors) and General Oceanography (non-majors). After the SSA experience, he incorporated new techniques and analyses that focused the labs on a “pollution gradient” emanating from a storm drain into Mission Bay. The storm drain lab in General

Oceanography addressed a major concern in San Diego: the potential effect of El Nino rainfall patterns on non-point source pollution entering bays and beaches from overflowing storm drains. Teams of students prepared environmental assessments to determine if major storm drains entering Mission Bay should be connected to an already overburdened sewage treatment system. Students scoped the problem, decided on the magnitude of the project, designed a sampling protocol, collected and analyzed data, and wrote mini- EIAs. Each student had to perform the technical analyses for nutrients, coliforms, grain size, and infaunal abundance and diversity, and play a role in a mock public hearing. Students were required to use the physical, chemical and biological data collected by the class to defend their positions.

Oregon and **Wyoming**: David Fuller (Professor, Biology, Rogue Community College, Grants Pass, OR) and Craig Thompson (Associate Professor, Engineering, Western Wyoming Community College, Rock Springs) propose to jointly run two regional workshops, one in each state. Since participating in the 1993 UFE/SSA workshop, they developed several multi-disciplinary (Fuller is a microbiologist, Thompson is an engineer), field-based courses emphasizing western streams. 1) "Ways of the River" uses field experience, lab analysis and careful observation to teach principles of hydrology, water chemistry, macroinvertebrate ecology and river survival skills. 2) "The River in Art and Science" teaches the value of scientifically accurate, well-written and well-illustrated field journals using stream ecology as the primary focus. 3) "The Floating Classroom" shows high school teachers four, afternoon length "package laboratories," each emphasizing how streams fit into larger ecosystems. In addition, Dr. Fuller developed four "Participating Agreements" with the USDA Forest Service. Through service learning, environmental science students at RCC earn credit and pay while assessing biological and chemical water quality, conducting stream surveys, and assisting channel restoration on high

mountain streams in the Rogue River, Siskiyou, Umpqua and Winema National Forests. Drs. Fuller and Thompson provide opportunities for significant regional links to the community college professoriate that faces unique teaching challenges, including how to adapt and implement innovative curricula with fewer opportunities to gain external support.

v. Workshops at National Meetings: Increasingly, national scientific societies sponsor "continuing education" activities for their members in conjunction with annual meetings. In addition to three workshops per year organized by the PIs and regional leaders, we propose to organize one workshop per year in conjunction with a major scientific meeting. These workshops, led by the PIs, will run in the few days before or after the meeting. Models exist for such workshops in conjunction with meetings of the Geological Society of America and the American Fisheries Society (our primary professional affiliations). In recent years, workshops on "effective teaching strategies" have been offered at national meetings of both organizations. Presenters have advocated using student teams and project-based classes, and they have suggested alternative evaluation mechanisms, but they have not specifically addressed the advantages and particular mechanisms of using multi- and interdisciplinary themes/projects in science education. We will address these topics explicitly. We have also contacted the Ecological Society of America (ESA), and the chair of their Education Section has expressed interest in hosting our proposed workshop. Other scientific societies we will approach include the National Science Teachers Association, American Chemical Society, and Sigma Xi.

vi. Workshop Logistics: This project will be directed from the SUNY College at Brockport and Alfred University. Previous faculty enhancement and curricular development experiences make the PIs particularly well suited to carry out the proposed project.

Annually, beginning in January of 2001, the PIs will: 1) identify three regional leaders

and one society willing to host workshops for the coming year (i.e., four workshops per year, 2001-2005), 2) work with the three regional leaders and the society to organize and deliver the workshops, including attendance and presentations by the PIs at each, 3) prepare summaries of key curriculum implementation & adaptation and proposal writing strategies and techniques to share with workshop participants (this will be accomplished before June 2001 with updates in subsequent years), 4) involve workshop participants in a model cooperative learning exercise that demonstrates our approach to stimulating undergraduate science students, and 5) work with regional leaders and participants after workshops, via e-mail list-serves and the project web site, to adapt, fund and implement curricular innovations at the participants' institutions.

Soliciting Participants

We will provide a model brochure, patterned after successful UFE brochures, for each regional leader to use to advertise his or her workshop. We will use mailing lists from Peterson's Education Services in New Jersey for the states each regional leader wishes to target. Brochures will be mailed to science departments and to affirmative action offices at 2- and 4-year colleges and universities in the region. In addition, the regional leaders will use institutional mailing lists and e-mail list-serves to recruit 20 qualified undergraduate faculty for each workshop. Once our web site is established, we will also advertise there. In particular, we will target faculty from underrepresented populations or faculty who teach at schools with large minority enrollments (see section C.2.b.viii) and on faculty from Ph.D-granting institutions. Both groups were underrepresented in our previous UFE programs.

For each workshop, we will seek 20 undergraduate faculty in biology, earth sciences, chemistry, engineering and other disciplines who teach courses related to environmental science. A curriculum vita will be requested from each applicant, and applicants will be asked to answer

the following questions: Why do you want to participate in this workshop? What undergraduate courses that you teach would it impact? Which workshop concepts and techniques do you plan to introduce into your course(s) or program? Our major selection criterion will be the demonstrated potential for incorporation of material from the workshop into the participant's instructional program. Acceptance decisions will be made by the Regional Leader and PIs (society meetings).

Daily Schedule

Day 1 (pm) Participants arrive

Day 2 (am) The Problem Solving, Cooperative Learning Approach (e.g., Stressed Stream Analysis, Environmental Impact Analysis; addressing problems in local communities PIs)

New Environmental Science Techniques (e.g., community indicators of stream health, biological indicators of pollution, modeling fate and transport of pollutants with spreadsheets;; PIs)

(pm) Classroom Applications of the Approach and Techniques (discuss/provide summaries of outstanding examples, [see sections C.2.b.iv and I.2] from UFE participants' adaptation and implementation activities; PIs, Regional Leader)

Day 3 (am) Model Cooperative Learning Activity to Demonstrate Our Approach (e.g., divide participants into teams with equivalent backgrounds; provide a hypothetical project for a stream; ask them to brainstorm likely impacts, data required, sampling [physical, chemical, biological, hydrological] needed; give them an environmental assessment form and ask them to state whether or not the project is likely to have a significant impact; PIs, RL)

(pm) Writing Competitive Curriculum Development Proposals (discuss and provide

models of successful proposals [see sections C.2.b.iv and I.2]; Hluchy, RL)

Small Group Brainstorming of Participants' Curriculum/Proposal Ideas (PIs, RL)

Individual Participants Outline Curriculum Adaptation/Implementation/Proposal Ideas

Day 4 (am) Individuals Share Ideas for Critique by Project Team (PIs/RL) and Participants

(pm) Wrap-up Discussion and Departure

Follow-up Activities

In the year following each workshop, each participant will be asked to adapt and implement curricula in ways consistent with our strategies and techniques, to prepare a grant proposal to support their activities, and to file a report for inclusion on the proposed web site (see below). We will hold five workshops at national society meetings, one each year. At the next annual meeting of each society, we will organize a paper session for the most successful participants in the preceding year (three regional workshops, one national meeting) to report on their adaptation, implementation and funding activities. The strategy of requiring reports and presentations at meetings one year after previous UFE workshops stimulated a 94% activity rate among participants (see section I.1).

vii. <u>Project Web Site</u>: In the course of developing and teaching the Stressed Stream Analysis and Great Lakes Ecosystem Dynamics programs, we created powerful curricular tools, using state-of-the-art scientific equipment and techniques, for faculty to teach undergraduates how science is really done (addressing real problems, hands-on, teamwork) while students address local environmental problems. However, bulk, cost and time constraints make it difficult to disseminate widely and effectively the results of these very successful NSF/DUE/UFE projects (the eight reports on curriculum development range from 250 to 570 pages each). The purpose of this part of the proposed project is to: 1) place the best reports of UFE faculty on a worldwide web site, 2) extensively advertise the site nationally and form a national list-serve of interested faculty, and 3) seek submissions for the web site of other innovative adaptations and implementations of curricula in the broad areas of problem-based and cooperative learning

strategies in science courses. The result will be wide and effective dissemination, not achievable by other means, of tested, successful curricular innovations and our more quantitative evaluations of student learning (see below).

Planned activities to accomplish this part of the project include: 1) request submission of updated information on curricular adaptations and implementations from previous UFE program participants, 2) edit and enter the full text of uniquely valuable contributions and informative summaries of other contributions into web files, 3) create a cross-indexed worldwide web site that will allow users to easily access files by subject and geographic location, 4) create a national list-serve of science faculty interested in adapting and implementing science curricula to involve problem solving or cooperative learning, and 5) advertise the availability of the web site and list-serve nationally by electronic means and by mailing lists purchased from Peterson's Education Services. This work will be completed during the first 2 years of the project by PI Haynes and undergraduate assistants from SUNY Brockport's Computer Science Department. The web site and list-serve will be maintained in the future by PI Haynes with assistance from Academic Computing Services at SUNY Brockport.

SUNY Brockport is well positioned to carry out this project. The college has a new E-4500 Sun (Unix-based) computer dedicated to handling campus web applications now and in the future. Computer Science is one of our largest departments and will provide students well able to assist in constructing the web site and list-serve. There are several ways to approach construction of the web site: 1) creation of Adobe Acrobat (.pdf files) documents accessible to web browsers (good for static documents, but not for documents that need periodic updating), 2) using HTML (hypertext markup language) programming to create a separate web page for each piece accepted by the site (complicated programming for such a large number of pages), or 3) putting all summaries into a database (e.g., My Sequel, Oracle) with links to a single web page using a standard ODBC (open database connection) program. At the moment, for reasons of simplicity and editing, we are leaning toward the last approach.

Creating a web site based on proven curricular innovations and placing interested faculty

throughout the nation in easy contact with one another, will achieve these goals: 1) disseminate environmental problem solving widely as an integrative, challenging, and effective way for faculty to stimulate undergraduate science students, majors and non-majors, 2) enhance faculty knowledge about concepts and field and laboratory techniques available for contemporary environmental analysis that have been adapted and implemented for use by undergraduates throughout the nation, 3) enable unlimited numbers of faculty and teachers to communicate easily and directly with hundreds of peers throughout the nation who will have used our techniques successfully, and 4) stimulate new faculty to contribute their curricular innovations in undergraduate science education, particularly in regard to addressing problems in a cooperative learning context, to the web site and list-serve for consideration by all.

viii. <u>Reaching Out to Underrepresented Populations</u>

We teach at institutions with large majorities of students of European American descent, and more than 90% of the participants who applied to our UFE programs came from similar backgrounds (all applicants from underrepresented populations were accepted). Despite our best attempts to reach faculty from underrepresented populations through lists obtained from many sources, of the 147 UFE participants five were of African descent, one was Hispanic, and 17 taught at predominately minority enrollment institutions (nine of those at mostly or all women's colleges). Women were well represented in our UFE programs.

Three UFE participants teach at historically black colleges and universities (HCBUs, 1890 schools). A similar network now exists for Hispanic and Native Americans (SACNAS, Society for the Advancement of Chicano/Latino and Native Americans in the Sciences). These organizations will provide names of colleagues and mailing lists for institutions throughout the nation. Also, we will try to hold a workshop at an annual meeting of one or both organizations.

Although not underrepresented in the generally accepted sense of the term, our UFE program experiences indicate that newly minted Ph.Ds entering the job market desperately need and are eager to learn teaching ideas and skills. In our UFE programs, wonderful synergies developed between young scientists with the latest knowledge and experienced teachers with accumulated wisdom. We want to

recreate this synergy in the workshops proposed here. But, a key factor that limits the ability of new Ph.Ds and faculty from underrepresented populations to attend conferences like ours is money. Although the NSF normally requires that conference participants pay for their travel to conferences, we propose to offer travel stipends to remove financial impediments for applicants from these underrepresented populations.

c. Experience/Capability of the PIs

The project will be directed by Dr. James M. Haynes, Professor and Coordinator of Center for Applied Aquatic Science and Aquaculture at SUNY Brockport and Dr. Michele Hluchy, Professor and Director, Environmental Studies Program at Alfred University. Dr. Haynes was the project director or lead instructor for eight Undergraduate Faculty Enhancement projects funded by the NSF. He initiated, along with other SUNY faculty, the environmental analysis course for students that formed the basis for these eight projects. Dr. Haynes is a fish ecologist and Certified Fisheries Scientist with extensive research and teaching experience in fishery science and environmental analysis, and he was an officer in the Education Section of the American Fisheries Society. He prepared illustrated or photographic keys for fishes of the Hudson River (book), Great Lakes (slide set) and Bahamas (slide set), and in 1999 he received the SUNY Chancellor's Award for Excellence in Teaching. He organized scientific workshops and community outreach programs dealing with fisheries and environmental issues in the Great Lakes region, and he has extensive experience speaking at professional meetings, before citizens groups, and in classrooms ranging from the elementary to the graduate level. He has published numerous papers on fish and invertebrate ecology and environmental education (cf., Haynes *et al*. 1983, Haynes 1998a). For 4 years he chaired the Monroe County Water Quality Management Committee responsible for overseeing preparation of the Rochester Embayment Remedial Action Plan that includes three watershed management plans, and he serves on technical committees that advance water quality planning and pollution remediation in the county.

Dr. Hluchy is a geologist specializing in hydrogeology and clay mineralogy and currently chairs the Division of Environmental Studies at Alfred University. She was a PI for six NSF/DUE-funded projects over the past seven years (three ILI, two CCD, one CCLI A&I), and

she served as a DUE review panelist in 1992, 1993, 1996 and 1998. Dr. Hluchy participated in Dr. Haynes' Great Lakes Ecosystem Dynamics program in 1994 and subsequently addressed his UFE groups in 1995, 1996, 1997 and 1998 about how she integrated her UFE experiences into the Environmental Science curriculum at Alfred and about her experiences writing and reviewing DUE grant proposals. Dr. Hluchy has given numerous professional presentations about undergraduate teaching, particularly addressing interdisciplinary science courses (see section I.3). Following her UFE experience in 1994, she initiated an Environmental Impact Analysis course that has since evolved into a Natural Resources Management course, cross-listed between Environmental Science and the Business School at Alfred. Dr. Hluchy's activities in professional societies also reflect her strong interests in science education. She is an elected geology councilor for the Council on Undergraduate Research, and she has supervised over 50 undergraduate research projects in 12 years at Alfred. Dr. Hluchy regularly addresses community groups and high school classes on groundwater contamination and supply issues, and she has set up an on-campus hydrogeological field station at Alfred. She is one of six faculty members in the sciences and mathematics at Alfred who teaches a NSF-initiated, year-long, interdisciplinary, project-based science/math course to non-science majors.

d. Evaluation Plan

Following guidelines presented in NSF (1993), we will develop and employ a variety of evaluation strategies and instruments to monitor the progress of this project. At the end of each regional workshop or conference short course, we will conduct an Implementation Evaluation (see model in section I.4) to gauge participants' responses to the program and to make changes in future workshops. Also, we will create a list-serve for each workshop group through which we can encourage progress in developing curricula and proposals and conduct Progress Evaluations. Each year, we will conduct a Summative Evaluation in which we will determine how many participants actually created/adapted/implemented new curricula and prepared/submitted relevant grant proposals (see section C.2.b.vi re: written reports and presentations at national meetings), and in which we will get feedback on student responses pre- and post- new curriculum delivery.

Cumulative Summative Evaluations will continue throughout the life of the project.

Our UFE participants reported that they and their students were very enthusiastic about our approaches and techniques. However, a limitation of our UFE programs was that we did not systematically survey and compare student learning outcomes before and after UFE participants adopted our approach. Quantitative corroboration of the participants' anecdotal reports (Haynes 1999, 1998b, 1997, 1996, 1995, 1994, 1993, 1991) comes from SUNY Brockport's instructional assessment system (IAS). PI Haynes teaches BIO 488/588, "Environmental Impact Analysis" (patterned after Haynes *et al.* 1983), and consistently receives the highest marks from students for this course among the eight courses he teaches in a two year cycle. Briefly, Brockport's IAS system, in use for 20 years, evaluates student responses to 24 questions about a course and compares ratings for a particular course to the campus-wide average for that type of course (lecture, performance, etc.). PI Haynes' average scores for these questions for the EIS course range from 0.1 to 0.4 vs. a campus-wide average of 1.0 to 1.3 on a 0 to 5 scale (0 = excellent, 5 = very poor), whereas his more traditional lecture/lab courses are rated at or better than the campus averages (0.6 to 1.0). The EIS course melds field work, independent research, and writing of an Environmental Impact Statement by teams of four students. High IAS scores come from students engaged in an intense and demanding cooperative learning experience that uses many of the techniques we have shown to undergraduate teaching faculty from around the nation.

Evaluations of PI Hluchy's courses that use student teams to solve environmental problems also have been exemplary. An external evaluator (from Colgate University) for "Methods in Environmental Science", a completely project-based course, stated that the course was "critically important" to the Environmental Studies Program at Alfred University and that student learning in this course was maximized because of the approach that the instructors had taken. Student responses to this course and her EIS course (based on her 1994 UFE experience) also were positive. Students recommended that: 1) all students should be required to take the courses and 2) more courses should be taught in this manner.

Meaningful evaluation of curriculum change is perhaps the most difficult task undertaken

by faculty. Even when "standardized" evaluations (like Brockport's IAS system) are conducted, it is difficult to interpret the results in terms of whether or not specific curricular changes have made a difference in students' learning, often because there is no "normed" assessment before and after changes are made. Thus, most faculty use anecdotal assessments to support contentions about what does and does not work, and this is what UFE alumni did. As an integral part of this project, we will ask regional workshop participants to provide quantitative data regarding the effectiveness of our approaches and techniques in their curricula, before and after they make curricular changes. In addition to local survey instruments they may use, we will ask them to administer Brockport's IAS evaluation to students in their courses, pre- and post-revision. Forms will be scored at Brockport, and results will be used as part of evaluating the success of new curricular innovations in a more quantitative and standardized way than was done before.

e. Dissemination Plan

The hands-on, cooperative learning approach we have pioneered is extremely successful and is worthy of wide dissemination. Among the 147 participants in our UFE-supported programs, 94% created new curricula (section I.1) ranging from laboratory exercises or modules (86%) to courses or course modules (49%) to entire environmental science majors or minors (24%), and 37% submitted curriculum development proposals, of which 59% were funded.

This is a national dissemination proposal. Over the past 12 years, the NSF invested heavily in the development of diverse curricula by our UFE program participants, in the broad areas of problem solving and cooperative learning in undergraduate science, that have stimulated undergraduates in many science disciplines at campuses across the nation. This proposal seeks to give these ideas and techniques the wide dissemination they deserve and, in so doing, to encourage further development, adaptation, implementation and funding of innovative techniques by the 400 faculty who will participate in our workshops and share our ideas and techniques with their colleagues. One year after each regional and conference workshop, the regional leaders and the PIs will solicit reports from the participants on their curriculum adaptation, implementation and funding activities, and place their reports on the proposed web

site. Through presentations at national professional society meetings and the list-serves we will establish, we will develop a communication network that will expand our approaches and methods by repeated chain reactions. In this way, we will try to establish a new culture of teaching and pedagogical scholarship in science throughout the nation.

Providing proven curricula as models for further adaptation and implementation, and teaching proposal writing skills to help faculty initiate and sustain curricular change, is the best way encourage pedagogical creativity among scientists across the nation. This is done best one-on-one in a workshop setting followed by regular communication as ideas are adapted and implemented. Our UFE programs demonstrated that faculty are very likely to implement new curricula after personal interactions with faculty experienced in new approaches. While our web site will serve as a library of curriculum adaptation, implementation and assessment activities nationwide, it can not substitute for the personal interactions provided in workshop settings that are required to stimulate most faculty to adopt new teaching methods. Our experiences make us confident that the personal contact dissemination approach we propose is the best way to stimulate undergraduate faculty across the nation to adopt new scientific concepts and techniques and tested and successful teaching methods to stimulate undergraduates in their classrooms. By doing this, we will achieve the conditions needed for faculty to adapt and implement new and better methods for teaching science in undergraduate classrooms across the nation.

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Budget for Prototype Regional Workshop (salary = your monthly on 9 month basis)

Itemized Subcontract Budget (12 months)

Personnel	No. Months	Salary/Mo.	Cost
Regional Leader	1.0	$5,200.00	$5,200.00
Student Assistant	1.0	$1,500.00	$1,500.00
	Subtotal		**$6,700.00**
Fringe Benefits	Rate	Salary	Cost
Regional Leader	0.3	$5,200.00	$1,560.00
Student Assistant	0.1	$1,500.00	$150.00
	Subtotal		**$1,710.00**
Travel	Number	Rate	Cost
Pre-Workshop w/ PI s	1	$700.00	**$700.00**
Workshop Expenses	People	Rate	Cost
Room and Board	22	$320.00	$7,040.00
Advertising	Number		
Brochure	1500	$0.15	$225.00
Mailing List	1500	$0.12	$180.00
Mailing	1500	$0.33	$495.00
General Office			
Mail			$50.00
Telephone			$100.00
Supplies			$150.00
Report Preparation			$750.00
	Subtotal		**$8,990.00**
Total Direct Costs		**$18,100.00**	
Indirect Costs	Rate	TDC	Cost
On TDC	0.2	$18,100.00	**$3,620.00**
REGIONAL LEADER TOTAL		**$21,720.00**	

Section I.1. Summary of undergraduate faculty follow-through after participating in the Stressed Stream Analysis and Great Lakes Ecosystem Dynamics NSF/DUE Undergraduate Faculty Enhancement Programs, 1990 - 1999.

	Stressed Stream Analysis		Great Lakes Science	
Category	Faculty	Percent	Faculty	Percent
Participants Involved				
Total	60		87	
Active	57	95%	81	93%
SSA Program Activities Implemented				
EIS/Cooperative Learning	37	65%	43	53%
Role Playing	13	23%	22	27%
Hydrology/Water Analysis	32	56%	NA	NA
Biotic Indices	37	65%	NA	NA
Computer Modeling	NA	NA	34	42%
Analytical Chemistry	NA	NA	12	15%
Insect Deformities	7	12%	NA	NA
Electrophoresis	3	8%	NA	NA
Microbial Analysis	5	25%	NA	NA
GIS/Riparian Analysis	11	55%	NA	NA
New Curricula Developed				
Labs/Lectures	48	84%	70	86%
Courses/Modules	26	46%	39	48%
Majors/Minors	12	21%	20	25%
Independent Studies	16	28%	6	7%
Grants Developed				
Submitted	27	47%	24	30%
Funded	19	70%	11	46%

NA = Not Applicable in program

Section I.2. Prospective Future Regional Workshop

The following UFE program participants (Stressed Stream Analysis/SSA or Great Lakes Ecosystem Dynamics/GLED), who have revised or created new curricula based on their UFE experiences and who have displayed curriculum development grant proposal skills, also have expressed interest in becoming regional workshop leaders. The information that follows is from their UFE program reports (Haynes 1999, 1998b, 1997, 1996, 1995, 1994, 1993, 1991) and subsequent communications while preparing this proposal.

In **Arkansas, Charles Gagen**, Professor and Chair, Biological Sciences, Arkansas Technical University, Russellville, incorporated a variety of UFE/SSA techniques into his fisheries and aquatic science courses, including benthic macroinvertebrate and fish indicators of stream health and student teams tackling sampling and analysis of water quality and biological parameters in watersheds. Before attending the 1995 SSA workshop, he had successfully funded equipment purchases for the aquatic science program at ATU through a NSF ILI grant.

In **Illinois, Karen D'Arcy**, Professor, Chemistry, Governors State University, University Park, developed a new course, "Environmental Studies: A Case Studies Approach", modeled after her experiences in the 1992 UFE/GLED program, that involves students in the characterization and analysis of selected local, regional, and global environmental issues. For example, one class prepared an environmental assessment for the proposed third airport in Chicago. In her chemistry courses, Dr. D'Arcy has used a variety of techniques learned in the GLED program to analyze pesticide residues in local environments and, despite not attending our SSA program, she has moved into the area of watershed analysis, including team-generated "Environmental Consultants" reports, as a teaching tool for students in her team-taught "Aquatic Systems" course. Dr. D'Arcy was a Co-PI on a resubmitted NSF CCD grant, and several education/service grants are pending with the Thorn Creek Macro-site Ecosystem Partnership group. In conjunction with the Thorn Creek group, several GSU students have conducted GLED/SSA-related research projects.

In **Kentucky, David Oetinger**, Professor and Chair, Biology, Kentucky Weslyan College, Owensboro, used his 1995 UFE/SSA experience to refine development of the new Environmental Science minor, to update the introductory "Environmental Science" and "Topics in Environmental Science" courses, and to create a new "Environmental Impact Assessment" course. Dr. Oetinger has successfully written three NSF curriculum development proposals, including an ILI grant funded in 1997 to create "Environmental Impact Assessment: A Capstone Course for an Undergraduate Environmental Science Program."

In **Massachusetts**, **Kevin Curry**, Associate Professor, Biology, Bridgewater State University, Bridgewater, MA returned from the 1995 UFE/SSA program and worked with colleagues to revamp the required sophomore level "Ecology" course at BSU. With an emphasis on graphical analysis of environmental data, students conduct a four-week study of a local lake to learn the elements of investigative biology. They use a variety of equipment, funded in part by an NSF ILI grant, to monitor water quality changes, and teams of students conduct mini-projects to examine aquatic vegetation zonation, macroinvertebrate distributions, nutrient dynamics, etc. Dr. Curry also developed a new, project-oriented course, "Biomonitoring and Water Pollution,"

for upper division students that incorporates techniques learned in the SSA program, including starch gel electrophoresis for isozyme analysis of crayfish and migratory American eels and indices of biotic integrity for stream fishes and invertebrates. To support his curricular changes, Dr. Curry: 1) was a co-PI on successful ILI proposal to update equipment in the Biomonitoring," "Limnology" and "Ecology" courses at BSU, 2) received an Eisenhower Grant to develop curricula in the area of "Teaching Integrated Science Using Watershed Studies", and 3) received a grant from Raytheon Corp. to develop a Watershed Studies program for middle- and high school teachers. The last grant brought teachers to BSU for two graduate courses in the areas of remote sensing, hydrology, GIS, stream ecology or water quality monitoring. Subsequently, teachers developed curricular units for their students and had access to BSU facilities and equipment to teach their classes. At the end of the academic year, the middle-and high school students gave Power Point presentations to conclude their individual research projects.

In **Michigan, Brian Bodenbender**, Assistant Professor, Geological and Environmental Sciences, Hope College, Holland, began teaching "Advanced Environmental Seminar" after attending the 1997 UFE/SSA program. In his course, interdisciplinary teams of students conduct semester-long, self-directed research projects that focus on local environmental problems (e.g., effectiveness of in-stream settling basins in reducing suspended sediment loading to a local lake). To support curricular development in the Advanced Seminar and in two "Earth Environmental Systems" courses, Dr. Bodenbender helped write an NSF/ILI-IP grant, "Environmental Science Instrumentation for Interdisciplinary Undergraduate Research Teams," that provided a GIS laboratory and two spectrophotometers.

Four faculty from **North Carolina** participated in UFE/SSA programs and integrated a variety of content modules and team-oriented, problem solving approaches into their curricula. **Janet MacFall** (1997**)**, Director, Environmental Studies Program, Elon College, resubmitted an unsuccessful ILI proposal, participated in a successful Kresge Foundation grant for new computers and GIS hardware/software, and wrote a successful internal grant for a professional development workshop, based on her SSA experience, for Elon environmental science faculty. **Lynn Leonard** (1997), Assistant Professor, Earth Sciences, UNC-Wilmington, resubmitted an ILI proposal for a critical piece of equipment for her SSA-integrated "Environmental Geology" laboratory course. **Lawrence Kolenbrander** (1997), Professor and Chair, Geosciences and Natural Resources Management, Western Carolina University, Cullowhee, leads "Summer Ventures in Science and Mathematics," a program for gifted NC high school students and uses SSA problems and approaches with this group. **Jonathan Ladapo** (1995), Assistant Professor, Science Department, North Carolina Central University, an 1890 Land Grant school with nearly 100% African-American enrollment, has been attempting to improve curricula there, but needs some external support to gain the visibility needed to overcome administrative and financial obstacles at his institution. A solid core of experienced faculty exists to organize a regional workshop in North Carolina.

In **Ohio, Karl Korfmacher**, Environmental Studies Program, Denison University, Granville, has incorporated UFE/SSA (1997) watershed analysis techniques (e.g., chemical water quality analysis, discharge and loading, benthic macroinvertebrate indices, chironomid mouthpart deformities, fecal contamination assays, etc.) into the several GIS and environmental science courses he teaches. He also developed a stream invertebrate exercise for use by local

elementary school students. Together with colleagues, he secured a Mellon Foundation grant to improve the use of technology in classrooms, and he will conduct a series of faculty development/GIS workshops as part of that initiative. Several other curriculum development and SSA-related research grants are pending.

In **Pennsylvania, Margaret McFadien**, Director, Environmental Science Program, Chestnut Hill College, Philadelphia, was hired to create an environmental science program at a small, urban, religious, women's liberal arts college with no history of modern laboratory or field courses. In the year after participating in the 1995 UFE/SSA program, she wrote and received a NSF ILI grant to purchase a remote sampler, auto-analyzer, flow meter, air sampler, and computer enhancements. Armed with new equipment, new computer skills (acquired in the SSA program) and new software (spreadsheet, graphics, GIS packages), she used our watershed analysis approach to focus the new environmental science major. Each of several courses, emphasizing hands-on lab and field techniques and taken in sequence by environmental science majors, contributes data to a culminating course in environmental analysis that focuses on the problems of a stream running through the campus and the impacts of campus and regional activities on that stream. The enthusiasm and progress of her women students, who were plunged into a very unfamiliar cooperative learning, hands-on, problem solving setting, so impressed her administration that three additional faculty were assigned part-time roles in the environmental science program at her college.

Also in **Pennsylvania, Martha Ritter**, Biology, Clarion University, has focused on how to teach science better since participating in the UFE/GLED program in 1996. With internal and external funding, she works with colleagues at Clarion and with local high school teachers to demonstrate "constructivist models" for teaching science more effectively. The constructivist model emphasizes inquiry, discovery, innovation, personal cognition and social collegiality in the learning process. Constructivist classrooms provide environments where teachers behave in an interactive manner, pursue students' questions, view students as thinkers with emerging theories of the world, encourage students to work in groups, rely heavily on primary sources of data and manipulative materials, present curriculum from whole to part with an emphasis on big ideas, and assess student learning through observation, exhibitions and portfolios. This exciting approach to teaching, combined with our pragmatic techniques, should provide the basis for a very interesting regional workshop in the future.

Again in **Pennsylvania, Assad Panah**, Professor, Geology and Environmental Science, University of Pittsburg-Bradford, created a number of curricula following his participation in the UFE/GLED program in 1994. He chaired the committee that developed the new Environmental Studies major at the University, and he created a new Environmental Field Studies course using GLED environmental analysis techniques as a focus. In addition, Dr. Panah created a new Senior Colloquium course, "Living Dangerously," that covers controversial environmental issues and teaches environmental problem solving techniques. A variety of small grants from within the University have helped fund the curricular innovations described above. With funding from NASA, he built a Tectonics Interactive Remote Imaging System Laboratory that tracks orbiting satellites and compiles real time earth system data on a global scale.

Finally in **Pennsylvania, Alfred Hoffmann**, Director, Environmental Technology Program, Montgomery County Community College, Blue Bell, incorporated UFE/SSA (1993) techniques and the cooperative learning/problem solving approach to science into several lab/field courses. He successfully wrote two grants: an NSF ILI grant to provide SSA-related water quality monitoring gear plus a $10K donation from Sun Oil Co. to the Environmental Technology program at MCCC.

In **West Virginia, Bruce Edinger**, Assistant Professor, Biology and Environmental Science, Salem- Teikyo University, Salem, incorporated case study and team-learning activities into his courses, including "content-heavy, need-to-know-it classes such as 'Anatomy and Physiology' and 'Introductory Biology'" since attending the UFE/SSA workshop in 1995. He and colleagues have written three funded research proposals that involve undergraduates as research assistants, and he has written successful education grants as well. He coordinates a project funded by the Foundation for Independent Higher Education that is preparing curricular modules for a worldwide web site for environmental science instructors and students in the Appalachian region, and he has been involved in two Eisenhower Grants that use local watersheds and their problems to teach elementary- and high school teachers environmental science principles.

In **Wisconsin**, Dorothy Lagerroos (a lawyer by training), Professor, Government and Environmental Policy, Northland College, Ashland, developed a variety of team-learning, local, problem solving activities for her students upon returning from the 1996 UFE/GLED program. 1) A Zero Discharge workshop (with financial support from the Environmental Defense Fund) for which her students wrote a feasibility analysis for Northland College to become a "zero discharger" of the nine chemicals of greatest concern in the Lake Superior basin. 2) A Campus Masterplan for Sustainability, in which students proposed how Northland College facilities could become more Earth-friendly, and which resulted in changes on campus (e.g., passive & active solar heaters, wind generators, composting toilets, community gardens, etc.). 3) A Regional Trends Report on significant environmental issues that her students prepared for the League of Women Voters (this project was funded by a grant from the Bremer Foundation). With a botanist from the Natural Resources Department, she team-teaches a two course unit, "American Government" and "Outdoor Skills," in which students study native vegetation, meet resource management agency personnel, and prepare a plan for managing a local piece of land (e.g., 140 acre parcel owned by the college). Dr. Lagerroos brings a broad, unique perspective to interdisciplinary environmental studies.