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Full Project Proposal

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Project Description

Goals and Objectives The University of Massachusetts Amherst (UMass) in collaboration with the Springfield Public Schools seeks to establish a program, Science Technology Engineering and Mathematics UMass K-12 Connections (STEM Connections), with three main goals.

1. To provide science teachers in the middle schools in the Springfield school district with training in inquiry-based teaching and learning, including the opportunity to conduct research as a part of a team of GK-12 Fellows, teachers and UMass faculty.

2. To provide UMass graduate students and faculty with an opportunity to understand the needs and culture of the schools, laying the foundations for future collaborations.

3. To provide a diverse population of middle school students with role models and mentors

The teachers are working towards a Master's Degree in Science Education, for which STEM Connections will offer a year-long, six-credit course (taught by PI Davis) on Inquiry-Based Learning. The course for the teachers will start with a five-day summer workshop, will continue with evening meetings in the fall and spring semester, and culminate in a research conference. The course will be repeated twice.

STEM Connections will create six different project teams consisting of a UMass faculty participant, two graduate students (GK-12 Fellows) and two or three middle school teachers.

The GK-12 Fellows will be prepared for their role in helping implement inquiry-based projects in the middle schools through a number of activities early in the summer, including visiting schools, working with faculty, and taking a methods course for pre-service teachers. Fellows will join the middle school teachers for the Inquiry-Based Learning course, and also meet as a group at UMass.

Faculty participants will work with the GK-12 Fellows on the research themes during the summer, participate in the initial workshop, and work with teams during the remainder of the summer and the academic year. The research themes cover topics such as the hydrologic cycle, water chemistry, atmospheric ozone, arsenic in soil from pressure-treated decks, factors affecting plant growth (including microgravity), pollen and seed cell growth, and the ecology and behavior of birds. Further details of the projects are provided later in this section and in Appendix 1. The faculty participant vitae are also given later.

Despite a decade of efforts to reform science education, student achievement in science at the middle school level is less than desired. Forty percent of US eighth graders score below a basic level in science, and only 27% score at or above the proficient level (Henry, T. 1997; O'Sullivan, Reese, & Mazzeo, 1997). This weakness is reflected in the TIMSS reports comparing the scores of US students with those from other countries (National Center for Educational Statistics, 2001). The scores of US students fall throughout their K-12 careers. In 1995, U.S. fourth graders performed above students from 26 countries in science. A downward trend starts in middle school and continues through high school: the twelfth grade scores were below average and among the lowest of the twenty-one nations compared (NCES, 2000; 2001). In Massachusetts, only 37% of eighth grade students are proficient in science (Henry, 1997), and 31% score below the basic level.

Recent educational standards call for pedagogical approaches based in inquiry. Here, students identify issues, questions, and problems they find meaningful, choose methods of exploration, carry out their studies, and engage in discussion about their findings and ideas (NRC, 1996). Under these standards, teachers provide a learning context where students interact and voice their ideas, as well as express and choose their individual approaches, and where students' ideas are acknowledged and are incorporated into the problem-solving process (Davis, 1999). Active participation in scientific inquiry allows learners to target issues, questions, and problems they find meaningful, outline methods of exploration, carry out their studies, and engage in discourse and debate about their discoveries and ideas. It is especially important to the middle school student that science education focus on the present and the future (Hurd, 2000). What are the unresolved problems and issues facing science and society today? Improving the quality of life has always been a goal of science education and that objective must transfer into a "lived curriculum" which enables students to make sense of science in their daily lives, and engage in science practice (Hurd, 2000).

b. Project Plan This STEM Connections proposal is being submitted by the Science, Technology, Engineering, and Mathematics Education (STEM) Institute at the University of Massachusetts Amherst (UMass). The STEM Institute, the Principal Investigators, and the University overall have an outstanding record in promoting effective teaching in science, technology, engineering, and mathematics. They have an equally strong record in effective collaboration with teachers and schools. Formally created in 1995, the STEM institute traces its origins to 1992. Its broad educational mission in science, technology, engineering, and mathematics education includes research, curriculum development, and teaching improvement in the schools and colleges of the region. Its director is Morton M. Sternheim, Professor of Physics, one of the Principal Investigators of this proposal and of the STEMTEC project discussed below (see Section 3.f). STEM receives University funding to support a variety of workshops, seminars, and other programs, and also has external grants from several sources. The UMass School of Education and the STEM Education Institute have long worked with the Springfield schools to provide professional development for in-service middle school science teachers. This urban district serves 27,000 students; 72% are from minority groups (mostly African Americans and Hispanics), and 77% receive subsidized meals. Test scores are low overall, with 75% of the eighth grade students failing the Massachusetts Comprehensive Assessment System (MCAS) science test in 2000.

Strengthening the teachers' science content knowledge and pedagogic skills is an important element in improving student performance. In 1997, at the request of the Springfield Schools teachers and administrators, we began a master's program in science education. This program is targeted at teachers with K-8 certification who are teaching science in the middle schools, generally with little science teaching preparation. UMass science and education faculty with strong credentials in content and pedagogy teach two science courses in Springfield each fall and spring, and one or two each summer. Teachers complete the 11 courses (33 credits) needed for the M.Ed. degree in 2 or 2.5 years, and apply for Teacher of General Science (5-8) certification by transcript evaluation from the Massachusetts Department of Education. This program also serves the increasing number of elementary teachers serving as science specialists in their schools. The third cohort of approximately 20 teachers will begin in September. Evaluation has been very positive; the teachers and the school administration are enthusiastic about the quality of the program and the professional growth of the teachers. The project is self-supporting; the relatively modest tuition fees cover costs.

STEM Connections would strengthen the masters' program by providing a strong research component for its participants. School teachers rarely have had a research experience at any point in their careers, so they are not in position to offer one for their students. This point was stressed in meetings with school administrators and teachers. As explained elsewhere, the teachers will take part in a summer workshop and a year-long 6-credit course in inquiry-based teaching. They will start by carrying on research themselves in small teams of teachers, graduate students, and college faculty, and then help their students to conduct their own investigations. In addition to the value of the experience, incentives for their participation will include the opportunity to earn credits toward their degree without paying the usual tuition fees, as well as the opportunity to attend professional conferences.

The STEM Connections program is summarized in Table 1. The training activities for the Fellows and teachers are described in more detail below.

GK-12 Fellows Training. Following selection for the program in the spring semester, Fellows will be matched with faculty advisers, learn about the research themes and visit middle school classes. Involvement in research activities will increase from June 1st, the formal start of the program. During the early part of the summer, Fellows will take a School of Education Teaching Methods course designed for pre-service science teachers. This would introduce the topics of co-operative learning, group work, problem-based learning, projects, inquiry-based learning, alternative assessment, frameworks, progress indicators, standards, teaching in a diverse environment, and learning styles. Springfield professional development staff will provide additional workshops on the issues involved in teaching diverse students. Fellows will also receive training in the use of educational technology,
Table 1 Summary of STEM Connections Program.

Time	GK-12 Fellows	K-12 faculty	K-12 students	PI's	College faculty	Project manager
Spring semester 2002	Submit applications get matched to faculty adviser. Visit middle school classes.	Register for summer/fall courses		Meet weekly. Solicit applicants & select Fellows. Organize summer seminars & workshops	Plan summer workshop for K-12 faculty	Design forms, appoint Fellows, start files, contact K-12 faculty
June 2002 July	Work with college faculty. Visit schools Take Methods seminar course as intro to teaching and learning in the K-12 sector			Plan fall course. Plan K-12 faculty workshop. Plan fall course.	Work with Fellows on content of research topics	Book rooms, speakers for summer conference. Hire office staff
August	Technology training Participate in K-12 faculty workshop as tutors for research theme 2 x 1-day follow-up meeting with team	3-day intro to research topics 2-days on research in teams 2 x 1-day follow-up meeting with team		Plan fall course. Develop and implement 5-day workshop for K-12 faculty Attend 5-day workshop for K-12 faculty.	Technology training Attend 5-day workshop for K-12 faculty 2 x 1-day follow-up meeting with team	Manage workshops, schedule fall events
Fall semester 2002	10 h per week in schools. Attend course on inquiry-based learning 1 evening per week in Springfield (8 sessions), to include team progress reports & sharing experiences.	Work with grad students to develop and implement the project-based curriculum. Course on inquiry-	Get involved in inquiry –based research activities. Plan experiments, collect samples, make measurements	Weekly meetings. Review requests for materials and educational technology purchase. Teach course	Work with teams as needed. Attend evening meetings with Fellows and K-12 faculty as needed.	Make weekly visits to class sites for assistance and evaluation, liaison with teachers, grad students and faculty mentors, manage evening

	Approx 4 meetings at UMass. Meet regularly with College faculty. Attend STEM seminars, regional professional society conference. Keep journal, start electronic portfolio. New cohort submits applications.	based learning 1 evening per week in Springfield (8 sessions). Attend regional professional society conference(s)	interpret results, build web-site, keep written records. In-school, end-of-semester presentation	Attend evening meetings with Fellows and K-12 faculty as needed. Recruit and select Fellows for fall semester	Meet regularly with Fellows	events Oversee purchase of materials, supplies, educational technology.
January 2003	Assemble portfolio Work with new team (2 Saturdays) 10 h per week in schools	2 Saturdays with team for new topic. Local professional society conference.	As for fall semester.	Facilitate 2 Saturday meetings. Weekly meetings. Teach course	Work with new teachers for 2 Saturdays	Schedule and manage spring intro. session, implement end of semester presentations
Spring semester 2003	10 h per week in schools. Attend course in Springfield (6 sessions) and meetings (6) at UMass. Meet regularly with college faculty. STEM seminars. Present at regional professional society meeting. Assemble portfolio. Journal article. Mentor new Fellows.	Work with grads in classrooms. Continue course on inquiry-based learning Present at regional professional society conference. Assemble portfolio. Journal article. New cohort registers	As for fall semester	Weekly meetings. Teach course Attend evening meetings with Fellows and K-12 faculty as needed. Journal article	Work with teams as needed Attend evening meetings with Fellows and K-12 faculty as needed. Plan summer workshop for K-12 faculty Journal article	Make weekly visits to class sites for assistance and evaluation, liaison with teachers, grad students and faculty mentors, manage evening events
End of semester	Conference in Springfield.	Conference in Springfield	Conference in Springfield	Conference in Springfield	Conference in Springfield	Conference in Springfield

including the use of appropriate software relating to web page construction, visual presentation (e.g. PowerPoint), data handling (e.g. Excel) and digital imaging and manipulation. The University's Center for Computer-Based Instructional Technology (CCBIT) will provide an introduction to the use of the internet for teaching, and individual faculty advisers would provide training in the use of relevant instrumentation for both laboratory and field measurements. The Fellows will attend the five-day workshop on the research topics for the middle school teachers, the last two days of which involve working in a team with their faculty adviser and two or three middle school teachers. During the academic year, the Fellows will attend the Inquiry-Based Methods Course taught by PI Kathleen Davis. This will consist of some 14 evening sessions in Springfield split unevenly (maybe 8:6) between the fall and spring semesters. Inclusive pedagogy, which is embedded in the course, is modeled throughout program. Participants will walk the talk on this issue. In addition, the Fellows would attend some 10 evening meetings at the university (split approximately 4:6 between the fall and spring semesters) to discuss pedagogical issues and share experiences. These meetings would be scheduled when there was no meeting in Springfield. Fellows would attend the bi-monthly STEM Institute seminars, and attend relevant local professional society conferences such as the Massachusetts Science Teachers Conference, the New England Association of Chemistry Teachers Conference, the Association for the Education of Teachers of Science, and the Massachusetts Environmental Education Society. Fellows would keep a journal, prepare an electronic portfolio and, in collaboration with their faculty adviser and the school teachers, would prepare an article for submission to an appropriate science education journal. Oversight of activities in the schools would be provided by the project manager, who would visit on a weekly basis, PI Davis and two doctoral research assistants from the School of Education. Recruitment and selection of the new cohort of Fellows would be done by the end of the fall semester to allow informal participation in relevant activities throughout the spring semester.

GK-12 Teachers. Training and Professional Development. The teachers in the STEM Connections program are participants in a Masters Degree Program in Science Education, for which the STEM Connections program provides a six-credit course in Inquiry-Based Learning. The teachers in the project will be those participating in the masters program for science teachers. They will be drawn from the five Springfield middle schools (Chestnut Accelerated, John J. Duggan, Forest Park, John F. Kennedy, M. Marcus Kiley) and the two K-8 schools (Elias Brookings, Rebecca Johnson.) During the course, teachers will participate in two teams, the first of which will be formed after the first three days of the summer workshop in which the research topics are introduced. In the final two days of the workshop, teachers will work with a faculty adviser and GK-12 Fellows to gain a greater understanding of the particular research theme. During the remainder of the summer teachers will spend two further days on research related activities. The course will meet approximately 14 times in the evenings in Springfield under the direction of PI Kathleen Davis, the course instructor. Initially these meetings will be devoted to formulating plans for the implementation of the various inquiry-based projects with their middle school classes. Later meetings will focus on progress reports and sharing experiences. Faculty advisers will attend these meetings as needed. In January, the teams will be reconstituted (same UMass faculty and GK-12 Fellows with new teachers) and will meet for two days prior to the implementation of activities in the schools.   As noted earlier, activities in the schools will be monitored by PI Davis assisted by two-part time research assistants (doctoral students the School of Education). Teachers would also document their progress, prepare a portfolio relating to curriculum development, participate in the local professional society conferences and prepare a manuscript for submission to a professional journal. A conference will be held in Springfield at the end of the spring semester which will involve all participants.

GK-12 Research Themes. The six research themes are described below, together with the faculty participants and their departmental affiliations. More detailed descriptions of the themes are provided in Appendix 1.

What is in our water and how did it get there? (Yuretich, Geosciences) The hydrologic cycle forms the basis for studying water at the Earth's surface: where it comes from, how the amounts change on a seasonal basis, the natural processes that change the chemical composition of water, and practices that introduce pollution into the water. Students will use a rain gauge and will also collect rain to analyze chemically. Under the guidance of a fellow, they will compare their rainfall data to historical trends. They will perform simple chemical analyses (e.g. pH, chloride) and compare their data to data from the National Atmospheric Deposition Project (NADP) via the web. Classes will visit area streams and use simple devices to measure the rate of stream flow. In class and in the field they will make simple measurements (pH, hardness, chloride, dissolved oxygen). Fellows will lead a class on a boat trip off the Massachusetts coast.

Stratospheric and Ground Level Ozone (Schneider, Astronomy) The ozone project begins by using the test strips in a directed exploration of some of the established factors affecting local ozone levels, such as sunlight and amount of air filtration. Students are then challenged to develop further hypotheses (using any of a variety of techniques, such as the four-question strategy) and test them around the school. Finally, the students develop larger group projects to study ozone further afield such as investigations of ozone levels in copier rooms, parking lots, cafeterias, and other school locations. They undertake group research projects studying the effects of elevation, local soil and plant conditions, seasonal changes, or degree of urbanization

Exploring environmental biology using Fast Plants and Bottle Biology (Musgrave, Biology) Projects include common duckweed to measure water quality assessing the effects of pH, salinization and exposure to atrazine on the growth and development of Fast Plants), Students will also use data down-links from the International Space Station to monitor an experiment in plant development. They will simultaneously run a simulation of the experiment in the classroom and compare their own data with the space flight data, and data from the scientists' control experiment at Kennedy Space Center. Students will also participate in a virtual tour of Bioshelters, a local business that produces fish and recycles their waste in the hydroponic culture of plants.

Pollen and Seed Cell Growth and Development. (Kunkel, Biology) The mathematics and geometry of growth, the development of simple systems, such as the linear growth of root meristem and pollen tubes, as well as the geometry of growing planar structures (leaves) will provide a rich source of study material, including a history of experimental approaches and modern cutting-edge approaches. Students will use computers to capture growing structures and analyze their growth under the action of several normal environmental variables, temperature, salinity and pH. The effects of abnormal conditions such as heavy metal and organic pollutants on the measurable variables will extend the interest of the students outward toward the environment

Sources and Fate of Pollutants (Tyson, Chemistry) In the "Pressure Treated Wood" project, students investigate the various hypotheses concerning the fate of the arsenic relating to leaching, bioconversion, volatilization and mineralization . Students, in sampling from sites containing pressure-treated timber structures, will take responsibility for the identification, and mapping and sampling of sites. The samples would be subjected to preliminary treatment at the schools (e.g. drying, weighing and extraction with simple solvents). Analyses would be done at UMass. The importance of the provision of reliable information about chemical composition is stressed.

Ecology and Behavior of Birds. (**Byers and Podos**, **Biology**) A series of exercises centered around observations of birds at feeding stations, will introduce students to basic themes in animal diversity, ecology and behavior. They will participate in Project FeederWatch (http://birds.cornell.edu/pfw/), that accumulates data from feeder watchers across North America, and allows observers to compare their local observations with those from a large data set. Accumulated feeder observation data will be used as the basis for a series of activities designed to explore a set of themes and questions. To assist questions about vocalizations, bird sounds can be recorded and interpreted using freely available computer software for creating visual representations of sounds.

History of UMass in K-12 activities. UMass has many formal and informal programs aimed at the state's schools. Teacher preparation and academic outreach have high priorities at this land grant university. The School of Education provides a range of pre-service and in-service programs for teachers. Most notably, it trains more Massachusetts science teachers than any other institution in the state. It offers a range of undergraduate and graduate programs for teachers, administrators, and guidance counselors. In Springfield, where STEM Connections will be based, in addition to the science education M.Ed. program, it conducts a very successful collaborative site-based teacher preparation program. Other departments and colleges sponsor many programs. A recent report lists approximately 200 different UMass K-12 outreach programs (Honan, 2001), many of which are in the sciences.

Co-PI Morton M. Sternheim, Professor of Physics Emeritus and the STEM Education Institute Director, is the lead PI of the Science, Technology, Engineering, and Mathematics Education Teacher Education Collaborative (STEMTEC) project now starting the fifth and last year of the original award. A $5,580,000 NSF CETP project (cooperative agreement #9653966), STEMTEC began as an eight-college, seven-school district collaborative dedicated to producing more, better-prepared, and more diverse math and science teachers; subsequently, it expanded to 21 colleges. Its institutes on reform pedagogy have been attended by 175 college math, science, and education faculty and 53 K-12 teachers, and new teacher preparation tracks and options have been created. STEMTEC's institutes promote the close and highly effective collaboration among K-12 and higher education faculty, with K-12 faculty serving as pedagogy experts in cooperative learning and alternative assessment, and college faculty the experts on content and research methodology.

The 40 UMass faculty participants in the STEMTEC institutes have each modified one or more undergraduate courses. Many STEMTEC courses have included a teaching experience as a course requirement, and some have featured a K-12 connection. For example, PI Tyson taught Chemistry 312, Analytical Chemistry for Non-Chemistry Majors. All of the 45 students chose a K-12 connection for their teaching experience. As they have been working in groups of 2 - 4, about 15 local schools have been involved in this exercise. In addition, a high school class joined in a collaborative research project and visited the laboratory section of the course at UMass. Student attitudes to this teaching requirement have been surveyed by questionnaire and are uniformly positive. The contacts made through STEMTEC and other STEM Institute programs provide a basis for the enhancement of the activities currently in place by the addition of graduate student K-12 Fellows to these collaborations. The STEM Education Institute also offers the Planet Earth program. Originally funded by NASA for three years, it is currently funded by the Massachusetts Space Grant Consortium. The program offers one-week summer workshops and academic-year, follow-up meetings that train teachers to use web based and hands-on materials in their classrooms (Planet Earth, 1999). Many of the Springfield science education master's students have enrolled in this program. Newer programs include a series of Science and Engineering Saturday Seminars for teachers funded in part by Raytheon and online science education netcourses for middle school teachers. STEM had Eisenhower funding for teacher enhancement courses in physics and nutrition, and several internal UMass grants to support outreach activities. (Nutrition Online@UMass, 1999; Cohen, Laus, Beffa-Negrini, Cluff, Sternheim, Sternheim, & Dun, 1999). Finally, it operates UMassK-12, a pioneering Internet service for Massachusetts schools with a unique 15-year history.

Needs and Benefits. *Teachers and Schools*. Despite the intensive call for instructional reform in science classrooms, change has not been extensive. Weiss (1997) reports that "'traditional' lecture/textbook methodologies" continue to be the focus of science instruction (p. 3). The largest percent of time in science classes is devoted to lecture and discussion (38%), followed by hands-on/laboratory work (23%), individual seatwork (19%), non-laboratory small group work (10%), and daily routines/non-instructional activity (10%) (Weiss, 1997). Only 41% of eighth science students report that they engage in science investigations at least once a week (National Education Goals Panel, 1995). Two thirds of middle school teachers emphasize the learning of vocabulary and science facts, and the most heavily emphasized objective in science classrooms is the learning of basic science concepts (83% of science classrooms) (Weiss, 1997). Only 38% of middle school teachers focus on students' acquisition of laboratory skills (NEGP, 1995; Weiss, 1997). In addition, science teachers have less-than-desired subject matter preparation. Weiss (1987) reports that only 43 percent of junior high school teachers have met the minimum number of college science credits set by the National Science Teachers Association (NSTA). Schools continuously face teacher shortages in mathematics and science (Glenn, 2000) which leads to the misassignment of junior and senior high school teachers in core curricular areas (Bennett & LeCompte, 1990).

In the past, teachers' accumulation of a specified number of credit hours in a particular discipline was indicative of their subject mastery (Anderson & Mitchener, 1994). However, the science courses that teachers take often communicate a false image of science and science learning. Many content courses emphasize the rapid learning of large amounts of unintegrated, factual information (NSTA, 1998). Major concepts are poorly delineated from less important concepts; thus, teachers acquire little knowledge and lack a unified, stable knowledge structure of their fields (Lederman, Gess-Newsome & Latz, 1994; Mason, 1992). Furthermore, many university science programs appear to consider laboratory activity as secondary to lecture and useful primarily to substantiate the information delivered by lecture and reading (NSTA, 1998). Teachers who learn science didactically and abstractly cannot be expected to teach children from a constructivist perspective and are unlikely to model investigative behaviors for their students. Lastly, science content courses rarely address issues of learning and teaching. Yet, making strong links between personal learning and the classroom context is important to facilitate teacher change in beliefs and practice (Anderson & Mitchener, 1994; Borko & Putnam, 1996).

GK-12 Fellows. Many scientists and their professional organizations believe that they share in the responsibility of educating today's youth to be scientifically literate (Atkin & Atkin, 1989; Colorado Alliance for Science, no date; Searles, 1990). The Colorado Alliance for Science (CAS) states:

There is far too much to do…Science, mathematics, and technology programs do not match the changing needs of today. Given the available personnel, unstable financial resources…can schools be expected to carry this burden alone?….Education is <u>everyone's</u> business. (CAS, no date)

However, scientists generally have little opportunity to come to know the ways and practices of public schools. This limits their ability to develop partnerships between institutions of higher education and local school districts. Thus, opportunities to engage teachers and students in relevant inquiry associated with their disciplines are lost. In addition, scientists often find themselves in the role as educators, especially if they join faculties at academic institutions. Yet, professional development for college faculty has been limited and further education beyond the doctoral degree traditionally has been up to the individual. Some of the GK-12 Fellows will teach formally and/or informally, and this experience will enable them to be better teachers.

Benefits of the Project STEM Connections addresses national and local educational concerns regarding the science achievement and participation of all students, the preparation of science teachers, and the need to provide valuable links between public school education and institutions of higher learning. Therefore, this project will:

- address issues, events, problems, or topics significant in science, mathematics, engineering, and technology and of interest to all participants;

- actively involve middle school teachers and students in relevant inquiry such that they investigate phenomena scientifically, use the skills and tools of science, mathematics, and technology, collect and interpret data, and make sense of findings;

- introduce middle school teachers and students to scientific literature, media, and technological resources that will expand their science knowledge and their ability to access further knowledge;

- provide diverse populations of middle school students with role models and mentors who will demonstrate and inform students of potential career opportunities, the pathways to successful completion of college programs, and the ways to address possible road blocks (Stanton-Salazar, Vasquez, & Mehan, 1995);

- provide contexts for collaboration among middle school teachers, students, and scientists enabling teachers and students to better understand and contribute to the culture and community of SMET disciplines;

- provide collaborations that will enable scientists (graduate fellows and their mentors in SMET disciplines) to learn the ways and practices of public schools so as to strengthen and further develop partnerships between institutions of higher education and local school districts. (National Research Council, 1996).

In order to achieve these goals, this project will focus, in particular, on the process of student and teacher learning and address issues of diversity and inclusion.

The Process of Learning The mission of science and science education is not only to motivate students to enter scientific professions, but, most importantly, to enable them to be scientifically literate. Such students have an understanding about the natural world about them. They use scientific knowledge and skills to make decisions important to themselves as well as the community in which they live. They participate intelligently in public discussions about scientific and technological issues and are economically productive as a result of their scientific knowledge and abilities (American Association for the Advancement of Science, l989; NRC, l996).

However, the vast majority of students often view science as static--a great wealth of facts known only by scientists that students must learn (Songer & Linn, 1991). Though science is a dynamic process, students are not often allowed to experience science in this way, if at all (Weiss, l994). Participation within community activity provides individuals with an open door to sources of knowledge and understanding (Lave & Wenger, 1991). Such participation in the science community includes: a) admittance to and interaction in science coursework, programs, and activities, b) working in a research laboratory or in the field under the mentorship of an experienced researcher, c) communicating with other scientists, d) attending and participating in science conferences, and e) publishing one's own research. Through "engagement in social practice" with experts and novices within a community of practice such as science, individuals a) acquire valuable resources; b) learn the knowledge, skills, and ways of the community; and c) become skilled and knowledgeable about activities, tasks, tools, and understandings valued within science (Delamont, 1989; Lave & Wenger, 1991). Full participation in a community of practice results not only in knowledge acquisition, but also in "*becoming* part of the community" and the development of an "increasing sense of identity as a master practitioner" (Lave & Wenger, l991, p. 111, italics are in the original).

The teacher-scientist and teacher-scientist-student collaborations can provide educators and their students with opportunities often reserved for those engaged in post-baccalaureate science. For example, Falk and Drayton (1997) report that high school teachers, who were teamed in a year-long collaboration with ecologists came away with benefits that more closely linked them and their students to the science community and its practices. Teachers acquired content knowledge and process skills with real world applications and continuing support in the form of equipment, materials, logistical help in conducting research, contacts with others, help with writing proposals, and exposure to the professional culture and funds. In addition, scientists modeled an inquiry-based pedagogy by sharing their scientific expertise with open-ended inquiry and questioning. In effect, for these teachers, the work of real science transferred as the pedagogy of the science classroom (Falk & Drayton, 1997). This is key, as scientists often report that they have very little to contribute to teaching in K-12 settings because of their lack of teaching experience. Likewise, teachers often view scientists solely as experts in their discipline and not educators. Yet, Herwitz and Guerra (1996) argue that a key aspect of teacher-scientist collaborations is the ability of scientists to provide teachers with a model of inquiry and discovery. Byron Waksman (1999), retired microbiologist, asserts:

Simply put, we are models of what everyone agrees pupils should say and do. We investigate, we think critically, we imagine, we use intuition, we are playful, and we think on our feet and with our hands. 'Hands-on,' 'discovery-based' activity is what we do for a living. (p. 104)

Students, given the opportunity to apprentice with scientists, develop knowledge of scientific practice (Richmond, 1999). Students broaden their views of scientists and the scientific process, and they are better able to associate themselves with the scientific enterprise. Students increase their use of technical language, grow in their appreciation for the complexity of the research process, and develop an understanding of the role a scientist and the larger scientific community play in the generation and acceptance of scientific ideas (Richmond, 1999).

Scientists who collaborate with teachers and students also benefit in many ways: working with others who are excited about the scientists' field of work, who share the love of the subject matter with others, and who consider pursuing the field as a career as a result of the collaboration (Falk & Drayton, 1997). Importantly, working with teachers and students in schools, provides the scientist with an opportunity to make connections outside of the laboratory and have an impact on the "real world" not normally visited and the "real people" in it. They come away with a better understanding of the ways of schools and the daily constraints that educators face.

Thus, in this project, middle school teachers and their students will engage in relevant SMET activities and, as a result, will come away with valuable knowledge and skills, a deeper sense of the practices of the science community, and a valued position in it. Teachers will have opportunities to see inquiry-based approaches to learning modeled for them as learners. They will then design inquiry-based instruction and implement these approaches in their classrooms where support and feedback is provided; work in collaborative settings with other educators; and interact with experienced professionals as mentors and guides (Anderson & Mitchener, 1994; NRC, 1996). Graduate teaching fellows will make key connections to the world of public school education, bringing opportunities for teachers and students to engage in relevant inquiry associated with their discipline and model an approach to learning embedded in their scientific activity.

The links between the various research themes and (a) State and local frameworks, and progress indicators and (b) State and local inquiry standards are illustrated in Appendix 2.

The Inclusion of Diverse Populations Despite efforts to facilitate the legitimate participation of all individuals in science, mathematics, and technology activity (AAAS, 1989), there persists the disproportionately low participation rate of females, some minorities (i.e., Blacks and Hispanics), and those from low-economic circumstances in SMET courses, educational programs, and professional careers (NSF, 1999; Oakes, 1990a). For example, though women comprise 46% of the labor force, only 22% are scientists and engineers (NSF, 1999). Despite the fact that underrepresented minorities comprise 23% of the U.S. population, they constitute only 6% of those working in science and engineering. This imbalance is also reflected in the SMET teaching profession. Historically, biased beliefs, sexism, racism, stereotyping, inequitable social structures, and unfair practices within the science community have served to limit and/or block the participation of females and minorities, and low-income students (AAAS, 1989, 1993; AAUW, 1992; Delamont, 1989; Harding, 1991; Oakes, 1990a, 1990b; Sadker, Sadker, & Klein, 1991). They are often denied academic programs, opportunities, and support needed to acquire the knowledge, skills, and credentials to pursue SMET study and careers (Oakes, 1990a, 1990b; Stanton-Salazar, Vasquez, & Mehan, l995).

Researchers find that teaching practices--like those described above--that situate students in meaningful activities and relevant contexts, and that engage students in discourse and interaction are important for student interest and engagement in science. This is especially true for females and minorities (Baker & Leary, 1995; Eisenhart, Finkel, & Marion, 1996; Mayberry & Rees, l997; Roychoudary, Tippins, & Nichols, l995). In addition, a commitment to developing human potential and equity is important. Networks, structures, policies, and practices must be inclusive and participatory. Individuals, like the students, teachers, graduate teaching fellows in this project, must be able to voice their experiences and needs and be heard; make choices based on their own perceptions and judgments; draft the blueprints and strategies for their learning and professional development; create and implement goals, policies, programs, activities, and career experiences; and reflect on the effectiveness of their choices and what goals, policies, and practices should be maintained, modified, or discontinued (Davis, 1999). All participants must have opportunities to be decision-makers. For example, within this project, classroom teachers have already engaged in conversations with PI's about the kinds of collaborations that would support them in their instruction and help their students' learning process. Their plans for collaboration are what comprise the project activities described below. The project, in working solely with the Springfield Public Schools will be impacting a significant number of special needs, under-represented minority and ESL students. As mentioned in previous sections and in the letter from the Superintendent of the Springfield Public School District (attached in Appendix 3), the District has a substantial number of students included in these categories. Springfield Public Schools has a policy of inclusion of all special needs and ESL students into regular classrooms. Therefore, programs offered within the middle schools in Springfield will reach all students and will be tailored to meet their needs. In addition, our project will provide through the summer Methods Course for the Fellows, diversity training and address innovative pedagogical techniques for working with special populations. As noted earlier, inclusive pedagogy is embedded in the year-long course taken by the K-12 teachers in which the fellows will participate. The involvement of minority Fellows is discussed under “recruitment and selection” below.

How the GK-12 Fellows will enhance Middle School SMET instruction is based in their role in implementing inquiry-based instructional strategies and materials as follows.

- Helping teachers and students develop "driving questions." "A driving question is a well-designed question used in project-based science that is elaborated, explored, and answered by students and the teacher" (Krajcik, Czerniak, & Berger, 1999, p. 66). Such questions are feasible, rich in science content and process, consistent with standards, relevant to lives of learners, meaningful, and able to sustain students' interest over several weeks.

- Aiding teachers and students in the development of investigations. Fellows model and assist in the processes of 1) wondering and making predictions, 2) refining questions so that they are productive (descriptive, compare/contrast, what would happen if) (Elstgeest, (1985; Krajcik, Czerniak, & Berger, 1999); 3) locating resources and evaluating the information provided there; 4) "messing about"--making initial observations, exploring, handling materials.

- Aiding teachers and students in the planning, designing, and carrying out investigations including how to write clear procedures; identify, define operationally, and control variables; and collect and record data. Fellows will assist with the selection, gathering, and setting up of equipment.

- Working with teachers and students to make sense of data and communicate findings in effective and meaningful ways.

- Helping teachers develop "benchmark lessons" (Krajcik, Czerniak, & Berger, 1999) and demonstrations. These lessons would help students learn particularly difficult concepts and important laboratory skills needed to further their project work and that are linked to curriculum standards (e.g. controlling for variables).

- Assisting teachers in developing a project- and standards-based curriculum. (see also Appendix 2)

- Linking teachers and students with experts and resources outside of the classroom and school.

c. Recruitment and Selection STEM Connections will work with the Graduate Program Directors in the appropriate departments and programs to identify potential Fellows from among the current and entering graduate students. The intent is to attract graduate students with strong backgrounds in their fields, excellent communication skills, and an interest in children and in teaching. Selection criteria will include the strength of the candidate's scientific background, interests in teaching and in children, communication skills, and recognition of diversity issues. Candidates will be asked to submit an application form including a personal statement written specifically for the GK-12 program.

Diversity is an important issue here, because the Fellows will serve as role models for the children will also work to facilitate the participation of all social, cultural, and economic groups in science and math so STEM Connections will also work closely with Ann Lewis, the Director of the Northeast Alliance for Graduate Education and the Professoriate. Funding for this program, of $500,000 per year for five years, has been obtained from the NSF Minority Graduate Education Program (HRD 9978878). The University has concrete plans for increasing the number of minority undergraduates going on to graduate school in the various SMET disciplines. While UMass seeks to increase the number of minority graduate students on the UMass campus, a major thrust of the program is to increase the size of applicant pool. A variety of strategies are planned under this initiative, including establishing links with a number of undergraduate institutions. The MGE program has a goal of doubling the numbers of Hispanic, Native, and African American students by fall 2004, and thus the pool from which K-12 Fellows may be selected will have an increased number of minority students from which to recruit. Faculty participants in the STEM Connections program will be encouraged to participate in the summer research experience for undergraduates funded by the MGE program

The most likely graduate programs from which the Fellows will be recruited are those of Animal Science, Astronomy, Biochemistry, Biology, Chemistry, Computer Science, Entomology, Food Science, Geosciences, Math, Microbiology, Molecular and Cellular Biology, Nutrition, Plant and Soil Science, Plant Biology, Physics, Polymer Science, and Wildlife and Fisheries Conservation. These programs had 878 students enrolled in the fall of 2000, of which 345 were women. Of the approximately 500 students who are US citizens or permanent residents, 50 are minorities. These figures were provided by the University's Graduate School (Graduate School Fact Book 2000-2001). In addition to the programs listed above, which are mainly those in the Colleges of Natural Sciences and Mathematics, and Food and Natural Resources, the University has seven programs in the College of Engineering in which about 400 students are currently enrolled. The College of Food and Natural

Resources has a further nine graduate programs with approximately 220 students. Thus the total pool of SMET graduate students on the UMass campus is of the order of 1500, of whom about 60% (900) are US citizens or permanent residents. If only 10% of these students are interested in participating in the K-12 Fellowship program, this represents a large pool (90) of talented students now on campus from which to select the K-12 Fellows. In addition to the recruitment of students from the UMass campus, information about the K-12 Fellowship program will be sent to institutions with large enrollments of students who are traditionally underrepresented in SMET graduate programs. This will be coupled with recruitment visits under the aegis of the NSF-funded Minority Graduate Education program.

The GK-12 teachers are those participating in the Masters Program in Science Education within the University's School of Education. The first cohort of these is already in place. Subsequent cohorts will be recruited through the activities of the School of Education working in collaboration with the Springfield School System. STEM Connections includes a number of high-visibility activities (in-school conferences, for example) that should ensure all SMET discipline teachers are aware of the opportunities for professional development. On-going activities under the aegis of the UMass STEM Institute (such as STEMTEC and Planet Earth) will also help publicize the STEM Connections program.

d. Organization and Management. As noted in the discussion of the results of previous NSF grants and in the vitae, PI's Tyson, Sternheim, and Davis have extensive experience in scientific and educational research, school-university collaboration, professional development, and teacher education. They will work closely in managing the project. The budget includes two ten-hour per week graduate research assistants. These are experienced teachers now working on their doctorates in science education, and they will assist in the classroom implementation of the project.

The primary responsibilities for various project components will be divided as follows:

- Recruiting and selecting Fellows (PI Tyson, with help graduate program directors)
- Arranging summer workshop, research conference (PI Tyson)
- Teaching inquiry course for Teachers (PI Davis)
- Monitoring the school experiences of the Fellows (PI Davis, with TA's)
- Dealing with the fiscal aspects of the program: purchasing, accounting, etc. (PI Sternheim)
- Supervising the technology components (PI Sternheim)
- Publicity and dissemination (PI Sternheim)
- Evaluation (PI Davis and evaluator Feldman)

The PI's will form an advisory panel with representative teachers, Fellows, and mentors that will meet regularly to provide feedback and to assist in planning.

Staff support: The University is committed to support of this project. Accordingly, it will reduce the overhead to zero, and will also return all the funds from the cost of education allowance to the project. Part of this money will be used to support a half-time Project Manager and a quarter-time secretary. Unlike a typical summer workshop for teachers, this project runs year-round. A lesson we learned from STEMTEC: faculty cannot run year-round educational programs requiring continual management without adequate support. Managing events and dealing with the complex paperwork required by the University and NSF is labor intensive. These staff positions will assure the smooth operation of the project, assisting in the recruiting, selection, training, oversight, and record keeping. It will handle the appointment of the Fellows to their positions, deal with other fiscal items such as purchasing and travel reimbursements, and manage the logistics for the summer workshops, academic year meetings, and student research conferences. The Project Manager will also work with the evaluator in data collection. David Hart, from the Center for Computer-Based Instructional Technology (CCBIT), will assist with the Fellows and teachers with their web site development. His support will also come from the cost of education funds.

Resources: There are no UMass programs funding science graduate students as co-teachers/resources in the K-12 sector, nor does the Springfield school district have plans to use funds for graduate student support. Thus the university will not use project funds to replace existing resources, but will instead subsidize the program, as detailed in the discussion of matching funds in the budget justification. Similarly, the schools will use the Fellows and their resources to strengthen their teaching, and will not use their services to supplant existing staffing or other funding.

STEM Connections will provide each Fellow with the following resources and benefits:

- UMass mentor
- School teacher mentors
- Summer methods seminar course, diversity workshops, summer K-12 workshop, and academic-year seminars
- Mileage allowance for travel to schools
- Materials budget of $1000 each (to be shared with the teachers)
- Toll call charges, voice mail
- Duplicating costs as needed
- Access to a pool of educational equipment including laptops, video equipment, digital cameras, a scanner, computer projectors
- University computer account with dial up access
- Access to funds for travel to conferences
- Free tuition, health insurance, and curriculum fee
- Graduate credits for their participation

The PI’s are investigating the possibility of continuing at least some of the Fellowships once the grant funding is ending with the aid of support from school districts and local companies. At least one company has expressed interest in supporting a Fellow.

e. Evaluation The purpose of this evaluation is to provide formative information to the project PIs and summative information to the PIs and to NSF. The evaluation uses a goal-based design. That is, it consists of a set of methods to collect data to evaluate whether the project is meeting its goals (summative), as well as date to provide PIs with the information needed to help the project to meet its goals (formative). The evaluation will rely as much as possible on tested techniques and instruments developed by evaluator Feldman in his previous evaluation studies, as well as those used for the evaluation of other NSF-funded projects (e.g., Frechtling & Sharp, 1997; McGinnis, Shama, Graeber, & Watanabe, 1997). Table 2 provides an overview of the types of methods that will be used to evaluate formatively and summatively the attainment of each of the project goals. These methods are described more fully below.

Surveys Pre- and post-surveys will be used to investigate participants' beliefs and attitudes about science, teaching and learning, and the projected/actual benefits of the proposed collaboration. The surveys will also be used to gain information about the K-12 teachers’ and graduate fellows’ experiences in workshops and training sessions. They will also be used to obtain demographic information.

Interviews and focus groups The goal of interviewing is to gain an understanding of the participant's experiences and the way he or she understands them. Interviews will focus on participants' beliefs and attitudes about students, learning and their teaching science, their experiences within the project, the significance and interest level of their SMET activities, the benefits they received from the project, the obstacles/limitations they encountered, and the ways in which they think about the culture and community of SMET disciplines and/or education. A semi-structured protocol will be used and all

Table 2. Overview of the methods that will used to evaluate the attainment of the project goals.

Project goals	K-12 teacher portfolios	Grad fellow portfolio	K-12 teacher interviews and focus groups	Grad fellow interviews & focus groups	K-12 teacher surveys	Grad fellow surveys	Observations of Grad fellow seminars	K-12 student interviews and focus groups	K-12 Classroom observations
1	X	X	X	X			X	X	X
2	X	X	X	X				X	X
3	X	X	X	X	X	X	X	X	X
4	X		X	X	X		X	X	
5		X		X		X	X		

Goal 1. Address issues, events, problems or topics significant in science, mathematics, engineering and technology of interest to participants.

Goal 2. Actively involve K-12 teachers and students in relevant inquiry to investigate phenomena using the processes, skills and tools of science, mathematics, engineering and technology.

Goal 3. Introduce K-12 teachers and students to the literature, media and technological resources that will expand their science, mathematics, engineering and technology knowledge and their ability to access further knowledge.

Goal 4. Provide contexts for collaboration among K-12 teachers and students, and graduate teaching fellows in science, mathematics, engineering and technology to better understand and contribute to the culture and community of SMET disciplines

Goal 5. Provide collaborations that will enable graduate teaching fellows in science, mathematics, engineering and technology to come to know the ways and practices of public schools to strengthen and further develop partnerships among institutions of higher education and local school districts.

interviews will be audiotaped. Participants will also be interviewed in focus groups as a way to encourage their thinking out loud about the project and to increase the efficiency of the evaluation process.

Observations The evaluators will observe K-12 classrooms and project workshops to evaluate the influence of the project on learning activities in classrooms, the level of significance and interest of participants in SMET activities, and the ways in which teachers and students use literature, media, and technology in their knowledge acquisition. Observations will be recorded in the form of field notes, and audio- and videotaped. Observation protocols will be used to determine the degree to which instruction is standards-based.

Portfolios As part of the project each K-12 teacher and graduate fellow will document their instructional approaches, students' learning activity, and their use of media and technology in a portfolio. Portfolio entries will include items such as course syllabi, lesson plans, unit plans, teaching materials, examples of students' work, students' assessments, photographs and videotapes of students' activities. Rubrics will be developed that will allow the evaluator to use the portfolios to assess the level of attainment of the project goals.

Use of standardized exams There will be two innovative aspects of the evaluation plan. First, the evaluation will test the value and validity of the use of standardized test scores to evaluate the effect of the project on teachers' classroom practice. In the past education reform efforts have assumed that if teachers' practice is changed, then student achievement will improve. This is not the assumption of this evaluation. Figure 1 (in appendix 4) illustrates the relationships between the project, K-12 teachers, students, and the Massachusetts Comprehensive Assessment System (MCAS) scores. The separation among the three parts of the model are indicative of the loose coupling (Weick, 1976) between the different types of participants. Much of the effort in this evaluation will be to determine if teachers' practice changes so that it is more inline with the standards documents (NRC, 1995; MADOE, 1996; NCTM, 2000). It will also attempt to obtain student scores on the appropriate portions of the middle school Massachusetts Comprehensive Assessment System (MCAS) exams and determine if they correlate in any way with observed changes in teachers' practice. It is important to note that this is not an attempt to use the MCAS scores to "grade" the success of the project. Rather, it is a test of the degree of coupling between the teachers' use of standards-based methods and the students' performance on the MCAS exam. This finding could be of great use to the evaluation community

Case studies The second innovative aspect of the evaluation plan will be to incorporate in-depth case study methods (Yin, 1989) as part of the overall evaluation within the constraints of the evaluation budget. During the first year of the project all participants will be surveyed and take part in focus group interviews at the beginning and end of cycle 1. The initial survey and focus group data will be used to identify two teams to study in-depth using the other evaluation methods in Table 1. This will be repeated in cycles 2 and 3. In addition, the K-12 teachers and graduate fellows from the selected teams in cycle 1 will be followed into years 2 and 3, and the K-12 teachers and graduate fellows from the selected teams in cycle 2 will be followed into year 3 (see Figure 2 in Appendix 4).

f. Results from Prior Support PI Julian F. Tyson, Professor of Chemistry, is the lead PI for a NSF Instrumentation and Laboratory Improvement (ILI) grant "Valid Analytical Measurements in Undergraduate Laboratories," (DUE 9850636,1998-2001). An award of $60,000 is matched by UMass funds. The project will make major changes in the undergraduate courses in analytical chemistry. One of these changes concerns the introduction of project work in which graduate students, undergraduates and high school students collaborate on environmental projects which require the provision of information about chemical composition. The graduate students develop the methods that are used in the teaching class by undergraduates to analyze samples collected by the school students. He is also the recipient of the University's first grant to support the introduction of a Preparing Future Faculty aspect in the Chemistry Graduate Program. The American Chemical Society will provide $20,000 over two years (1999-2001). Tyson was a faculty participant in the STEMTEC program, and is now on the National Visiting Committee for the Maine CETP collaborative.

Co-PI Morton M. Sternheim is the lead PI of the Science, Technology, Engineering, and Mathematics Education Teacher Education Collaborative (STEMTEC). This $5,580,000 NSF CETP project was described above in section 3b, along with the NASA funded Planet Earth program. Sternheim was PI on two earlier NSF teacher enhancement grants to Five Colleges, Inc., the consortium of UMass and its neighboring liberal arts colleges, Amherst, Hampshire, Mount Holyoke, and Smith Colleges. SpaceMet (TPE8850948, $650,000, 1989-1992) used space science and exploration to get students and teachers excited about science. The 5C5E project (TPE 915026, $880,000, 1992-1995), showed teachers how to help students to conduct their own environmental science research projects (Wilson, 1996). A 1995 PALMS grant to Five Colleges supported a version of the 5C5E program.

Co-PI Kathleen S. Davis, Assistant Professor of Science Education, is co-PI of a $59,000 SGER grant from the NSF entitled "Identifying and Understanding the Effects of SMET Education Undergraduate Reform on K16 Teachers." This project examines the ways in which a Collaborative for Excellence in Teacher Preparation (CETP) project affects the development of new science teachers. In 1998-99, she was Co-PI of a $14,965 PALMS (NSF/SSI) grant, "Orchestrating Learning in Science and Mathematics for All." This project provided on-going, long-term support for the professional development of preservice science and mathematics teachers. Earlier awards to Professor Davis include an internal University of Nevada at Las Vegas grant, a NASA pre-service teacher workshop grant, and a $28,364 Dwight D. Eisenhower Professional Development grant entitled "Authentic Integration of Science and Technology in Field-Based Settings."

David Hart from the University's Center for Computer-Based Instructional Technology (CCBIT) will provide technology support for teachers and Fellows. CCBIT has been a collaborator on K-12 projects for several years with local school systems. One is an NSF-funded intelligent tutor, AnimalWatch, teaching arithmetic and fractions in the elementary grades. A second collaboration is a history project funded by NEH and the Massachusetts Department of Education in which CCBIT staff members are working with a local history museum to bring its collections into the Frontier Regional Schools via the Internet. CCBIT has been a participant in the STEMTEC project from its beginning and has recently joined the school of Education in a Title II grant consortium for professional development in urban school systems. Teachers in Springfield's Chesnut school are currently working with CCBIT-developed technologies.

g. Faculty participants. Bruce Byers (Biology), David Hart (Executive Director Center for Computer-Based Instructional Technology and Center for Knowledge Communication) Joseph Kunkel, (Biology), Mary Musgrave (Biology, Associate Dean, School of Natural Sciences and Mathematics), Jeffrey Podos (Biology), Stephen Schneider (Astronomy), Julian Tyson (Chemistry), Richard Yuretich (Geosciences).

h. Modifications to proposal. This proposal has been revised in the light of the reviewers' comments on last year's submission. The project has been given greater focus by alignment with the masters course in science education, and thus the training aspects for the teachers is now much more focused and targeted to their expressed needs. The pedagogical development of the Fellows has been given greater prominence: additional opportunities are now included (they will, among other activities, participate in a course with pre-service teachers—in which issues of diversity, learning styles and culture will be covered--and a year-long course on inquiry-based learning for in-service teachers, the main focus of the project). Various organizational details, such as the number and frequency of meetings, have been clarified. In preparing the proposal we have had extensive discussions with the Science Curriculum Adviser for the Springfield schools (where the project will be based) as well as teacher participants in the MS program,. Activities in the schools will be monitored by one of the PI's and two research assistants. The alignment of the proposed activities in the schools with the appropriate State and local frameworks, inquiry standards and progress indicators is clearly articulated.