GK-12: Graduate Fellows in Science and Mathematics Education

A. Results from Prior NSF Support: No GK-12 related prior support.

B. Project Goals and Objectives: The main goal of this project is to *educate, train and interest science and mathematics graduate students to be better teachers and communicators of STEM knowledge and methods, with K-12 teachers and students in particular, and with non-technical audiences in general*. With STEM training, participating graduate fellows will be more likely to engage the broader community in scientific issues throughout their careers and may be more interested in pursuing non-traditional careers. Over the next 5 years, we intend to achieve this goal by involving 50 graduate fellows in rich and interactive relationships with K-12 teachers from 4 urban and rural schools in Duluth, Minnesota and the surrounding area. The fellows will work with K-12 teachers to define the needs and limitations for improving STEM teaching in their schools and create a variety of innovative STEM exercises and projects for K-12 students using an inquiry-based learning process that will take advantage of the expertise and interests of graduate students in three M.S. graduate programs: *Integrated Biological Sciences*, with tracks in cellular-molecular-physiological biology and ecological-organimal-population biology; *Geological Sciences*, with areas of interest in hard-rock geology, Quaternary geology, hydrogeology, geoarchaeology, and physical and chemical limnology; and *Applied and Computational Mathematics*, with concentrations in discrete mathematics, probability, statistics, and data analysis. We have already begun developing relationships with area schools that have a strong desire to develop improved science and mathematics instruction. Our specific objectives include:

***Graduate Fellows will*:**
1. learn to successfully use inquiry-based pedagogy to teach STEM knowledge and skills.
2. appreciate the challenges, rewards and needs of K-12 education.
3. develop and share effective methods of communicating their scientific and mathematical expertise with non-technical audiences in general, and the K-12 community in particular.
4. become critically reflective teachers of STEM knowledge and skills.

***K-12 teachers will*:**
1. strengthen their content knowledge and skills in specific STEM disciplines.
2. engage students in authentic scientific and mathematical inquiry-based learning with increased confidence and effectiveness.
3. gain increased technical knowledge and resources/equipment for authentic STEM learning activities and projects in the classroom.
4. enhance their repertoire of teaching through mentoring of the graduate fellows.
5. develop productive and enduring partnerships with University faculty and graduate fellows in STEM disciplines.

***K-12 students will*:**
1. discover and learn the nature and process of scientific and mathematical inquiry by participating in a range of student-centered projects and activities.
2. gain proficiency, confidence and interest in science and mathematics.
3. see themselves as scientifically literate citizens and perhaps potential scientists through their increased understanding and appreciation of who scientists are and what they do.

Participating University staff, graduate fellows and K-12 teachers will share their experiences and results with their colleagues, parents, and the public, locally, regionally and nationally, thereby gaining a greater appreciation of the potential mutual benefits of developing and maintaining strong collegial working relationships and greater appreciation and understanding of the STEM educational resources the University of Minnesota Duluth has to offer.

C. Project Plan: ***Background***. Recent research has changed our understanding of how people learn (Brown, Cocking & Bransford, 2000). Trained scientists tend to organize information and learn from it differently than novices. Understanding how different groups of people think and learn is of great use for teachers to design courses and for experts to communicate better with novice audiences (D'Avanzo, 2003). For a GK-12 program to be successful at reaching traditionally underserved populations (e.g., rural populations, ethnic minorities), sufficient time must be provided to build individual and organizational relationships, the training of teachers must be more explicitly grounded in the discipline, and facilitators of that discipline must be exposed to the theory and practice of teaching to different groups (Heimlich, 2001).

To identify key instructional issues and to develop and evaluate classroom instruction, graduate fellows and K-12 teachers in our proposed program will use the action research process. Action research is a reflective process by which educators systematically study specific problems in order to guide, correct and evaluate their decisions and actions to improve the teaching and learning in their individual professional context (Chandler, 2003; Dick, 2004; Latterell, 2003). The action research approach mirrors the inquiry-based instructional strategy that will be used in classroom instruction.

Grad fellows. The changing nature of academic career opportunities for graduate students in STEM disciplines requires training and proficiency in teaching (Adams, 2002; Applegate, 2002). Increasingly, STEM graduate students are pursuing careers outside of traditional academia in the public and private sectors where excellent communication skills are essential, particularly with non-technical audiences. In the preparation of graduate fellows for taking an active role in the K-12 classroom, initial and ongoing training in pedagogy will include an introduction to learning theory, how different students learn content-specific knowledge and skills, and how to create and use appropriate instructional, assessment and management strategies (Darling-Hammond & Bransford, 2005; Ebert-May, Williams, Weber, Hodder & Luckie, 2005). Throughout their participation in the program, fellows will be provided opportunities for critical reflection of their teaching experience and for sharing experiences with other participants in the planned Summer Institutes, seminar courses and through an ePortfolio action research process.

K-12 Teachers. Despite the wider availability of innovative science and mathematics educational workshops and the availability of resources online, K-12 teachers often report that they lack the time, institutional resources and confidence in the methods of inquiry-based education to successfully integrate it into their day-to-day teaching. The graduate fellows will provide needed support so that these teachers can successfully and permanently integrate inquiry-based STEM content and skills in their classroom. Our graduate fellows will be the link through which teachers gain access to University resources in STEM disciplines as we create sustainable relationships between K-12 institutions and University faculty. A range of professional development opportunities will also be provided to K-12 teachers in the planned Summer Institutes and through an ePortfolio action research process. All teachers will participate in training and practice in the use of inquiry-based instructional methods. In subject areas, such as mathematics, where teachers have expressed a need for additional knowledge, more intensive training will be provided through development of college level courses tailored to their needs.

K-12 Students. Experiential learning is a critical component for increased science literacy (National Research Council, 2000). Inquiry-based instruction involves real-life projects with outcomes that have consequences that the students understand and that actively engage students in their own learning process leading to greater understanding and interest in STEM. The inquiry instructional strategies incorporated into this project will lead to the development of critical thinking skills because the students will define problems; develop hypotheses; gather, evaluate and synthesize information; and draw conclusions and devise solutions. Further, through direct contact with K-12 students, STEM professionals will be important role models and demystify the nature and role of science and scientists in their daily lives.

Project development. Over the last several years, a diverse group of University personnel and K-12 teachers and administrators from participating schools have designed a program to maximize the benefits to graduate fellows and the K-12 community by addressing the needs and circumstances of both. We held meetings in 2004, 2005, and 2006 with UMD faculty and staff, K-12 teachers and administrators, and other professionals who provide and/or support STEM instruction in the K-12 schools. These meetings identified ways to improve STEM instruction in the schools, ways that the graduate fellows might contribute to these efforts, and ways to provide the training and support for the graduate fellows. In addition, we surveyed local schools to determine their needs and how UMD, in particular, could meet them through funded projects. In addition to increased support in the biological and earth sciences, one very clear result was that K-12 teachers need and want more mathematics training.

The UMD Mathematics Department has been involved in assisting Duluth Public Schools as they incorporated technology into mathematics courses and has also been involved in easing the transition to college mathematics by conducting focus groups of 7-12 grade mathematics teachers and college mathematics professors. These focus groups have concentrated on placement testing and adjusting ending high school courses and beginning college courses in the hopes of a smoother transition for their students into collegiate mathematics.

Three divisions of the University of Minnesota Duluth have worked with us to assemble a range of proven tools and resources to support fellows and K-12 teachers in this project. The Instructional Development Services (IDS) has worked with this team in the past on a range of instructional issues and is currently assisting the Mathematics Department to identify and assess the factors affecting low success rates of freshman students in Precalculus and to develop strategies to enhance student success. Information Technology Systems and Services (ITSS) provides a course management platform called WebCT that will enable faculty and the project manager to create and manage Web-based learning activities and course materials. WebCT is based on 12 years of experience with thousands of courses and students and provides a range of Course Management Tools, Communication Tools, Evaluation Tools, and Content Tools. The Knowledge Management Center (KMC) brings ten years of electronic portfolio experience to the project including software development and extensive implementation experience using the Open Source ePortfolio platform with over 45,000 University of Minnesota users. UMD's ePortfolio is a web-based tool that the graduate fellows and K-12 teachers can use to document professional development. We will also use ePortfolio to provide training materials and templates for formative and summative evaluations based on the action research model. At the end of the year, each fellow and K-12 teacher will have created a professional ePortfolio that will be permanently available for their continued use through their careers. The WebCT and ePortfolio platforms will allow easy access to evaluative and communication tools for fellows, K-12 teachers and project partners despite the geographic separation teams will experience.

Project Description. The project's primary objectives include 1) increasing the interest, desire, skills and effectiveness of graduate fellows to teach and communicate STEM knowledge with non-technical audiences and K-12 students; 2) increasing the knowledge, disciplinary specific skills, and confidence of K-12 teachers to effectively teach science and mathematics, and; 3) increasing student interest and learning in science and mathematics. These objectives will be realized through three major categories of project activities including Summer Institutes, academic year activities in the K-12 schools, and activities to provide ongoing training, interaction and support among the graduate fellows and the K-12 community. In total, these activities will create a rich, interactive context in which graduate fellows and K-12 teachers will collaborate to select, develop and implement an innovative STEM curriculum for their school. The diversity of project participants will yield a valuable interdisciplinary perspective for students, teachers and fellows. STEM discipline faculty will work with and supervise fellow/teacher teams to ensure high quality STEM content, support team efforts and provide access to needed University resources.

Project Activities

1. Summer Institute. Each year, a 10-day summer training institute will be held in August to provide initial orientation, training and team building for the upcoming year's cohort of graduate fellows and K-12 teachers (Table 1). Throughout all sessions, inquiry-based, best teaching practices will be modeled by instructors/facilitators who will include University of Minnesota Duluth faculty from the STEM disciplines, Instructional Development Services, Knowledge Management Center, and the Education Department.

All participants will be introduced to the "action research" model, which provides a systematic framework for the design and delivery of innovative teaching methods by integrating theory, practice and critical reflection to improve practice (Dick, 2004; Latterell, 2003; Reason & Bradbury, 2001). By putting the teacher in the dual role of user and researcher of educational theory, it is both a way of increasing pedagogical knowledge and improving practice. People trained in this method adopt a methodical, iterative approach that helps them identify problems, and plan, implement, evaluate, and reflect upon actions taken to address them. The insights gained from the initial cycle inform the second cycle, where the action plan is modified and the research process repeated (Riding, Fowell & Levy, 1995).

In the first week of the Summer Institute (Table 1), graduate fellows will receive training in learning theory, teaching pedagogy, assessing classroom teaching, and understanding the role of state and national standards in developing K-12 curricula in science and mathematics. K-12 teachers will also receive training in the nature of scientific inquiry in the STEM disciplines and instruction in the specific STEM areas that have been identified as priorities in the pre-workshop surveys and the participant selection interviews. Critical reflection and sharing of insights and experiences among all participants through the use of interactive online software resources, WebCT and ePortfolio, will lay the ground work for ongoing action research efforts during the next year. The reflective process using ePortfolio will follow the DATA method (describe, analyze, theorize, and act) as described by Peters, 1991. In joint sessions, the fellows and K-12 teachers will identify obstacles to implementing inquiry-based education in the classroom and develop strategies for overcoming them. They will also explore a range of inquiry-based educational resources to reinforce the teaching and content lessons learned earlier and to gain practice and confidence in the methods of inquiry learning. The week's activities will end with the formation of fellow-teacher teams who will work collaboratively in the following week to develop individualized academic year plans for their schools.

TABLE 1. Tentative Summer Institute Schedule:

Morning Sessions		**Afternoon Sessions**
Fellow activities	**K-12 teacher activities**	**Joint activities**
Day 1: Learning theory, including how people learn and working with special student populations Introduction to WebCT	The nature and history of STEM disciplines Introduction to WebCT	Examination of effective teaching examples in mathematics and science. Identifying and overcoming obstacles to inquiry-based instruction in the classroom.
Day 2: Pedagogy, including assessing and teaching to different learning styles and children versus adult learners Q & A using WebCT	Grade level specific mathematics content from probability/statistics Q & A using WebCT	Trigonometric lesson including introduction to technology and National Council of Teachers of Mathematics resources.
Day 3: STEM discipline specific pedagogies, including the commonalties and differences of experts versus novices Individual/group reflection using WebCT	Grade level specific biology content from ecologically based natural resources management Individual/group reflection using WebCT	Targeted inquiry-activities: "Water on the Web" http://waterontheweb.org/ "Monarch lab" http://www.monarchlab.umn.edu/ "Minnesota Worm Watch" http://www.minnesotawormwatch.org
Day 4: Classroom assessment techniques Formative assessment using WebCT	Grade level specific geology content from quaternary and bedrock geology of MN Formative assessment using WebCT	Targeted inquiry-activities: "Geology by Light Plane" http://www.geology.wisc.edu/~maher/air/air12.htm "Cookie mining" http://www.fcx.com/aboutus/rockit-part2.htm
Day 5: The role of national and state standards in K-12 science and mathematics instruction Introduction to ePortfolio:	Grade level specific, active inquiry (content the choice of participants) Introduction to ePortfolio:	Form fellow-teacher teams Targeted inquiry-activities: "Schoolyard Ecology" http://www.ecostudies.org/syefest/ "MN Environmental Atlas" http://www.lmic.state.mn.us/EPPL7/Atl

Summative reflection	Summative reflection	as/ "The Paleontology Portal" http://www.paleoportal.org/

Morning Sessions	**Afternoon Sessions**
Day 6: Intro. to the "Action Research" Model (Becoming critically reflective teachers and planning, implementing, observing and reflecting: an iterative process for improving teaching practice) Individual/group reflection	Designing learning environments that are learner-centered, knowledge-centered and assessment-centered Individual/group reflection
Day 7: Team Planning 1: Identify teaching issues fellow-teacher teams will explore in the academic year and identify specific STEM content and skills teachers want to focus on developing in their curriculum Share insights and reflection among teams	Using 21st century technology to support learning by engaging students using tools for data visualization, modeling and analysis Individual/group reflection
Day 8: Team Planning 2: Plan the nature and scope of particular inquiry-based instruction the teams will utilize during the school year and align the instructional plan with state and federal standards and testing requirements	**Team Planning 2:** Define the roles and responsibilities of fellows in day-to-day classroom operation, interaction with students and other activities and define the roles and responsibilities of K-12 teachers in supporting the fellows Share insights and reflection among teams
Day 9: Team Planning 3: Create a timeline for all project activities for the academic year, and explore evaluation tools teams may use throughout the year	**Team Planning 3:** Create a list and budget for equipment, supplies and other resources teams will need to implement their academic year plan and work with faculty to identify UMD and other community resources teams may want to utilize to support their instructional plan Share insights and reflection among teams
Day 10: Team Planning 4: Teams finalize their individualized instructional plan for the academic year Sharing and feedback with other teams	Summarize lessons learned at institute ePortfolio: Documenting professional development and summative reflection; sharing team plans

In the second week of the Summer Institute (Table 1), fellows and K-12 teacher teams will develop their own academic year plans. In addition, the fellow-teacher teams will identify teaching issues that they may want to explore during the academic year. The cyclic nature of the action research approach will allow fellows and K-12 teachers to explicitly examine the effectiveness of their teaching methods, which will help improve teaching throughout the year. The academic year plan will detail strategies that implement inquiry-based instruction in STEM disciplines in classroom activities. It will describe plans for utilizing the fellows in the classroom and what the nature and role of their relationships with students will be. The plan will include a time line of activities, culminating in a year-end Parent-Community event, and a budget for equipment, supplies and other resources they will need to implement their plan.

A major goal of the Summer Institutes will be to improve communication skills among all participants by breaking down barriers between STEM disciplines, academics, teachers and students. For example, not only will the vocabulary used in STEM disciplines (e.g., the Latin names of plants and animals) be taught, but the reasons for the use of specialized language and examples of how and why it works in the real world will also be discussed (e.g., Latin names provide a common language). Similarly, graduate fellows and STEM university faculty will be learning the language K-12 teachers use and the circumstances they face. Finally, fellows and teachers will practice using creative and non-technical language to explain scientific ideas and concepts without "dumbing them down".

An example of a potential individualized instructional plan teams may develop: During the past 4 years and with NSF funding and cooperation with the Fond du Lac band of Ojibwe (Chippewa), John Pastor, one of the participating university faculty in this proposal, has been researching the relation of productivity of wild rice to its effects on nutrient cycles. Wild rice is an important food and natural resource for Ojibwe and an important part of their spiritual culture. There is much confusion about the relationship of traditional Ojibwe spiritual and ecological views to those of Western science, making the teaching of science in traditional tribal schools and colleges problematic. This cooperative project provides a ready platform to build an action process inquiry with the Fond du Lac Ojibwe School. An action process inquiry could be developed to implement the following curriculum in the ecology of wild rice and its role in Ojibwe and Western culture and society. PART ONE: Ecological Focus: Interactions of wild rice and the environment. Goal: Teach students how to systematically observe and investigate cause and effect and reflect on it. Activities: 1a. Conduct an experiment growing rice with different water levels and/or sediments from different lakes. Learning goal: Wild rice *reacts* to environmental conditions. 1b. Add different amounts of rice straw litter to experiment 1a. Learning goal: Wild rice also *causes* environmental changes through accumulation of nutrients in decomposing straw and their transfer to sediment. 1c. A long term observational study in natural lakes with the wild rice. Learning goals: The population cycles of wild rice happen over many years but continuity exists in the natural world in the face of change. Deeper philosophical/social issues: Like wild rice, we all react to changes in our environment but we also cause changes in our environment. These changes happen over long periods. How can we "manage" the natural world if these things all happen? Can we ever truly "manage" a resource or do we just react to its changes? How do we communicate with each other if we are reacting to and changing the environment over long times and in unexpected ways? PART TWO: Mathematical Focus: Summarizing and analyzing data. Goal: Teach students how to discover broad patterns given individual variability, make tentative predictions, and reflect on the relationship between membership in a population and individual traits. Activities: 2a. Measure individual rice plants in the experiment 1a over the growing season. Learning goals: For a group of individual plants, there is an average value of a given measurement, but there is a spread of measurements around the average; e.g., not all plants growing under the same conditions are alike. How do we distinguish two different populations with different averages but wide enough spread in measurement values so that the populations overlap? How do we know which population a single plant belongs to if its measured value (height, etc.) falls into the zone of overlap? 2b. Make a very simple model of nutrient cycling in wild rice to show how to think about the interaction between the living and nonliving world as scientists do and use it to make predictions under different scenarios. Learning goals: Wild rice affects its environment through the transfer of nutrients from dead rice to sediments. Does the future as predicted by the model behave like we would think, or does it behave in surprising ways? What is a "surprise" - does it indicate something about the way the world works or something about our ignorance of the way the world works or both? Deeper philosophical/social issues: What does it mean to be a member of a population even though all the individuals differ from one another? How can two individuals be members of one population while they are still different? If they are different, how do we know they are not members of two populations? Why is it that just like wild rice plants are all different but also members of a population, so, too are members of the tribe each different but they are also members of a larger population? Descent from a common ancestor, perhaps? If we all came from one ancestor, why are we different and how did we become different? In what sense are Ojibwe and white populations in Minnesota two populations? In what sense are they one population? How do scientists think about the ways that the living and nonliving parts of the world interact? What does the Ojibwe view of the world teach about how the living and nonliving parts of the world interact? Where do they agree and differ? PART THREE: Geological Focus: How geologic history and processes affect where wild rice grows. Goal: Teach students how to read maps and see how the glacial/geologic history of an area affects its landscape. Activities: 3a. Map natural wild rice habitat in their geographic area. Learning goal: How to read maps and use them to place particular objects or landscape features within a spatial context. 3b. Identify and describe the glacial/geologic features on the landscape and their relationship to wild rice habitats. Learning goal: Identify relationships between the spatial context of the landscape and the temporal context of glacial/geologic history. Deeper philosophical/social issues: How does glacial/geologic history and nature of a landscape affect what lives and grows there thousands or millions of years later? How can maps help us to understand these patterns of change over long periods of time? How does this geologic history affect how humans have interacted with the landscape over time? What other factors affect how humans interact with a landscape and what are some consequences of various ways that humans interact with the landscape?

2. Academic year activities in the K-12 schools. Graduate fellows and K-12 teachers will work in school-based teams formed during the Summer Institute to implement the individualized instructional plans they created (Table 2). The instructional plans will be aligned with state and federal standards and benchmarks (National Council of Teachers of Mathematics, 2000; National Research Council, 2000). Educational materials will be adapted to address specific educational needs of special student populations (e.g., underrepresented minorities, students at risk, ESL). In particular, at the Fond du Lac Ojibwe School, the Fellow-Teacher teams will meet with the administrators and tribal leaders in order to identify and discuss the needs of the Native American population and the concerns of tribal leaders for their children. At all schools, fellows will work directly with K-12 teachers at least 10 hours a week with 5 more hours of preparation outside of the classroom. Fellows' time in the K-12 environment will include classroom hours where they interact with K-12 students by assisting and/or leading classroom teaching, demonstrations, or labs (including data collection and analysis). Fellows and K-12 teachers will work cooperatively to improve their communication and teaching by using the action research

process to plan, assess and adjust their practices throughout the year. Further, this project will help build and enhance the educational infrastructure in the K-12 schools for all students by providing specialized supplies and equipment, computers, software or other technical and online resources to serve specific educational goals.

Within the context of the inquiry-based instruction provided, particular focus will be paid to addressing the perceived inapplicability of much of science and mathematic instruction (labs in particular) to students' real life experiences. Fellow-teacher teams will select lab activities to teach important STEM concepts, knowledge, and/or skills that effectively relate teaching activities to students' lives, communities, and relevant local issues. When possible, inquiry projects will extend over multiple years, giving students a true investment in the project and demonstrating the realistic time frames often needed to answer scientific questions. For example, students in grade 3 may start a project of growing wild rice in stock tanks, and these students may continue with that project through grades 4 and 5, documenting and exploring the changes that occur and using this as a touch point for teaching important concepts and skills.

TABLE 2. Example graduate fellow roles in K-12 schools for the academic year:

Week 1-3. Opportunity to experience the classroom context with focus on classroom management and understanding the perspectives and abilities of particular K-12 audiences. Informally interact with students (e.g., helping with labs). Make classroom observations and critical reflection. Fellow-teacher teams refine the plans developed in the Summer Institute as needed to fit the particulars of the classroom situation.
Week 4-7. Work with students and teachers to identify specific student-centered, inquiry-based projects they will work on in the coming year (as defined by their individualized instructional plan). Begin implementing the action research process and create teaching evaluation tools and use them to gather desired information.
Week 8-20. Work with students and teachers to facilitate inquiry-based projects, assisting them in the process of developing methods; collecting, summarizing and analyzing data; drawing conclusions; and critically evaluating their efforts (repeat this process throughout the year as described in their individualized instructional plan). Provide or facilitate access to equipment, supplies, resources and STEM professionals in the community to assist students in their projects. Critically evaluate the results of the action research process to inform teaching practice in the classroom and use the results to formulate a second action research question to be explored in the remaining weeks.
Week 20-30. Work with students and teachers to prepare presentations of their inquiry-based projects for a year-end Parent-Community event. Complete the second action research cycle, further informing teaching practice; write paper(s) describing their action research project for a series of publications for wider dissemination in the University and academic communities.

The fellows will serve as STEM role models with whom K-12 students can relate and interact with on a regular basis. In addition, the fellows will facilitate the interaction of other STEM professionals in the community with students relating to specific concepts or skills, and in providing additional or specialized support for student-centered active inquiry projects.

This project starts in the elementary grades to prepare student for things they will be doing and learning in middle and high school by introducing them to "precursor concepts" that are needed to learn scientific thought in general or specific science or mathematics concepts. For example, while students do not take a course in algebra until middle school, younger children can and should be introduced to "algebraic thought" in preparation for learning algebra (National Council of Teachers of Mathematics, 2000). Also, by introducing and letting younger children learn and explore the concepts of "the diversity of life" and processes and realities of "change", they will be better prepared to learn and understand the issues related to evolution, glacial history, etc. when they are introduced to them in middle and/or high school. The focus on elementary grades gains importance as kids are getting "turned off" and loosing their sense of interest and enthusiasm in science much earlier than was previously the case.

The academic year will culminate in the hosting of a Parent-Community event at each school, planned and executed jointly by the students, fellows and teachers. The year-end event will involve presentations and demonstrations by students to parents and other community members about the projects they have been involved in over the year and what important lessons, knowledge and skills they have gained from the year's activities. This event will be widely publicized to, supported by, and attended by the Duluth area community. It will be an opportunity for all participants to demonstrate the contributions and value of the GK-12 program to the community.

3. Ongoing training, interaction and support activities. Graduate fellows will participate in a graduate teaching and communication seminar series (Table 3). The seminar series will meet twice a month over 2 semesters (3 credits). Seminars will include a variety of pedagogical topics as well as broader topics related to outreach and communication with the non-technical audiences. Similarly, STEM discipline specific, graduate-level, K-12 teacher seminar series will be designed and offered in direct response to expressed needs of the project K-12 teachers in particular content areas. The seminar series will meet in the evenings, twice a month over 2 semesters (3 credits).

TABLE 3. Example graduate fellow and K-12 teacher seminar series:

Graduate fellow teaching seminars	**K-12 teacher STEM content seminars**
Sept. Classroom management. Dealing with difficult students. Diversity in the classroom.	Numeration and Number Theory. Extinction.
Oct. Becoming a critically reflective teacher.	Estimation. Environmental impacts of mining.
Nov. Classroom discussion techniques. Classroom assessment techniques.	Algebra. Energy.
Dec. Grading: Letting students know what you expect.	Geometry and spatial sense. Solar System.
Jan. Assigning, managing and grading group work.	Functions. Natural Resources.
Feb. The Native American and Hmong cultural perspectives.	Data collection and analysis. Change.
Mar. Helping students learn critical thinking skills.	Probability and statistics. Space.
Apr. Developing a teaching philosophy. Developing a teaching ePortfolio.	Discrete Mathematics. Mass.

May. Writing for non-technical and educational audiences.	Structure. Time.

WebCT (introduced during the Summer Institute) will provide an online platform for communication between and support among the different school-based fellow-teacher teams and to provide ongoing formative programmatic evaluation. The project manager will monitor and facilitate discussions through WebCT on a weekly basis. The WebCT platform is intended to function as a "teaching circle", where the geographic distances among participating schools is great enough to preclude such regular face to face contact. Through WebCT a supportive professional environment will be created and maintained. As particular questions, issues or situations arise, fellows and teachers can provide and receive support and feedback from other project participants. STEM faculty or the project manager may also pose particular questions for fellows and teachers to discuss and explore. In addition, WebCT will be a platform for informal and ongoing programmatic evaluations.

The ePortfolio tool will be used by fellows and K-12 teachers to document professional development progress and formal programmatic evaluations. Through ePortfolio, project participants will accumulate and present evidence for competence and confidence in using student-centered, inquiry-based classroom instruction that meets mathematics and science teaching standards. The fellow and teacher action research efforts will be documented through ePortfolio, further demonstrating their process of becoming critically reflective teachers. The type of evidence provided in ePortfolio may include artifacts (e.g., samples of work from various projects), action research (e.g., plans and/or results from an action research project), reflection (e.g., a daily journal and/or written summary of reflections on the Summer Institute experience), and production (e.g., classroom lessons and/or project plans). In addition, ePortfolio will be used to provide monthly formal programmatic evaluations to improve future management plans and strategies. An ePortfolio entry wizard will be created for project participants to facilitate understanding and ongoing use of this valuable professional resource. Using ePortfolio entry wizards developed by UMD's Chemical Engineering and Minority and Indian Health programs, a STEM entry wizard for this project will be created to facilitate the inclusion of personal, educational, and professional categories aligned with the STEM framework. Participants will share ePortfolio presentations with other project participants and faculty and Knowledge Management Center staff for periodic feedback and to guide training on this technology.

Dissemination and Broader Impacts. Participating UMD faculty and staff, fellows and K-12 teachers will provide presentations of our projects efforts and successes through local and regional science and mathematics educational conferences (e.g., Minnesota Science Teachers Association, Minnesota Council of Teachers of Mathematics, Minnesota Association of Environmental Educators, Minnesota Academy of Science). A series of articles related to the action research projects will be published in science, mathematics, and education related peer-reviewed journals. So that other programs can benefit from our project efforts, the ePortfolio STEM entry wizard developed and example ePortfolio presentations will be made available through the University of Minnesota ePortfolio platform to all members of the University of Minnesota community as well as to the broader Open Source ePortfolio Initiative (http://www.theospi.org/) for free download by any interested parties worldwide.

D. Recruitment and Selection: Graduate Fellows: In each year of the project, the management team will recruit two to four fellows in each graduate program in Biology, Mathematics and

Geological Sciences, ensuring substantial representation of women, underrepresented minorities and students with disabilities. When applying to the program, prospective fellows will be asked to provide information on course preparation, research and other experience in STEM disciplines, and experiences with K-12 students or teachers. They must demonstrate their ability or desire to work with non-technical audiences and K-12 students in particular. Recommendations from the applicant's advisor, faculty members or others familiar with their work and who can speak to the applicant's quality of work and interpersonal skills will be requested. Preference will be given to students who have not previously participated in the program with a maximum of 2 years participation for any fellow.

Particular effort will be made to attract Native Americans fellows. In the past 4 years, seventeen American Indian programs have been implemented at UMD in a wide range of disciplines and UMD's Chancellor Kathryn A. Martin has accepted an invitation to become a member of the All Nations Louis Stokes' Alliance for Minority Participation Governing Board. This project's management team recognizes both a national shortage of Native people in the mathematics and sciences and the research that shows that Native youth must have role models. With a strong belief that it is possible to attract Native people to our program, the management team will take a three-prong approach. First, we will advertise nationally through bachelor granting institutions with populations of Native American students, the Native American Science and Engineering Society, the Tribal Colleges and Universities Program, and in such publications as *Winds of Change: American Indian Education and Opportunity.*

Second, we will work with faculty in UMD's American Indian Learning Resource Center to better target our own Native American bachelor degree students in STEM majors. We will also collaborate with Dr. Joy Dorscher, president of the Association of American Indian Physicians and director of UMD's Center for American Indian and Minority Health, and Amy Bergstrom, director of Gekinoo'imaagejig (The Ones Who Teach), a joint program of UMD and Fond du Lac Community College, in recruiting efforts for this project. Dr. Dorscher's organization has a national reputation for their ability to recruit Native people into Medical School and is now second in the nation graduating Native American Medical Doctors. Ms. Bergstrom's program recruits Native people to become bachelor degree holding teachers. In addition, Ms. Bergstrom, a Native woman, has agreed to join our project management team. She will serve as a source of Native American candidates from her own program, as well as oversee the entire recruitment process of Native Americans.

Finally, we will work to enlist the nationwide network of tribal leaders to whom we already have many connections through the administrators of Fond du Lac Ojibwe School, research colleagues with the White Earth and Leech Lake tribes of northern Minnesota and other Native American colleagues across the country, to assist us in recruitment efforts among their communities.

The management team will meet in early February to review applications and select those to be interviewed. Finalists will be evaluated based on the applicant's general scientific and/or mathematical knowledge, their ability to communicate that knowledge with a non-technical audience, and interest in science and mathematic education. Final selection will be made with consideration of the interests of participating teachers and their schools. Final acceptance as a fellow is contingent upon acceptance into one of the eligible graduate programs and sponsorship by one of the participating faculty.

<u>K-12 Teachers.</u> Our goal is to provide graduate fellows in STEM disciplines with a rich and rewarding experience in the K-12 community. The hope is that they will continue to be active collaborators with the greater K-12 community and have a desire to communicate scientific and mathematics knowledge to non-scientists through a variety of educational outreach opportunities. In order to maximize our success, we intend to place fellows with teachers and schools with whom we have developed a strong working relationship, which have expressed a strong interest in our program, have a commitment to science and mathematics education, and have demonstrated an ability to provide needed mentorship to fellows (e.g., those with experience supporting student teachers). The principles and teachers in each participating school have expressed their eagerness to host fellows.

E. Organization, Management and Institutional Commitment: The 12 member management team for this project will include four K-12 teachers or principles (one from each partner K-12 school), four STEM department faculty and staff (Latterell, Hale, Pastor and Morton), one education department faculty (Munson), one Native leader from UMD (Bergstrom), one Knowledge Management Center Faculty (Mr. Paul Treuer), and a graduate fellow representative. As lead-PI, Dr. Latterell will serve as the project director and have primary responsibility for overall grant administration, writing progress reports and will take the lead in developing the K-12 teacher's seminar for mathematics content. Dr. Hale will serve as project manager and have primary responsibility for the day-to-day project management and coordination. In addition, Dr. Hale will also coordinate the efforts related to fellow and teacher recruitment and selection, management and planning for the Summer Institutes, and facilitate and manage communication among fellow-teacher teams throughout the academic year. She will also facilitate the participation of additional University faculty and staff for specific project activities. Additional, specific responsibilities among team member include: designing the Summer Institutes (Munson, Latterell and Hale lead), coordinating fellows' seminar (Hale lead), coordinating K-12 teacher seminars (Latterell, Pastor and Morton lead), placing fellows in schools (Munson and K-12 teachers lead), WebCT and ePortfolio interface development (Treuer lead), and coordinate dissemination efforts (Latterell lead).

The management team will meet bi-monthly. Management team meetings will be open to all graduate fellows and collaborating K-12 school and University faculty and staff. They will receive notice of all meetings and a summary of minutes from each. All graduate fellows and K-12 teachers will be required to attend the December management team meeting to provide an opportunity for all participants to meet face to face to discuss problems, issues and insights. In addition to ongoing evaluation efforts to inform project management, we will conduct bi-annual formal programmatic evaluations to provide feedback to determine if any changes are needed in the structure or management of the program.

University institutional support and integration of GK-12 program components include the development and dissemination of ePortfolio wizards for use by the wider University and academic communities to support scholarly activities related to graduate student training in teaching and learning, the development of a teaching pedagogy and communicating with non-technical audiences course for STEM graduate students, and the development of graduate-level STEM content and inquiry-based learning courses for K-12 professional development in mathematics, biological sciences and geological sciences.

F. Evaluation: A combination of self-reflective and evaluation methods will be used throughout the project to assess achievement of the stated objectives (Table 4). Throughout all project activities a range of classroom and informal assessment techniques will be used to modify teaching practice in response to student learning measures and benchmarks (Angelo & Cross, 1993; Williams, Ebert-May, Luckie, Hodder & Koptur, 2004). Ongoing individual self-reflection related to teaching issues and periodic group reflection related to the action research process will be documented using WebCT and the ePortfolio tools and facilitated by the project manager. The evaluation process will be lead by MGT of America, Inc, an outside evaluation group with 30 years of experience within the higher education community.

TABLE 4. Tentative GK-12 evaluation plan:

Objectives	Assessment tool
Fellows: Learn inquiry-based pedagogy to teach STEM knowledge and skills.	pre and post survey of fellows at Summer Institute and in academic year; interview subset of fellows; direct observation; survey teachers Dec and May
Fellows: Appreciate the challenges, rewards and needs of K-12 education.	year end survey of fellows compared to year end survey of graduate students not involved in GK-12 program
Fellows: Develop and share effective methods of communicating their scientific and mathematics expertise with non-technical audiences in general, and K-12 community in particular.	survey teachers and students in Dec and May; direct observation; action research projects; fellow-teacher team instructional plans
Fellows: Become critically reflective teachers of STEM knowledge and skills.	self-reflection diary in ePortfolio; WebCT activity; documentation of the action research process and results in ePortfolio
K-12 Teachers: Strengthen their content knowledge and skills in specific STEM disciplines.	pre and post survey of teachers at Summer Institute and in academic year; interview subset of teachers
K-12 Teachers: Engage students in authentic scientific and mathematical inquiry-based learning with increased confidence and effectiveness.	direct observation; fellow-teacher team instructional plans; survey teachers in Dec and May
K-12 Teachers: Develop productive and enduring partnerships with University faculty, staff and students.	WebCT surveys of teachers and University faculty, staff and students; pre-summer institute and post-academic year survey of teachers
K-12 students: Learn the nature and process of scientific and mathematical inquiry.	assessment of inquiry projects carried out in class; presentations at Parent-Community event
K-12 students: Gain proficiency, confidence and interest in science and mathematics.	assessment of inquiry projects carried out in class; presentations at Parent-Community event; teacher survey of student learning; interview subset of students; state and federal required standardized

	tests in grades 3, 5 & 8; pre and post survey of students
K-12 students: See themselves as scientifically literate citizens and become more likely to see themselves as potential scientist.	pre and post survey of participating students and non-participating students

G. University of Minnesota Duluth Faculty and Staff Participants: The lead PI and 2 of the Co-PIs represent the disciplines of mathematics, geology, and biology with Dr. Carmen Latterell (a mathematics professor), Dr. John Pastor (a biology professor), and Dr. Penny Morton (a geology professor) taking those roles. Dr. Latterell, an associate professor in mathematics, holds a BA and MS in mathematics and a Ph.D. in mathematics education and has taught secondary mathematics and collegiate mathematics for a combined total of 13 years. Dr. Pastor, Director of Graduate Studies in Biology, has 25 years of experience as an ecosystems ecologist. His work utilizes mathematical, field observational, and experimental approaches, especially long-term field experiments. He also teaches a freshman Biological Illustration class, where students learn how to observe the natural world through drawing and keeping a nature journal, teaching techniques which would also work well in K-12 classes. Dr. Morton, an associate professor of geology, has 30 years experience teaching geology. She has taken a special interest in making geology approachable for the general public and other non-geologists.

Dr. Cindy Hale, a research associate at The Natural Resources Research Institute, Center for Water and the Environment, and the Educational Director of the Boulder Lake Environmental Learning Center, takes the role of the third Co-PI. Dr. Hale holds a BS and MS in ecology and a Ph.D. in forest ecology with a doctoral minor in science education. She has a rich background in science education with K-12 students and substantial experience translating current scientific research methods and results to non-technical audiences.

The fourth Co-PI and the senior personnel are experts in Education. Dr. Bruce Munson, professor and department head in Education, holds a Ph.D. in science education. He has extensive experience working with the K-12 science teachers and classrooms. Mr. Paul Treuer in UMD's Knowledge Management Center and Dr. Shelley Smith in UMD's Instructional Development Service Center will provide ongoing support in regards to WebCT and ePortfolio. Ms. Amy Bergstrom will serve as the liaison between UMD and tribal leaders (especially for program development and implementation), as well serve as the main recruiter of Native American Fellows.

H. School District Involvement: Fond du Lac Ojibwe School has 420 students enrolled in K-12. Virtually all students (99%) are Native American and 90% receive free and reduced lunch. Approximately one-third of the student body has identified/diagnosed disabilities (e.g., EBD). Cloquet High School has 727 students enrolled in 9-12 with 25% on free and reduced lunch and 15% are Native Americans. Proctor Middle School enrolls 474 students, with 22% designated with poverty status. Harbor City International School enrolls 153 students, with 31% on free and reduced lunch and 16% in special education.