GK-12 Project Description ***Graduate Teaching Fellows in STEM High School Education: An Environmental Science Learning Community at the Land-Lake Ecosystem Interface***

A. PROJECT GOALS AND OBJECTIVES

Our GK-12 program will partner advanced University of Toledo (UT) graduate students with high school teachers, their students, our Canadian international collaborators at the University of Windsor (UW), and environmental agencies to build an **Environmental Land-Lake Science Learning Community** at the land-lake ecosystem interface. UT, UW, and our participating high schools are located on western Lake Erie, where the Maumee River is the largest single source of sediments and nutrients that adversely affect the Great Lakes – the world's largest freshwater ecosystem. Our learning community's goal is to build student STEM skills via developing hands-on solutions for environmental problems in local schoolyard streams and waterways feeding the Great Lakes. Research on environmental problems is a mechanism through which students can give back to their own local communities, thereby building an educational network focused on making our lifestyles more interactive with the environment. Our GK-12 program thus embraces the philosophic concept of "public scholarship," which merges scientific research with civic responsibility to benefit the public and the community (see Cohen & Yapa 2003, Janke 2006).

This NSF funding opportunity will establish ***a permanent, internally supported GK-12 program in Environmental Sciences and Engineering,*** linked by ongoing collaborative watershed research projects and building on the existing high school Student Watershed Watch program (SWW) (www.maumeerap.org/ SWW) as developed by the Toledo Metropolitan Area Council of Governments (TMACOG). Using the Oak Openings - Maumee River - Maumee Bay - Lake Erie ecosystem continuum as a model, our program will center on the environmental study of urbanized and agricultural habitats to investigate multiple stressors and major ecological community change. Graduate fellows will translate their STEM knowledge and research experience into high school classroom exercises that encompass SWW data collection, analysis, and presentations in an annual Summit meeting. Building their STEM skills, graduate fellows, teachers, and high school students together will gain hands-on environmental science research experience as well as gain an understanding of the history, social development, and future vitality of the Great Lakes region. To this end, our learning community program will partner our graduate teaching fellows with local Ohio and Canadian high schools and environmental agencies, with the following goals and objectives:

1) **Graduate Fellows** will gain experience in inquiry-based methods to improve their ***teaching competence***, developing their ***communication, collaboration, mentoring, and team-building skills***. They will translate ***hands-on, leading-edge, research experience*** from their STEM graduate studies into helping high school students develop skills for conducting meaningful research and interpreting data collected toward resolving environmental problems. As role models, fellows will demonstrate the excitement and feasibility of university studies and careers in STEM disciplines. In turn, fellows will gain an enduring professional working relationship with K-12 educators, broadening their career options and ability to communicate their research to the public.

2) **High school Teacher**s (grades 9-12), through ***professional development opportunities***, will gain experience in inquiry-based methods and recent developments in STEM research knowledge to help meet and exceed the ***Ohio Academic Content Standards for Science (2003)*** and obtain assistance in sponsoring science fair projects. In turn, they will establish ***long-lasting professional relationships with the Environmental Science Learning Community*** and gain increased appreciation for scientific research and its integration. Our partnering high schools include three districts, Toledo, Sylvania, and Oregon Public Schools, which represent an urban-suburban-rural gradient along the Maumee Bay watershed, and include a 100% minority STEM school (TECHS; Toledo Early College High School) that is located on our campus.

3) **High School Students** will develop their STEM skills within a broader learning community, gaining ***enriched learning experiences*** that lead to greater understanding of the nature and conduct of science inquiry and its integration as a means of exploring the world. They will participate in ***hands-on environmental research and cyberinfrastructure,*** including sensor data collection and geographic information system (GIS) technology. Students will be encouraged and mentored by the fellows to engage in local, national, and international Science Fair projects, including the Intel International Science and Engineering Fair (http://www.sciserv.org/isef/) and presentations at Student Watershed Watch (SWW) - an annual water quality monitoring program that culminates in a Summit event each November. Students thus will gain insight to opportunities in scientific professions

through the role models provided by the fellows and their contact with the learning community.

4) **The Learning Community** will link the above with federal and state environmental agencies, and community organizations, fostering ***change in society's foundations and strengthened and sustained partnerships in STEM***. Participating agencies include the Ohio EPA (Environmental Protection Agency), US EPA, USDA (Department of Agriculture), the US Fish and Wildlife Service, the NOAA Great Lakes Environmental Research Lab (GLERL, in nearby Ann Arbor, MI), the US Geological Survey (also in Ann Arbor), the Ohio Division of Wildlife, the Toledo Metropolitan Area Council of Governments (TMACOG), the Ontario Ministry of Natural Resources, and others. Environmental organizations engaged in our Learning Community include the Joyce Foundation, Duck and Otter Creek Partners (housed at our Lake Erie Center), the Maumee River RAP (Remedial Action Plan), and Partners for Clean Streams, Inc. (PCS).

5) **Our International Partner** is ***the University of Windsor (UW) and Windsor, Canada area high schools*** – located about one hour from UT, thus facilitating regular ongoing collaboration. UW graduate students and Windsor area high school teachers will participate with UT fellows and teachers in the SWW research and Summit each fall. Every other fall, we also will participate in the biannual Lake Erie Millennium conference held at UW. Our UT fellows and selected teachers will travel to Windsor each spring to work with UW faculty, graduate students, teachers, and high school students. We will meet each May at the International Association for Great Lakes Research (IAGLR) annual conference, sponsoring outreach and scientific sessions on our results, and furthering our learning community. We are hosting the 2009 IAGLR annual meeting at UT, where we will highlight our findings. During our collaboration, UW will work towards developing a parallel program.

B. PROPOSAL IMPROVEMENTS: Our proposal has been improved following the panel and reviewer comments from the 2006 submission (NSF #063685), along with the 2004 and 2005 reviews. In response to these comments, we entirely reworked and reconfigured this proposal to center on our common research theme and to reduce the amount of reporting by teachers and fellows to a reasonable and sustainable amount. We clarified the research integration of our graduate fellows with high school STEM activities and science fair projects. We changed the lead PI to the Director of the Lake Erie Center (Dr. Carol Stepien), and retained the help of CoPIs Dr. Daryl Moorhead and Dr. Cyndee Gruden. We added CoPIs Dr. Thomas Bridgeman (who is the lead UT professor for the high school SWW program and will teach the summer water quality course) and Dr. Timothy Fisher (a lake geologist, who will facilitate the earth science component). Due to the new goals and increased research emphasis of the revised GK-12 program, our new CoPIs replaced those from our Education department. Building on existing collaborations, we developed this project in partnership with our Canadian colleagues at the University of Windsor, Canada, including 3 faculty collaborators who will serve on graduate fellow committees and develop a similar effort in Canadian high schools. We added UT professors who will sponsor the graduate fellows as Senior Investigators, and more clearly indicated their research roles. The end result is a focused research-oriented proposal that addresses all of the previous concerns of the panelists and reviewers.

C. PROJECT PLAN

1. Overview of our Environmental Land-Lake Science Learning Community: Our program will establish a new Graduate K-12 Program at UT in Environmental Science Research at the land-lake ecosystem interface, by joining our growing Ph.D. programs in Environmental Sciences and Engineering with the existing Student Watershed Watch (SWW) program for local high school students and teachers. SWW is coordinated by the Toledo Metropolitan Area Council of Governments (TMACOG; www.tmacog.org) and a local non-government organization, the Maumee Remedial Action Plan (MRAP; www.maumeerap.org). Since 1987, over 380 teachers and 16,000 students have participated in the SWW program (www.maumeerap.org/SWW), conducting water quality sampling and analysis followed by presentation of results in a public Student Summit (Mr. Matt Horvat, Coordinator; horvat@tmacog.org; see Mitchell & Stapp 1997; Global rivers education network). Local high-school teachers participating in SWW helped us to prepare this proposal and will serve as our year one teachers (Bollin, Bogue, Borger, HajIbrahim, Jacobs, Newport, & Wilkens).

In addition, we will work with the Joyce Foundation (www.joycefdn.org), which recently awarded $5 million funding to several environmental organizations to improve the environmental quality of the Maumee River watershed, further developing our Learning Community (see appended letter of support).

The proposal plan is to engage 10 highly qualified graduate fellows from our Environmental Sciences and Engineering Ph.D. programs at UT each year, then retain several of these experienced fellows for a second year

to serve as mentors to the new fellows in each subsequent year. Likewise, we will engage 10 local high-school teachers in year one (focusing selection on those who already participate in SWW), then retain several to mentor new teachers in each subsequent year. Fellows and teachers will receive training in pedagogical methods of project-based (inquiry-driven) science education (Krajcik et al. 2003), focusing on local water quality and habitat issues during two week-long summer courses at the Lake Erie Center. The courses will encompass coordinated and team-building field studies of water and habitat quality in local, rural, suburban, and urban landscapes. Those exercises will be used as templates for enhancing the SWW program and developing projects for use in high school classrooms and science fairs to further STEM education goals.

2. Partnerships in the Land-Lake Environmental Science Learning Community: The goal of our mentoring strategy in the Land-Lake Learning Community is for high school students and their teachers to experience the excitement of creating scientific knowledge by conducting meaningful research to improve our community's and the nation's overall environmental health. To reach this goal, we will work together to build student confidence, innovation, and competence through exposure to independent research. We will link the students and projects by building a true learning community of the graduate fellows, teachers, high school students, professors, and environmental and agency professionals centered on a common ecosystem theme. By providing students with a community of peers and mentors with common goals and an investment in their future, we will encourage them to pursue science and engineering careers and to become educated citizens.

The key stakeholders—UT, TMACOG, Maumee RAP, PCS, Joyce Foundation, and local school districts—along with our UW international partner will actively participate in all aspects of this project. These partners have worked for the last several years to develop this grant proposal, and the SWW program is now in its second decade of collaboration with UT faculty and area schools. UT will provide professional development and formal education to fellows and teachers, and facilitate the SWW program. TMACOG will continue to coordinate the SWW program, and facilitate interaction between UT and local schools. Fellows and teachers will work together as teams to develop and implement instructional strategies that reflect project-based research methods focused on water and habitat quality, in a manner that addresses the *Ohio Academic Content Standards for Science* (2003). These new standards emphasize: (1) scientific ways of knowing, and (2) scientific inquiry. This is a substantial methodological and philosophical departure from earlier, content-based science standards, and places new pedagogical demands on teachers that many school districts are struggling to meet. Local school districts will contribute to this partnership by providing schools and classrooms to pilot these new strategies as well as to provide resources and advice in content and curriculum areas. Finally, our program will directly support three new, collaborative initiatives between UT and local schools, designed to increase enrollments of underrepresented groups at UT (see below; 6a) Addressing Representation).

3. Scientific Context and High School STEM Development: This program centers on water and habitat quality; which has significant implications to the economy and public health of northwest Ohio and the Great Lakes region, forms a major focus of scientific research at UT, and constitutes the focus of the local SWW program. The combination of scientific expertise, teachers and students, and local science educational activity resembles Schoolyard Long-Term Ecological Research (LTER) programs (schoolyard.lternet.edu) supported by the NSF. The SWW program has been increasing student awareness of watershed issues for 19 years, without the benefit of an in-depth scientific research program. Our proposed project will add this important dimension.

Currently, the SWW program includes water quality testing performed by high school students at local stream sites. Equipped with testing materials supplied by this program, students and teachers travel to select locations in mid-October to evaluate physical, chemical and biological characteristics of local streams. From the results of these tests, students develop a health assessment for their particular stream segment to present at a public Student Summit, held in November at the Toledo Zoo.

The limited financial and technical support available for the existing SWW program makes it extremely difficult for students to utilize inquiry-based techniques beyond the single time and location of their data collection. Additional scientific and technical support from graduate fellows and UT will extend these efforts to include other sites and dates, as well as data collected by other schools and in other years, allowing more detailed comparisons and analyses of temporal and spatial patterns in water quality. Indeed, a logical extension of these investigations is to develop a more comprehensive watershed-monitoring plan and implement local remediation strategies based on scientific hypotheses (see below; 4. Graduate Research).

A product of the new GK-12 program will be an internet-accessible database of water and habitat quality data from past and ongoing studies. Data collected by high school students will be electronically conveyed to

the Lake Erie Center's Communications and Data Coordinator through the center's online data entry gateway. Once data quality has been verified, the data will be posted to a website maintained by the Lake Erie Center using an internet mapping server (www.lakeerie.utoledo.edu). Our goal is not only to strengthen the existing SWW program by providing additional technical support to both teachers and students, but also to develop an information network among participants in SWW program and our learning community. This network will promote a scholastic community beyond the boundaries of any single school, and will add the excitement and enrichment of an international experience.

Aside from the educational benefits of developing a database for the Maumee River watershed, long-term, repeated measures of water and habitat quality are essential for developing a scientific framework for urban stream studies. Such data are seldom collected, especially at geographic scales larger than single streams or that incorporate gradients of urban disturbance (Paul & Meyer 2001), characteristic of the Maumee River watershed within the Toledo Metropolitan area. However, current studies of urban watersheds within the Long-Term Ecological Research program (LTER) at Baltimore, Maryland (www.beslter.org), demonstrate the feasibility of this approach. Thus data collected by our high school program will provide a scientifically valid database where none currently exist, and are anticipated to augment dissertation research projects for fellows.

4. Graduate Fellow GK-12 Research Program Synthesis: In recent years, many areas of the Great Lakes have experienced improvements in water quality due to increasing controls of point source pollutants. Maumee Bay and western Lake Erie, however, continue to suffer from degraded water quality due to intense land use within the watershed; including non-point source pollutants from agricultural, municipal, and industrial sources. Four interconnected research issues (Fig.1 and below) stand out as the most important ecological and economic issues of degraded water and habitat quality to be investigated through our GK-12 Program. We will focus on water quality and habitat studies that include both the watershed and Lake Erie. In the Maumee Bay ecosystem, graduate fellows, teachers, and students will examine (a) the role of suspended sediments and nutrients from the Maumee River in triggering harmful algal blooms and factors that have contributed to the ongoing success of exotic species, (b) the problem of declining fisheries due to habitat destruction and the emerging viral hemorrhagic septicemia (VHS) virus, (c) use of wetlands to improve water quality (suspended solids and bacterial contamination) and to limit community changes due to invasive species, and (d) the linkages between terrestrial and aquatic ecosystem services**,** including agricultural conservation, pathogen transport, and sustainable development.

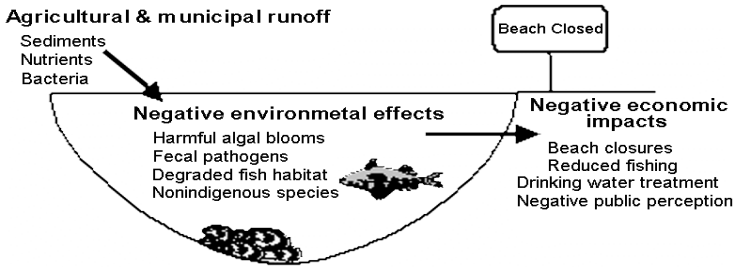

Fig. 1. **Connections between human activities and their environmental and economic impacts, which necessitate scientific data collection in the western Lake Erie ecosystem.**

Sample Graduate Fellow Research Projects to Link with Watershed Watch and Involve High School Students through classroom laboratories and Science Fair Projects include the following four research areas (*lettered a-d*):

a) Toxic Algal Blooms, and Exotic Species (Faculty: Bossenbroek, Bridgeman, Czajkowski, Dwyer, Gruden, Heckathorn, Krantz, Mayer, Philpott, Sigler, Stepien + International Partners: Ciborowski, Corkum, Higgs).

In recent summers, massive blooms of the toxic blue-green alga *Microcystis aeruginosa* formed in western Lake Erie, containing high concentrations of the toxin microcystin and forming foul smelling, rotting, algal mats (Fig. 2). Under these conditions, beaches and recreational boating areas are commonly rendered unusable, sport fishing is adversely affected, fish populations are stressed, and drinking water supplies are threatened. Our data suggest that blooms might be triggered by high, suspended

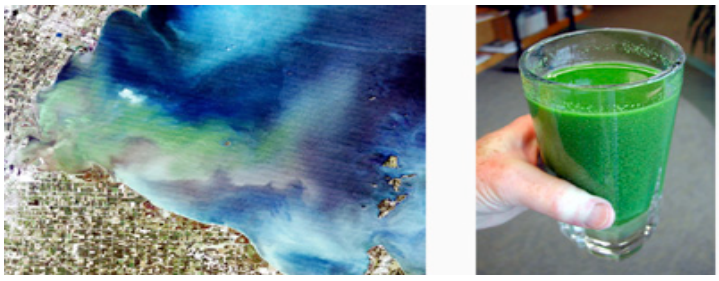

Fig. 2. **Satellite photo of plume showing green toxic algal bloom in western Lake Erie (left), and a glass of the *Microcystis* algae (right). The Lake Erie Center is located at the epicenter of these blooms.**

sediments/low-light conditions in the Maumee River plume (NOAA Sea Grant funded). GK-12 fellows and students will help test this hypothesis using field monitoring, gene- and protein-based techniques, and GIS and remote sensing technology to map spatial patterns and extent of blooms. Results will provide important data for reduced nutrient and sediment loading, shifts in the timing of dredging activity (USDA funded), and an early-warning system for harmful algal blooms (see Vincent et al. 2003, Moorhead et al. 2005, Bridgeman et al. 2006).

Other examples of GK-12 fellow projects include:

- examining the ecological genetics of invasive gobies and dreissenid mussels in the Great Lakes (NSF and USEPA funded; see Stepien et al. 2005, Stepien & Tumeo 2006),
- the possible acoustic control mechanisms for invasive gobies (NSERC funded; Rollo et al. 2007),
- the ecological interactions of *Dreissena* and native mayflies (Lake Erie Protection Funding; DeVanna et al., in review), localized effects of *Dreissena* on benthic primary production, the mechanism of these effects on benthic microbial community structure and function (see Lohner et al. 2007),
- bioeconomics of terrestrial exotic species, including the emerald ash borer (USDA funded, Bossenbroek).

Current graduate students who would be appropriate for GK-12 fellowships in this area include Matthew Neilson (Ph.D. candidate, DES (Department of Environmental Sciences); evolution and biogeography of invasive gobies), Joshua Brown (Ph.D. candidate, DES; comparative population genetics of invasive gobies and dreissenid mussels), Kristen DeVanna (Ph.D. student, DES; ecology of dreissenid mussels and benthic invertebrates), and Betsy Bodamer (graduating M.S. student, entering our Ph.D. program in fall 2007; limnology of weather-driven hypoxia in western Lake Erie).

b) Declining Fisheries due to Spawning Habitat and Emerging VHS Viral Disease (Faculty: Bossenbroek, Bridgeman, Gottgens, Krause, Mayer, Sigler, Stepien + International Partners: Corkum, Higgs).

Habitat modification of Great Lakes' tributaries may influence the migration and distribution of fish and the biological community as a whole. GK-12 fellow projects will evaluate the effect of plant intrusion in channelized streams on community composition and structure in the headwaters of the Ottawa River, a western Lake Erie tributary. Research activities include quantifying the impact of dam removal on ichthyofauna by repeating a study that was completed before dam removal. Another opportunity is to employ genetic technologies for delineating fishery stocks and spawning area contributions. For example, most of the walleye caught in the Great Lakes are produced in primary spawning tributary and reef areas in western Lake Erie.

The binational Great Lakes Fishery Commission is working with us by providing non-lethal fin clip samples for genetic characterization of fishery stocks of walleye, yellow perch, and smallmouth bass. GK-12 fellows and students will employ genetic analyses and advanced microchemistry to quantify the contribution of specific spawning groups in relation to the overall numbers and distribution of fishes, as well as resistance to disease such as VHS, which became epidemic in 2006. Analyses will be combined in a GIS spawning-site characterization, as well as sedimentation and water quality effects (USEPA, NOAA Sea Grant, and Great Lakes Fishery Commission funded) (see Strange & Stepien 2007a,b, Stepien et al. 2004, 2007, Haponski & Stepien, in press).

Declining fisheries are potentially related to long-term changes in water quality and the foraging capabilities of different fish species. Therefore, other projects within this research area would include field studies to characterize the water quality parameters of important spawning areas in Maumee Bay and the Maumee and Sandusky Rivers, as well as spatial modeling of water quality in the western basin of Lake Erie. Results of these studies will be linked to laboratory studies of the effect of turbidity on yellow perch foraging (GLFC funded).

Current graduate students who would be appropriate as GK-12 fellows in this area include Oswaldo Sepulveda-Villet (Ph.D. candidate, DES; population genetics of yellow perch), Amanda Haponski (new Ph.D. student, DES; genetic bottlenecks of Great Lakes fishes), JoAnn Banda (new graduate student, DES; population genetics of walleye), and Nathan Manning (new Ph.D. student, DES; modeling of yellow perch growth).

c) Wetlands and Water Quality (Faculty: Apul, Bridgeman, Czajkowski, Dwyer, Escobar, Fisher, Gottgens, Gruden, Kim, Lawrence, Moorhead, Sigler, Spongberg, Weintraub; International Partner: Ciborowski).

Marshes along the coastline of western Lake Erie are generally maintained behind dikes and managed as habitat for aquatic plants, waterfowl and wildlife. Such management reduces the effectiveness of these marshes to provide ecosystem-level services that benefit water quality and flood control. Graduate fellows and high school students will participate in projects designed to field-test the natural ability of coastal wetlands to trap and transform runoff from residential, industrial, and agricultural land.

Since the mid-1800s, 95% of the southwestern Lake Erie marshes were drained and converted for agriculture and development. Subsequent changes in hydrology (watershed drainage, dikes, high lake levels), biology (exotic

species), geology (erosion, sediment transport and composition), and chemistry (water quality) further magnified wetland losses. Concerns about Great Lakes water quality, the emergence of anoxic "dead zones", and possible threats to productive fisheries add ecological and economic urgency to testing the ability of marshes to purify polluted waters. GK-12 students will be involved in collecting surface water and sediment samples for microbiological characterization (enumeration, community structure), along with physio-chemical characterization of temperature, dissolved oxygen, conductivity, turbidity, pH, chlorophyll concentration, as well as concentrations of plant nutrients that may contribute to algal growth and the formation of "dead zones".

Other examples of GK-12 fellow projects include:

- assessing wetlands for their benefit for reducing bacterial contamination (Ohio Lake Erie Commission funded) from septic systems, wastewater overflows, and agro-urban runoff (USDA funded)(see Gottgens 2000, Lauber et al. 2003, Spongberg et al. 2004, Sigler & Pasutti 2006),
- conducting field mesocosm studies to test wetland designs for *E. coli* removal (USDA funded),
- assessing the ability of wetlands (including invasive plants such as *Phragmites* and purple loosestrife) to remove nitrogen and phosphorus from runoff, which are the nutrients most associated with eutrophication and anoxia in lake waters.

Graduate students in this area who may serve as GK-12 fellows include Todd Crail (new Ph.D. student, DES; ecology of unionid mussels in wetlands) and Olya Mileyeva-Biebesheimer (Ph.D. student, Civil Engineering; CIVE; development of biosensors for water quality applications).

d) Terrestrial Impacts on Watershed Services (Faculty: Chen, Czajkowski, Dwyer, Fisher, Heydinger, Kumar, Lawrence, Moorhead, Philpott, Sigler, Stierman, Weintraub + International Partner: Ciborowski).

A close linkage exists between northwest Ohio's terrestrial ecosystems and Lake Erie. Urban, rural and agricultural ecosystems all combine to form a dynamic and fragile mix that directly impacts the Great Lakes. Students will have the opportunity to take part in research aimed to elucidate the mechanisms of nutrient (carbon, phosphorous and nitrogen) and contaminant (chemical and biological) transport (USDA-funded) by operating a series of lysimeters located in our natural laboratory, the Stranahan Arboretum. The Oak Openings region, a globally distinct savannah ecosystem, serves as a unique site for scientific investigations of carbon and water cycles as well as natural disturbances in managed landscapes. Since a large proportion of land area in northwest Ohio is dedicated to agricultural production, GK-12 fellows and students will take advantage of faculty expertise in addressing the roles of agricultural systems in conservation, pathogen transport (USDA-funded), and sustainable development. Associated with these efforts are opportunities for students to examine how differences in agricultural management (e.g., crop plant diversity, agrochemical use, tilling, and farm size) affect biodiversity, water contamination, and ecosystem functioning. These effects include pathogen transport, pollination, pest control, hydrological services, and movement of dissolved nitrogen and carbon through the soil, along with their subsequent transport through the groundwater. Graduate students in this research area who may serve as GK-12 fellows include Kris Barnswell (Ph.D. student, DES, Brownfield phytoremediation), Joshua Saunders (Ph.D. student, DES, *E. coli* transport) and Sarah Petree (DES, Maumee River water quality).

5. Professional Development of Fellows and Teachers

Table 1. Training and Integration Timeline and for New (N) and Continuing (C) Fellows and Teachers

Date	Activity	Fellows	Teachers	Program Benefit
Last week of May (N,C)	IAGLR: International Assoc. Great Lakes Research annual meeting-alternates between U.S./Canada; 2009 host is UT	Present research & participate in science education symposia (C), International (N,C)	May present in science education symposia (C), Engage in learning community (N,C)	Overview of research, International experience, Meet the research community
June (week-long, 2 credits) (Bridgeman) (N)	*Water Quality* graduate course at the LEC (N)	Advanced concepts and common techniques in water quality and aquatic ecology (N)	Advanced concepts and common techniques in water quality and aquatic ecology (N)	Shared background for GK-12, integration with Student Watershed Watch (SWW)
June (week-long, 2 credits (team-taught, PI, all CoPIs, fellows, teachers) (N,C)	Graduate course: *Science Education and Learning Community in Environmental Sciences at the Land-Lake Interface*	Plan study sites, curriculum, and activities for year with teachers, meet with agencies, learn GIS, WWW database	Plan study sites, curriculum, and activities for year with fellows, meet with agencies, learn GIS, WWW database	Plan study sites, high school student activities, curriculum development, cyberinfrastructure, build learning community
Fall semester (team-taught, PI, all CoPIs, international	*Graduate Environmental Education Methods Seminar* for fellows and guest internat.	Weekly integration and education methods seminar (N,C)	Selected teachers will be invited, guest internatl. lecturers (N,C)	Integration and synthesis of fellows & partners, Teaching ideas exchange

partners) (N, C)	partners (1 unit)			
Fall semester (N,C)	Fellows working in rotating teams in classrooms, integrating with high school curricula, conduct SWW sampling	Fellows work with teachers to give classroom presentations, coordinate SWW sampling, data analysis (N,C)	Teachers work with teams of fellows in classrooms, integrating water & habitat quality research (N,C)	Fellows & teachers develop curricula, enhance high school STEM, introduce students to research
November (N,C)	Student Watershed Watch (SWW) Summit meeting; Lake Erie Millennium conference (altern. Yrs.)	Help with SWW Summit, provide research component (N,C)	Help with SWW Summit, participation, research component (N,C)	Synthesis with larger learning community, other high school students
Spring semester	Student science fair and classroom activities; Collection of data for SWW	Fellows in classrooms and sponsoring high school science fair projects (N,C)	Teachers working with fellows in classrooms (N,C)	Translation of research experience of fellows to high school students, mentorship
April	Intel International Science Fair and local competitions, such as UT Sigma Xi Scientific honorary society, International work with University of Windsor	Presentation of student projects research integration; development of website classroom data (N,C), visits to Canadian classrooms	Presentation of student projects; research integration; development of website classroom data (N,C)	Culmination of high school student project presentations, building research presentation experience

a) Joint Activities for Fellows and Teachers: An organizational meeting will be held in mid-May for fellows, teachers, PIs, program coordinator, program evaluator, faculty, international partners, and representatives from participating schools, TMACOG, and MRAP. The purpose will be to make introductions, review the program, and establish a basis for continued communication and discussion throughout the coming year.

This GK-12 program will support the participation of fellows and teachers in the International Association of Great Lakes Researchers (IAGLR) annual conference (500+ scientists and alternating between the U.S. and Canada in late May), which we will host in 2009. The Education and Outreach sessions will be especially appropriate forums for our GK-12 program. Fellows and selected teachers will present results of their research and teaching programs, and will meet with our UW partners to further develop and grow our learning community.

New fellows and teachers will enroll in Dr. Bridgeman's *Water Quality* course in June at the Lake Erie Center, and will have the opportunity to take other courses in the summer series (see www.lakeerie.utoledo.edu; we are currently offering courses in GIS technology in the Lake Erie region, Lake Erie Fish Ecology, Lake Erie Field Geology, and Phytoremediation). To aid the transition between coursework and practice, a second 2-credit hour course will be offered the following week, *Science Education and Learning Community in Environmental Sciences at the Land-lake Interface* featuring scientifically oriented, team-building exercises in water and habitat quality. The exercises will be conducted at or in proximity to home schoolyards, at upland, rural, urban, and lakeside sites in the Maumee River watershed. The exercises will be designed to help build curriculum and serve as a focus for potential science fair projects. In addition, we will build cyberinfrastructure, web-based data presentation, and GIS skills; thereby developing the linkages for our learning community. Partner teams of a fellow and teacher will consult curriculum materials, including *Benchmarks for Science Literacy Project* 2061 (AAAS 1993), and the Ecological Society of America's new on-line journal, *Teaching Issues and Experiments in Ecology* (TIEE; tiee.ecoed.net), to develop inquiry-based modules consistent with recommendations of the *Ohio Academic Content Standards for Mathematics and Science* (2003) that emphasize inquiry-based experiences for students. Our evaluator will provide training in development and interpretation of performance assessment measures to be used in conjunction with the science-inquiry projects. This will allow participants to self-assess instruction strategies and effectiveness. In addition, teachers will facilitate an afternoon session for fellows focused on secondary classroom management, etiquette and instruction techniques.

A day-long meeting of all partners will be held a week prior to the start of the GK-12 academic year to prepare for the SWW program and complete a schedule of project-based curriculum. Several discussions with other GK-12 program directors pointed to the need for more than one year of effort to sustain implementation of inquiry-based activities in the fellows' and teachers' classrooms. Thus, several experienced fellows will participate for a second year, mentoring the new fellows; and several experienced teachers will participate for a second year, mentoring new teachers; forming a support network and ensuring greater success for inquiry approaches. Program continuity among teachers also will be enhanced through the SWW program and continued

participation in the Land-Lake Environmental Science Learning Community. Quarterly meetings of all teachers, fellows and PIs will be held with a primary agenda of lessons-learned and the goal of improving strategies.

A critical component of this project is maintaining ongoing communication among the fellows, teachers and faculty. We will achieve this goal by scheduling regular meetings and by use of Internet resources provided through the Department of Environmental Sciences (DES; www.eeescience.utoledo.edu) and the Lake Erie Center (www.lakeerie.utoledo.edu) at UT. Each fellow and teacher will be issued a laptop computer (purchased with funds provided by an Ohio Board of Regents (OBOR) grant) that will be used in the training program and for real-time, Internet-based communication. Internet resources will be used to support classroom activities, providing a site where data from the SWW program and additional class investigations can be posted and downloaded. We additionally will link to our UW and Learning Community partners.

University computer accounts will be established for each fellow and teacher. Fellows and teachers will report monthly highlights of experiences on the MyUT online system, sharing key challenges and successes. The CoPIs and program coordinator will review postings, meet with fellows to discuss these data, and prepare a monthly synopsis for posting. This process ensures close communication among participants, regular incorporation of successful activities, and response to developing problems. These data will be used to define quarterly meeting agendas, for program evaluation, to monitor both the changing perspectives and attitudes of fellows and teachers, and to assess the progress of inquiry-based curriculum development and application.

b) Roles of Fellows: The main contribution of the fellows to high school education is to serve as resources to teachers in the SWW, and to serve as both resources and role models for students by demonstrating scientific activities and mentoring science fair projects. Because we are preferentially selecting PhD candidates in water and habitat- related dissertation projects, fellows will have sufficient knowledge and experience with scientific research to serve as sources of practical insight to analytical methods and broader STEM subjects. In addition, they will provide guidance for high school student career choices.

Fellows will participate in the program for at least one year (with some continuing a second year) and earn 5 hours of graduate coursework credit for the year 1 coursework (4 summer, 1 fall). They will learn inquiry-based education methods that can be applied at all levels of education. An obvious advantage of this expertise is improved teaching effectiveness in their future careers as faculty members (D'Avanzo 2003, Handelsman et al. 2004). This will enhance their employment options and professional advancement. In addition, they will become more aware of and more engaged in a broader array of educational activities with high schools. They also will gain a valuable international experience through partnering with our UW team.

Fellows will spend 10 hours per week during the academic year working with the teachers and students in classrooms, as well as individually with high school students and groups of students in science fair project mentoring. During fall semester, the activities will center on SWW data collection, data analysis, data presentation, and the November summit meeting at the Toledo Zoo. During the fall, the fellows will work in teams of 2-3, rotating among different teachers and schools. In the spring semester, the fellows will work on integrating their own research into curricula, and will focus more intently on working with a single teacher, as well as one-on-one with students developing projects for spring science fairs. It is anticipated that each fellow will mentor 1-2 science fair projects. In addition, during the spring, fellows will travel to UW to introduce their research methods and curricula to Canadian high school classrooms; and present their results in May at IAGLR.

c) Role of and Benefits to Teachers and High School Students*:* In response to recent changes in the State of Ohio science education standards that mandate inquiry-based experiences for students, school districts must adopt and implement more inquiry-based educational curricular materials. Moreover, local area GK-12 teachers continue to enroll in inquiry-based science education courses offered through UT. Fellows will aid the transition to inquiry-based learning approaches through direct personal contact and in developing classroom-teaching strategies. The need for assistance is especially strong in grades 9-12, whereas most previous efforts and collaboration between UT and local area schools were focused on elementary and middle school levels (grades K-8). Grades 9-12 is the period when students take more advanced science courses and begin considering career choices.

Teachers will participate in the program for one or more years and earn 4 hours of graduate credit for summer coursework that applies towards a Master's degree, continuing education requirements, and/or re-certification. They also will have options for additional courses and research units. They will develop inquiry-based teaching techniques and strategies for science education, improve their content knowledge, gain new analytical skills, and establish broader contact with scientists and education resources. Their careers will benefit

from this expanded expertise as well as the success of their students. They will be better able to meet new demands for inquiry-based education (*Academic Content Standards for Science)* adopted by the State of Ohio (2003). They also will gain new educational ideas from our Canadian partners and the Environmental Science Learning Community.

High school students will benefit from "learning science by doing science", which has been demonstrated to alter individual perspectives of subject and self. They will be exposed to a wide range of scientific information and protocols, graduate students and faculty working at the cutting edge of their disciplines, and experience the challenges, excitement and gratification of learning through the process of discovery. They will be better prepared for continuing education and likely be more successful in any career that requires self-directed problem-solving skills. Their exposure to the Learning Community will help develop career choices.

6. Communication and Integration via the Environmental Science Learning Community

a) Addressing Representation: The Toledo Metropolitan area includes a very diverse mix of cultures, including traditionally underrepresented groups, and Windsor is the 3rd most diverse ethnic city in Canada. The Toledo Public School system (TPS) enrolls ~35,000 students including 46% African-American and 7% Hispanic students; 47% of students qualify for free or reduced-price lunches. Culturally diverse students consistently prefer peer or extended family learning environments (Barba 1995) and constructivists suggest that students build knowledge of science within a social context (Lorsbach & Tobin 1992). Thus an inquiry-based learning environment involving students working in cooperative groups and focusing on scientific topics of local interest (water and habitat quality) provides a context of learning that may improve the performance of culturally diverse students (Nelson 1996). Our GK-12 summer training program will include a focus on cultural and international diversity, addressing concepts of "Inclusion" to raise awareness of fellows to special needs of culturally diverse students and enhancing their abilities as successful role models.

The University of Toledo is both expanding and consolidating its outreach, recruitment, and retention programs for underrepresented groups at all academic levels. UT has a memorandum of understanding with TPS to establish a transitional pathway between high school and post-secondary education. In 2005, UT and TPS established the Toledo Early College High School (TECHS) on the UT campus, with help from the Knowledge Works Foundation of Bill and Melinda Gates. The school follows UT's academic schedule with the goal of delivering accelerated instruction (including university courses) to facilitate transition to college. The entering freshman class of 2005 included 55% African-Americans, 7% Hispanic, and 65% females. These students attend university courses and UT professors participate in TECHS classes. TECHS is a key partner in our project. In addition, the Department of Environmental Sciences sponsors a week-long environmental sciences camp for TECHS students during June. These interactions clearly benefit both TPS and UT, and provide a base for our GK-12 program in graduate STEM education at UT (see below; *c) Institutionalization* and appended letters).

b) Community Resources: Special resources and facilities at UT and in the local community will be incorporated in this project. The university will provide access to advanced education, environmental science and engineering resources, as well as field facilities at the Stranahan Arboretum (www.arboretum.utoledo.edu) and the Lake Erie Center (www.lakeerie.utoledo.edu). The Lake Erie Center will be the hub for cyberinfrastructure, which will include data storage, web development, information transfer, and linking with environmental agencies and the Learning Community. This cyberinfrastructure will grow and add a true research component to the existing Student Watershed Watch (SWW) educational program (see C1. Overview of our Environmental Land-Lake Science Learning Community and letters of support).

c) Institutionalization: The GK-12 program is an opportunity to develop a permanent graduate fellows program and Environmental Science Learning Community at UT, partnering with our local high schools, environmental agencies, and the University of Windsor. It will prompt the development of new graduate courses as well as changes in existing courses to increase focus on inquiry-based science education, and thus ensure a shift in the educational philosophies of graduate students in STEM disciplines beyond those participating in this project. Fellows will receive NSF support for 1-2 years, prior to and after which our home departments will provide support through externally funded grants or as teaching assistants. When NSF support ends, UT is committed to providing 4 or more graduate student stipends plus tuition waivers, annually (PhD level), dedicated to continuing this program of graduate training in environmental science and engineering (see below; Institutional commitment). The collaborations between UT and TPS, in establishing TECHS and broader memorandum of understanding (see above; Addressing Underrepresentation), define continuing avenues of formal interaction between STEM UT graduate students and high school classes in TPS. We also will seek additional funding to

support teachers from other sources such as the Ohio Board of Regents, which supports an annual grants program (www.regents.state.oh.us/ mainpages/rfp.html) for similar teacher education initiatives. We will seek additional resources to build a similar program at UW.

***d) International Collaboration*:** The Canadian collaboration involves interactions with researchers and their graduate students at UW (Ciborowski, Corkum, Higgs). NSF funding through our collaboration will be used to build graduate and high school student environmental leadership and foster skill exchanges between the UT and UW teams. Our partnership will seek to have two Windsor teachers participate each year in the SWW program and to establish a sister program in Windsor to the SWW program in Toledo. NSF funds will be used to send UT faculty, graduate fellows, and selected high school teachers to joint conferences to interface with the UW team, including the Lake Erie Millennium (www.lemn.org/) and the International Association of Great Lakes Research, IAGLR (www.iaglr.org). Toledo and Windsor teachers and graduate students there will exchange STEM results of research activities in special Outreach Symposia, building our learning community.

Collaboration with UW will build on their existing funded programs established by the UW Faculty of Science for GK-12 teachers and students, ASPIRE (A Science Partnership in Research and Education) and Y-STOP (Youth, Science and Outreach Program). ASPIRE interfaces UW faculty and graduate students with high school science teachers in inquiry-based laboratory exercises (Biology), including: Multimedia Instructional Modules (Physics), Secondary School Programming Competition (Computer Science), GIS Workshops and Guest Lecturer Class Visits (Earth Sciences), Partners in Problem Solving (Mathematics and Statistics), and University Mentors for Science Fair Entrants (Chemistry and Biochemistry). Y-STOP features hands-on sessions in Materials Science, Numeracy, Health Science, Earth Sciences, Environmental Science, Physics and Computer Science; and joins the Windsor South Science Centre with UW science labs. Its Science Cafés feature guest Scientists who present "hot science topics" in the news geared towards a general audience. The Youth CONNECT (Creating Opportunities and New Networks for Conscious Teens) environmental leadership summit held at Riverside Secondary School (Windsor) fosters youth empowerment in creative critical thinking towards promoting environmental community leaders, and received the gold medal for the Senior Division Green Team Challenge category for the Canadian Environment Awards 2007. In January 2006, the Essex County District School Board (Windsor and County Schools) launched its *EcoSchools Program* with the objective to conserve energy, reduce waster and enhance natural landscapes. Our international partnership will interface with these UW programs, contributing valuable ideas and expertise for developing STEM high school education at UT.

This NSF partnership opportunity thereby will provide a networking forum for UT and UW graduate students and Toledo and Windsor area high school teachers and students to interface their successes in environmental leadership, helping to build our Land-Lake Environmental Science Learning Community.

D. RECRUITMENT AND SELECTION

1. Recruitment of Fellows: Current and pending graduate degree programs, coupled to a rapidly expanding research base at UT, provide a strong foundation for recruiting fellows into this project. Extramural funding for departments and institutes focusing on environmental research increased from $1M in 2001 to $5M in 2005, primarily in the Departments of Environmental Sciences, Geography and Planning, Civil Engineering, Chemical and Environmental Engineering, and the LEC. At present, over 180 graduate students are enrolled in graduate programs in environmental sciences and engineering at UT, including more than 60 PhD students. The proposed GK-12 program clearly supports these goals, and in turn, will gain considerable support from the facilities, as well as expertise and funding of faculty and researchers at the Lake Erie Center.

The Graduate School at UT (gradschool.utoledo.edu) has a permanent recruitment officer who is dedicated to expanding diversity in the graduate student body. Our recruiter attends the National Black Graduate Student Association (NBGSA) conference, a McNair Scholars recruitment fair, hosts McNair preview sessions at UT, and has successfully recruited McNair scholars. Recruitment includes an intensive suite of web-based recruitment tools, as well as attendance at key meetings and conferences, such as the annual Ohio Board of Regents' Student Achievement in Research and Scholarship (STARS; www.regents.state. oh.us/stars) meeting and National Society of Black Engineers (NSBE; eee.nsbe.org) meeting. Indeed, the College of Engineering at the UT has an active student chapter of the NSBE. Our graduate recruiter will help promote our program at the meetings she attends. The Offices of Latino Initiatives, African-American Initiatives and Student Support Services at UT have also pledged to assist recruitment efforts.

Finally, departments offering graduate programs in environmental sciences and engineering at UT will use

traditional methods of graduate recruiting in support of this project, including dissemination of posters at professional meetings, mailing posters and fliers to colleges and universities throughout the USA, and linking their web sites to the GK-12 site. For example, the Engineering College launched a diversity web page (www.eng.utoledo.edu/diversity_initiatives) and will add information on this project. A description of the GK-12 program and requirements for application will be added to the package of departmental mailings to potential applicants. We also will link the GK-12 website to those of other supporting offices, colleges, and centers at UT.

2. Selection of Fellows: Our priorities for selecting fellows are for PhD candidates with independent research experience involving water and/or habitat quality, experience or strong interest in education, and members of underrepresented groups. We offer PhD and MS degrees in Biology (Ecology), Civil Engineering and Chemical and Environmental Engineering, and MS degrees in Geology and Geography. Fellows will be selected by application completed by February 1 of each year, and must have a 3.2 gradepoint and be recommended by their advisor and graduate committee.

3. Recruitment and Selection of Teachers: Teachers have already been recruited in collaboration with school administrators, union representatives, and via personal contact through the SWW program. The SWW program holds teacher workshops at the annual Student Summit, at which several teachers who are collaborating on this proposal were contacted in November 2006. Another teacher recruitment source is our summer *ARRT (A River Runs Through It)* program for high school teachers (also housed at the Lake Erie Center). The GK-12 program will be helped by the lead teacher from the TECHS TPS program, Mr. Tim Bollin, who is conducting fish genetic research in 2007-8 through NSF RET (Research Experiences for Teachers) funding with Dr. Stepien (see H below). We will continue to recruit teachers who have a strong background and interest in participating in inquiry-based science activities, and established pedagogical and communication skills to work with the fellows. A recruiting team, composed of the PIs and evaluation team, will meet with area school-based representatives (teachers, union leaders, and principals), to identify and select applicants who best meet program objectives. We will match the fellows' areas of interest and study schedule with those of an interested teacher.

E. ORGANIZATION, MANAGEMENT, AND INSTITUTIONAL COMMITMENT

1. Organization and Management: To ensure accountability and efficient decision making for day-to-day operations, the Principal Investigator (Stepien) will have overall responsibility for the administration of the grant, assisted by the lead CoPI (Bridgeman), the other three CoPIs (Fisher, Gruden, & Moorhead), and the Program Coordinator (Lohner). The PI and CoPIs will organize and manage the program, and serve as the principal contacts between NSF and UT and among the university, school districts, community organizations, and UW. They also will assume primary responsibility for coordinating activities involving fellows, teachers, international partners, and faculty; and will teach the summer program and organize the quarterly meetings.

Our Executive Board will comprise the PI, CoPIs, program coordinator, a lead University of Windsor professor, the evaluator, an administrator and teacher from each of the school districts, chairs from each of the participating departments, and two fellows elected by their peers at the end of the summer training session. The board will meet four times each year, in May, August, November, and March at locations that will rotate through the participating school districts and the University. The Board will decide major issues of project plans and implementation. Three action teams will be appointed for (1) recruitment and selection of fellows and teachers, (2) training and professional development of fellows and teachers, (3) program evaluation and reporting.

The program coordinator (Lohner) will serve as the daily point-of-contact for this project, keeping the PIs appraised of emerging problems, providing a conduit of information among all participants, and assisting with scheduling. Participating faculty members will play several roles, primarily as advisors to fellows and helping with scientific guidance to teachers and fellows. Teachers will assume primary responsibility for coordinating and conducting in-class exercises for high-school courses, which includes oversight of the fellows' participation in developing, assisting, and/or leading classroom activities. Teachers and fellows will also participate in on-line discussion, attend quarterly meetings, and advise the coordinator and PIs of problems requiring rapid attention.

2. Institutional Commitment: Faculty members from two colleges (Engineering and Arts and Sciences) will contribute significant effort to develop this program (also see above; *Graduate research*). The Lake Erie Center and the Stranahan Arboretum will provide additional support, and convenient sites for training and research activities. Web, e-mail, and database support will be provided by UT, and will be coordinated by the Communications Coordinator/Data Manager at the Lake Erie Center. Our international UW partner faculty will serve on graduate committees, assist with outreach and educational sessions at the annual IAGLR conference, and

will seek Canadian funding to establish a similar partner program.

Continuing university commitment is substantial. The courses offered in support of teachers already exist as a permanent part of the curriculum at UT. The Department of Environmental Studies proposes to formulate a new, permanent graduate course in environmental science inquiry, *Science Education and Learning Community in Environmental Sciences*. To continue this program beyond the NSF funding, the Graduate School will commit two Graduate Assistants (one dedicated to TECHS and one more broadly dedicated to TPS), the College of Engineering will commit one Graduate Assistant, and the Department of Environmental Sciences will commit one Graduate Assistant; graduate assistantships include stipends and tuition waivers, for a total monetary value of nearly $30,000 apiece (current value of direct costs). These fellows will work with new teachers rotating into the SWW program, as well as support the new initiatives targeting underrepresented groups (see above; *Addressing Underrepresentation*). In addition, we will continue building our international partnership.

F. EVALUATION PLAN: The following revised evaluation plan is designed to measure project-specific goals as well as the overriding goals of the NSF GK-12 program in order to facilitate the eventual NSF program-wide evaluation. Adaptations have also been made to account for revisions made to the project itself (i.e., smaller number of teachers and fellows). To ensure reliable and valid methodology, the measures used in this evaluation are drawn from existing metrics that are either accepted in the K-12 science community (Reformed Teacher Observation Protocol [RTOP]) or have been used in other NSF GK-12 projects (Classroom Practices & Teacher Characteristics for High School Science). Revisions also simplify the data collection process thereby reducing the time commitment of both the participants and the evaluator. All surveys will be administered online to make data collection more efficient and to reduce the amount of error that occurs due to data entry. Basic demographic information will be collected on the fellows, teachers, and students including the number of underrepresented minorities participating.

Metric	Target	Variable Measured	Frequency
UT EEES course evaluation	Fellows & Teachers	Participants' perception of course and instructor.	At conclusion of summer course.
Pretest/Posttest of knowledge covered throughout the course of the project administered by project coordinator.	Fellows & Teachers	Participants' knowledge gain of teaching inquiry-based lessons.	May and February (control & treatment group).
Classroom Practices and Teacher Characteristics for High School Science developed by Wisconsin Center for Education Research Council of Chief State School Officers (NSF funded).	Teachers & Fellows	Participants' perception of application of course content to classroom; teamwork opportunities between teachers and fellows; and of value of teacher/fellow collaboration.	Annually (April).
Documented observations of participants using RTOP.	Teachers & Fellows	The extent to which knowledge and skills are applied; the degree to which inquiry-based instruction is used, and the appropriateness of the knowledge and skills applied.	Annually (once per teacher/fellow team).
Adaptation of Ohio State University GK-12 Fellow lesson report.	Fellows	The extent to which Fellows use sound instructional strategies when working with high school students.	Form will be completed once per month online.
Ohio Achievement Test in Science.	Students	Student basic knowledge of science.	Annually.
Student participation in local science fairs and Intel Science Fair.	Students	Number of students participating, level of performance (awards, etc.).	Annually, collected by project coordinator.
Student performance on a survey of scientific career opportunities developed by evaluator and project coordinator.	Students	Student knowledge of and interest in pursuing career opportunities in science.	Annually, collected by project coordinator.

The evaluation is designed to test four hypotheses, as well as provide program evaluation for the project goals:

1) Participation in summer courses designed to meet the professional development needs of secondary school science teachers and graduate fellows in science will increase knowledge (pretest/post-test) of inquiry-based instructional strategies in science education;

2) Teachers and fellows will be more likely to apply new knowledge gained from professional development in the classroom than those who have not participated (control/treatment);

3) High school students will increase knowledge of science and scientific inquiry as a means by which to solve problems and gain new knowledge (control/treatment group);

4) High school students will gain insight into career opportunities and international concerns in science (control/treatment group).

Teacher and fellow pretest/post-test designs will measure knowledge gains annually. Because the sample is small, effect sizes rather than statistically significant differences will be examined to determine gains. To test hypothesis 2, participants from the treatment group will be compared annually with an equivalent control group of high school teachers and graduate students in the sciences but not participating in the project (budget compensates the controls). The Reformed Teaching Observation Protocol (RTOP) will be used to measure the degree to which science or math teachers utilize inquiry-based instruction or create inquiry-driven classrooms. Student outcomes (hypotheses 3 & 4) will include a random sample of 125 students from both treatment and control classrooms using cluster sampling (by classroom). Equivalency will be verified through comparison of basic demographic information including race, gender, educational level and experience (teachers), and socio-economic status (students) and if groups are not equal, an analysis of covariance will be administered to control for differences.

1. Data Collection Instruments and Methods: "Participants" include both fellows and teachers. Data collection for the project evaluation will be done by the CoPIs and the project evaluator (Mentzer). ***Reactions*** will be collected through an exit survey and focus groups interviews. ***Learning*** data will be measured through a test of general knowledge developed by lead project faculty for participating teachers. ***Organization support*** information will be collected annually, through surveys of science community relationships by contacting area school districts, community organizations, and UT faculty. Participating teachers will supply their curricula. ***Use of new skills*** will be measured by using the RTOP designed to measure science classroom environments. The PIs also will conduct a monthly review of the instructional log of a randomly selected sample of participants to verify evidence of new knowledge and skills as well as teacher-fellow collaboration. Finally, as part of each professional development course, there will be a "sharing assignment" in which participants will share information gained through the course with others in their field. Instructors will provide evidence of this aspect through student assignment grades. Participant attitudes about teaching science will be measured using the Context Beliefs About Teaching Science (CBATS) and the Science Teaching Efficacy Belief Instrument (STEBI). Results on these tests will be compared with the local control group and other GK-12 projects using the STEBI and CBATS.

2. Student learning outcomes will be measured through the Ohio Achievement Test in Science, through results of participation in the Intel Science fair, and through a brief survey of knowledge of career opportunities in science (developed by senior project faculty and evaluator).

G. FACULTY PARTICIPANTS (see also above; *Graduate Research*)

Principal Investigator: **Carol Stepien**, Professor of Biology in DES and Director of the LEC, College of Arts and Sciences (A&S). Stepien is an active researcher in conservation genetics of Great Lakes fishes and nonindigenous species invasions. She has served as PI for over $2.8 million of funding, and has two current NSF grants. She has published ~50 scientific papers. Dr. Stepien and the CoPIs will run the program.

Co-Principal Investigator: **Daryl Moorhead**, Professor of Ecology, DES and Director of the Stranahan Arboretum, A&S. Moorhead has published ~60 articles and served as PI or CoPI on over $14 million in extramural grants. He has developed inquiry-based methods for undergraduate laboratories in introductory ecology and non-majors, and environmental problems. He was the original PI of our former GK-12 proposal submissions. In this revised project, he will help the coordinator interface fellows, teachers, and classrooms.

***Co-Principal Investigator*: Cyndee Gruden**, Assistant Professor of Civil Engineering, College of

Engineering. Gruden is developing an active environmental science research program and taking an active leadership role integrating engineering principles with high-school education. Her department took the lead on creating an integrated engineering and education course as part of a NSF-funded Bridges to Education project. In this proposal, she will recruit and coordinate the engineering fellows and help to teach the summer LEC courses.

***Co-Principal Investigator*: Thomas Bridgeman**, Assistant Professor of Ecology, DES, A&S. Bridgeman is the lead UT liason for the SWW program, and will teach the primary water quality summer course. He will assist Stepien as lead CoPI at the LEC, help to coordinate the ecology fellows, link the high school classrooms and science fair projects to the Student Watershed Watch program and Environmental Science Learning Community.

***Co-Principal Investigator*: Timothy Fisher,** Professor of Geology, DES, A&S. Fisher is an active researcher in lake level changes in the Great Lakes and reconstructing Pleistocene glacial lake paleogeography. He has been PI for ~$1 million of funding including two recent NSF grants, and has published ~40 scientific papers. Fisher will coordinate the Earth Sciences education and the Geology fellows.

***International Coordinator:* Lynda Corkum,** Professor of Biology and Associate Dean of Science, University of Windsor, Canada is a behavioral ecologist who focuses on the Great Lakes, and is the President of the International Association for Great Lakes Research. She has engaged two other faculty as our international partners and will help integrate our GK-12 program with efforts to establish a similar endeavor in Windsor.

***Evaluator*: Gale Mentzer** will serve as the external evaluator. She is a professional program evaluator with over 10 years experience including federally funded projects. She has extensive training and experience in both quantitative and qualitative methodologies (see attached biosketch).

***Program Coordinator:* Rachel Lohner**, M.S. (Biology), Research Technician will work with Dr. Stepien to provide coordination among the graduate fellows, teachers, CoPIs, evaluator, and international partners. She will be funded 40% time and will work on other funded STEM research projects the remainder of the time.

Other senior faculty: see attached CVs and project descriptions. We include our Canadian partners from University of Windsor, as well as UT faculty who may sponsor graduate student fellows; anticipated as 2 Geologists, 2 Engineers, 1 Geographer, and 5 Biologists/Ecologists per year.

H. SCHOOL DISTRICT INVOLVEMENT: Lucas County is the sixth largest metropolitan county in Ohio, with 462,361 residents divided among urban (66%), suburban (22%), and rural populations (12%), and 85,058 youth, ages 5-17. Toledo is the fourth-largest city in Ohio with 75% of the population residing within the city limits. Toledo Public Schools is the fourth largest public system in Ohio, with a cultural diversity of 46% African-American and 7% Hispanic students, and 47% qualify for free or reduced price lunches. We are formally partnering with three school districts in the Toledo Metropolitan area/Lucas County area, as follows:

Toledo Public Schools has ~35,000 students in 47 elementary schools, 7 junior high schools, 8 senior high schools, and 13 specialized learning centers. Mr. Tim Bollin (tim.bollin@tps.org) teaches classes in Environmental Sciences (grades 9-12) and Senior Science (grade 12), and heads the sciences department at Toledo Early College High School (TECHS, http://www.aft.org/teachers/TFTonthepath.htm); his principal, Dr. Robin Wheatley, provided a letter in support of this proposal (attached); and Mr. Robert Borger (robert.borger@tps.org) teaches classes in Science Research (grades 11-12) in other TPS high schools. TECHS is located on our university campus, providing an ideal opportunity to partner with our proposed GK-12 program. TECHS was developed with a grant from the Knowledge Words Foundation of Bill and Melinda Gates, solely recruits underrepresented students, and focuses on developing STEM skills. Students attend TECHS for 4-5 years and will graduate from high school with an associate's degree or up to two years of college credit.

Sylvania Public Schools encompasses a more suburban and rural area located adjacent to TPS, bridging the local urban-to-rural gradient. Ms. Michelle Bogue (sysv_aca_mb@nwoca.org) and Ms. Abbey Cappell (synv_aca_ak@nwoca.org) offer courses in Horticulture, Environmental Science 1 & 2, and Agriculture-Environmental Foundations (grades 9-12) at Sylvania Northview and Southview High Schools. These are comprehensive high schools that serve over 2500 students and 160 teachers. Northview High School has organized study programs into a Career Pathways format, including a focus area in Environmental & Agriculture. Ten Mile Creek runs directly through the Northview campus.

Oregon Public Schools are located in a rural/agricultural setting adjacent to Maumee Bay on Lake Erie and the UT Lake Erie Center. Clay High School has 12 science teachers offering courses in Physical Science, Chemistry, AP Chemistry, Physics, Technical Physics, Biology, Anatomy, Principles of Technology, and Environmental Science. Out-of-classroom science experiences include hands-on environmental studies at the

Clay HS Shallow Wetland Research Site located on campus, a one-acre aquatic habitat established with the assistance of area Soil Conservation Districts, the Ottawa National Wildlife Refuge, and local contractors. The Ohio DNR Fish and Wildlife Division honored the Clay Wetland with the Wild School Site award in October 1999. Guided by Environmental Science teachers Ms. Hollianne Jacobs (ore_aca_hj@nwoca.org) and Mr. Caine Kolinski (ore_aca_cko@nwoca.org), Clay HS students have sampled and tested water from nearby Big Ditch and shared their findings in the annual Student Watershed Summit since 1998.

I. RESULTS FROM RELATED PRIOR AND CURRENT NSF SUPPORT: We have an NSF-funded summer REU program (EAR-9552552) that is entering its 8th year, in which we are active mentors, publishing with many of our students (senior investigators Spongberg and Mayer are the PI and CoPI). At her former institution, Stepien was the co-author and CoPI of a new NSF-funded REU program (DBI-0243878), from which seven manuscripts with undergraduates are published, accepted, and/or in press to date from those two years of the REU project alone. Stepien was awarded an NSF RET (Research Experiences for Teachers) award in 2007-8 for Mr. Tim Bollin (TECHS program, Toledo Public Schools) to learn fishery genetic research and apply it in his classroom ($10,000 supplement to *FSML-Field Station and Marine Laboratory* NSF award DBI-0627254 with CoPIs Gruden, Mayer, and Czajkowksi, who are CoPI and senior investigators here).

Stepien has sponsored two undergraduate student REU supplements (#0620942 and #0756972) on her NSF research grant, "*Molecular systematics, biogeography, and invasion identity of Neogobiin fishes*" #DEB-0456972 (www.goby.lakeerie.utoledo.edu), as well as a supplement (#0630172) of $10,000 for a visiting postdoctoral scientist from Ukraine and a graduate student from Russia. Project publications to date number 7, including 2 published (Stepien et al. 2005, Stepien & Tumeo 2006), 3 in press (Stepien et al. 2007, Kvach & Stepien 2007, Neilson & Stepien 2007), and 2 accepted pending revision (Kvach & Stepien, Ohayon & Stepien); given in References for this proposal). Two Ph.D. students (Neilson and Brown) are completing several other papers on the body of the project, as parts of their dissertations. Invited and contributed research presentations have included the Society for the Study of Evolution, American Society of Ichthyologists and Herpetologists (symposium on Gobiidae), International Conference on Aquatic Invasive Species, International Assoc. for Great Lakes Research, the Ohio Division of Wildlife, the Borok 2 Conference on Nonindigenous Species in Russia, Risk Assessment conference for Nonindigenous Species Invasions, and department seminars at US Geological Survey, New Mexico State University, Bowling Green University, University of Toledo, and Pennsylvania University Biology Consortium.

In addition, senior investigators Czajkowski and Spongberg worked with K-12 students through a GLOBE program NSF grant (GEO-0222905) on a project that centered on the energy budget. This project focused on student-scientist interactions and contributed to satellite algorithm developed by NASA scientists in the Hydrological Sciences Branch at Goddard Space Flight Center (Ault et al. 2006; Witter et al. 2006).