PROJECT DESCRIPTION

> **Science seeks to understand nature. Mathematics reveals order and pattern.** Whereas science seeks consistency with the natural/external world through empirical evidence, mathematics seeks consistency within its internal system through logical deduction. Each can contribute to the other [1, 2].

Hofstra University is submitting this three-year *Math Infusion into Science Project (M$_i$SP)* Phase II MSP proposal in partnership with the New York State Education Department (NYSED) and eight high-need Phase I school districts in New York. M$_i$SP will develop and research the academic potential of an instructional model and a set of prototypical materials that infuse standards-based mathematics into 8th grade science programs. While addressing all the MSP Key Features (see p. 3), M$_i$SP focuses on a specific innovative area of work (exemplary mathematics infusion into science) begun during the Phase I project, where evidence of significant positive impact is clearly documented and additional resources and time would produce more robust findings and results. M$_i$SP research and evaluation activities will be conducted by the Center for Advanced Study in Education (CASE) at the City University of New York (CUNY) Graduate Center. Approximately 6,000 students, 46 middle school mathematics and science teachers, eight principals, and five higher education STEM disciplinary faculty will participate. Results will be disseminated across NYS and nationally by NYSED and commercial publisher Pearson/Prentice Hall (see letters in Section J, Appendix 5).

Overview of Phase I Project

Mathematics Across the Middle School Curriculum (*The MSTP Project*) is a Phase I MSP project (ending in August 2009) targeted toward improving middle school (MS) mathematics teaching and learning in ten NYS districts where, on average, 74% of students failed to meet state standards in 8th grade mathematics. After five years, seven of the original eight schools that were No Child Left Behind *Schools In Need of Improvement* are "in good standing," and the percentage of students passing the NYS 8th grade mathematics assessment increased in eight of the targeted districts by an average of 20%.

MSTP established and enhanced ten Collaborative School Support Teams (CSSTs) comprising five school district personnel (mathematics, science, and technology teachers; the middle school principal; a guidance counselor or social worker) and two university STEM experts. CSSTs led summer and academic year workshops and offered ongoing building-based support to all STEM faculty.

RESULTS FROM PRIOR NSF SUPPORT – PHASE I RESULTS

The mission of the MSTP Project was to improve middle school student achievement in mathematics. All Phase I goals and associated benchmarks were attained or exceeded [3] and are briefly reviewed below. Lessons learned from prior NSF support are included in Section J, Appendix 9.

Goal 1. To Enhance Mathematical Understanding of Middle School Students in Participating Schools. Passing rates (on average) on the NYS 8th grade math assessments in the targeted districts doubled (from 26% to 52%). In mathematics, each Project school—with one exception—now exceeds its individual annual measurable objective (AMO), a performance target set by the NYS Education Department. All ten Project schools now exceed the AMO in science. Prior to the Project, students in these schools infrequently participated in group discussions, engaged in limited project-based learning, rarely integrated mathematics into interdisciplinary activities, and did not normally engage in group problem-solving activities. However, according to evaluators, these practices are now customary [4].

Goal 2. To Enhance Mathematical Content and Pedagogical Understanding of Middle School Teachers of Mathematics, Science, and Technology in Project Schools. Ten school-based interdisciplinary CSSTs participated in intensive professional development (PD) programs. Participating teachers reported that the Project made "a tremendous difference" and indicated that students see "concrete connections between what they're learning and what they do." Principals noted consistent infusion of mathematics into science and technology, and engagement of students in higher order thinking [5].

Goal 3. To Improve Higher Education Curricula and Enhance Faculty Pedagogical Skills. All higher education faculty members were members of CSSTs and participated in all MSTP PD activities, co-planned school-based academic year workshops for teachers, and learned new pedagogical techniques from their peers and middle school colleagues. During the 2007-2009 years, faculty conducted research projects to further explore connecting the goals of MSTP to their own teaching [6].

Goal 4. To Align and Improve STEM Curricula in Project Schools with Respect to NYS Mathematics Standards and Assessments. By 2006, 83% of teachers reported that they had coordinated curriculum across math, science, and technology disciplines. In all ten districts, mathematics has been aligned to NYS standards, and instruction has been pedagogically enhanced. Notably, a reform-based program has replaced local curriculum in five districts.

Goal 5. To Increase the Number of Underrepresented Minorities Entering the MST Teaching Workforce in New York State. A minority teacher recruitment and PD initiative prepared over 100 minority SUNYSB and Hofstra CSTEP students to serve as teaching assistants and mentors in MSTP schools. Five students have become teachers and four more are enrolled in teacher preparation programs.

Goal 6. To Enhance the Capacity of NYSED, Partner Universities, Schools, and Districts to Engage in Ongoing Improvement of Middle School Mathematics. Project co-PIs met with NYS Education Commissioner Richard Mills on December 4, 2007, to share lessons learned. Dr. Mills remarked that he was impressed by the Project's focus on achievement; clear goals; organizational collaboration; use of national curriculum frameworks; cooperation of many partners; imaginative use of existing structures; research-based formative and summative evaluation; and products that were created.

Goal 7. To Disseminate an Innovative Middle School Mathematics Program Model. Project activities have been disseminated through the MSTP Web site (www.hofstra.edu/mstp) and by presentations at conferences and school district meetings. A conference planned in conjunction with the NSF Show-Me Center for Learning and Teaching in Middle Level Mathematics was conducted in Project Year II (spring 2005). Over 400 local, state, and national participants attended. Project team members, including university faculty, have made 25 conference presentations, and seven papers have been submitted for publication in professional journals (see www.hofstra.edu/mstp). The 2009 MSP Learning Network Conference and the March 2009 National Symposium on Math Infusion into STEM highlighted the Project model and impact on teachers and students when implemented in middle school classrooms.

***Sustainable Outcomes*.** In summary, MSTP has brought about sustained gains in Project schools that include hundreds of math infusion lesson plans; enhanced STEM leadership teams and teachers in all Project schools; a model PD program underpinned by research-based STEM faculty learning communities; and the collaborative lesson planning, implementation, and peer review that have become part of the curriculum planning ethos in the participating middle schools.

In particular, MSTP developed, implemented, and conducted research on a potentially transformative model that infuses mathematics into 8^{th} grade science education. This model is the focus of the Phase II (M_iSP) project.

PHASE II (M_iSP) RATIONALE

According to *Foundations for Success*, the 2008 Report of the National Mathematics Advisory Panel (NMAP), American students' math achievement is "at a mediocre level" compared with that of their peers, and "the sharp falloff in mathematics achievement in the U.S. begins as students reach late middle school" [7]. The focus of M_iSP is to improve middle-level mathematics results (with a focus on algebra). M_iSP responds to the findings of the NMAP and other mathematics and science organizations and experts who point out the importance of the development of key skills and contextual learning.

The NMAP report describes a wide range of views in support of contextualizing mathematics in "real-world problems." Real-world problems are seen as engaging and motivational for students, as they are involved in work where they see mathematics as meaningful, important, and functional [8, 9, 10, 11]. The multistep, complex problem solving required to solve real world problems has been shown to engage students deeply and leads to enhanced student achievement and greater understanding of mathematics [12]. The report concludes that the use of real world problems shows promise for having positive impact on student achievement, and it recommends expanding research and development activities related to this instructional strategy. The National Council of Teachers of Mathematics (NCTM) also contends that "students should connect math to their daily lives, and to situations from science, social science, and commerce" [13]. Research findings indicate contextualized learning appeals to educators as well because it mirrors the real world, links subject areas, interests students, and fosters collaboration and networking among teachers [14]. In the broadest sense, contextualizing mathematics in real world problem solving has the potential for developing critical thinking and problem-solving skills referred to as 21st-century skills [15].

The rationale for contextualizing mathematics into science dates to the papers produced at the 1991 NSF-funded School Science and Mathematics Association Wingspread Conference. At Wingspread, conferees arrived at a rationale for mathematical *infusion* into school science. The benefits included bridging understanding between concrete and abstract representation; developing quantitative appreciation of reality with emphasis on information use rather than acquisition; providing opportunities to put ideas together and deepen understanding; and encouraging relevant, exciting science and mathematics in schools [16, 17]. As Steen further notes:

> Employing mathematical methods in science instruction has great benefits both for mathematics and for science. For mathematics, it would ensure that students see the mathematics they study actually being used, and it would reinforce their learning. For science, it would help advance instruction from the present descriptive (almost pre-scientific) stage to a form that provides an honest introduction to modern scientific method. Adding modest amounts of mathematics will help make school science scientific [18].

Despite these compelling rationales and the influence of the NCTM connections standard that suggests that students should recognize and apply mathematics in contexts outside of mathematics [19], math and science are still taught in an unconnected way in most schools [20] and instruction emphasizing mathematics–science connections remains an exception rather than a norm [21]. Obstacles to infusion include teacher inexperience, attitudes, and beliefs, and lack of subject matter knowledge even in teachers within math and science [22, 23, 24]. Of all of the reform recommendations by NCTM, making mathematical connections is among the most difficult yet most important to achieve, especially at the middle school level and in relation to algebra. Algebra is viewed as the gatekeeper that can exclude students from educational opportunities and experiences that can affect their career aspirations, societal roles, and sense of personal fulfillment [25].

Key Features

M$_i$SP explicitly addresses these MSP key features:

Partnership-Driven. M$_i$SP includes core partners Hofstra University, NYSED, and eight heavily minority Phase I school districts on Long Island, a region where income and school achievement disparities are among the widest in NYS. M$_i$SP will work closely with Boards of Cooperative Educational Services (BOCES), a national publisher, and professional teacher associations in math and science. Higher education disciplinary faculty members will support development efforts and serve on an Academic Advisory Board.

Teacher Quality, Quantity, and Diversity. M$_i$SP integrates three components: (1) refining Phase I math infusion protocols; (2) enhancing the content and pedagogical capability of Project teachers who will refine and further develop math-infused science materials; and (3) ensuring that research and development activities are conducted by ethnically diverse educators and tested in diverse settings.

Challenging Courses and Curricula. The Project will ensure that Project students use standards-based mathematics and science curricula aligned with NYS standards and assessments, and are prepared to succeed in Regents-level high school mathematics courses. The Project will research an innovative model that infuses math into science classes using reform-based pedagogy and curriculum.

Evidence-Based Design and Outcomes. The Project design is informed by current literature on mathematics teaching and learning, and connecting mathematics and science. Lessons learned from prior NSF projects managed by the co-PIs guide the design. Outcomes will be broadly disseminated and will, with NYSED leadership, inform statewide reform. The Project will collect disaggregated data by race, ethnicity, socioeconomic status, gender, and disability, and will include indicators of effectiveness of the M$_i$SP model on teaching and learning.

Institutional Change and Sustainability. The M$_i$SP model will be evaluated, documented, and disseminated to make replication feasible by other schools in NYS and nationally. NYSED and the core partners will sustain the implementation of M$_i$SP math-infused science curriculum.

In the face of these difficulties, a recent experimental study that illustrates the potential of infusion of mathematics into another subject area was undertaken by the National Research Center for Career and Technical Education (NRCCTE) [26]. The study examined whether infusing mathematics instruction into career and technical education (CTE) programs would improve student performance on standardized math tests. After one year of math-enhanced CTE lessons involving only 10% of class time, students in the experimental classrooms performed significantly better on two tests of math ability (the TerraNova and ACCUPLACER®) without any negative impact on measures of CTE knowledge [27]. Based on the positive results of the study, the NRCCTE has scaled up their math infusion efforts nationally.

Further attesting to the interest of contextualizing mathematics in science was a STEM Symposium MSTP-I sponsored in March 2009 that included over 40 highly regarded education theorists, instructional designers, and researchers with strong interests in this topic (see Appendix 13 for a list of attendees). Papers prepared for the symposium addressed the utility of making mathematics–science connections, disciplinary content that could be illuminated by these connections, mechanisms for making connections, teacher preparation and school contexts that would support connections, and the impact on students of interacting with math-infused science curricula. These symposium papers have served to inform the design of this Phase II project.

In addition to the rationale presented above, district policy makers are also advocating for the implementation of the M$_i$SP infusion model. At a planning meeting of superintendents of M$_i$SP school districts (where on average only 52% of students pass NYS 8th grade math assessments), the submission of a Phase II proposal to infuse mathematics within 8th grade science was unanimously encouraged as a means to improve student mathematics understanding and performance. Memoranda of agreement to support and recruit participants, from all participating schools, are included in Section J, Appendix 4.

In summary, researchers who have studied mathematics and science connections bemoan the paucity of research on interventions related to connecting science and mathematics teaching and learning [28, 29, 30]. M$_i$SP will address this need by developing, implementing, and researching the impact of a criteria-based instructional model and exemplary materials that infuse grade-related mathematics into 8th grade science in pedagogically compelling ways. The model was developed through explicit R&D activities conducted in the Phase I MSTP, as described in the section below.

MATHEMATICS INTO SCIENCE INFUSION: THE PHASE I R&D INITIATIVE AND FINDINGS

MSTP engaged in three major activities to develop an instructional paradigm for infusing mathematics into science. These were (1) the development of a theoretical and practical model for math infusion that included content, pedagogical, and professional development specifications; (2) development, application, and examination of a yearlong PD and curriculum revision activity that provided evidence of feasibility and teacher learning in the use of the model; and (3) two proof-of-concept studies of the efficacy of the model using a quasi-experimental design with two cohorts of teachers and students.

The <u>first activity</u> operationalized the infusion model using a lesson plan template (see Section J, Appendix 11) that guided science teachers in selecting science content, pedagogy, and assessments in their design of math-infused science lessons. The criteria-based math infusion model and its associated lesson template were developed through an iterative process based on literature reviews; the participation of math and science teachers, IHE faculty, assessment experts, and Project staff; and field testing by classroom teachers. The model (see p. 8) will guide the M$_i$SP Phase II implementation, research, evaluation, and PD activities.

The <u>second activity</u> was a yearlong PD and curriculum revision program in which 60 science teachers used the lesson plan template to develop, try out, and revise infusion lessons of one to three days in duration. This activity was completed twice. This program, known as the A/B workshop model, relies on teacher examination of student work and is described in the text box on the next page. Participating science teachers developed 335 math-infused science lessons. Feedback surveys, classroom observations, interviews, and lesson reviews showed high science teacher engagement, minimal teacher resistance to math infusion into science, positive impact on teachers' pedagogy and attitudes, and improved student learning as reported by teachers. In particular, over 90% of teachers reported the math-infused lessons resulted in students' having a deeper conceptual understanding of math; and 80% expected their students to score higher on state math assessments. However, teachers indicated that they wanted—and felt students would benefit from—a more intensive and recurrent math infusion experience. Furthermore, there was a need to increase the amount of infused mathematics, to enhance the use of reform-based math pedagogy and to ensure that teachers had the necessary content knowledge.

The third activity involved two proof-of-concept studies: the first in fall 2007, the second in fall 2008. In both, a pre-post quasi-experimental design was used in which classes of 7th and 8th grade students were taught with up to 20 days of infusion lessons and compared with 7th and 8th grade classes of students not receiving math-infused instruction.

Student and teacher change was examined using teacher surveys, math content knowledge assessments adapted from NYS math and science tests, an attitudinal assessment, classroom observations, and focus groups. These data were collected from experimental (infusion) teachers and their students and from comparison teachers and students. (Comparison teachers taught at the same school as the infusion teachers. Some had participated in earlier A/B workshops, but were not implementing the math-infused lessons.)

The first proof-of-concept study (fall 2007) included six math infusion teachers with over 600 students, and five comparison teachers with 400 students. Infusion teachers, with MSTP Project team support, developed 20 days of math-infused science lessons. In the fall 2008 study, eight math infusion teachers (500 students) and four comparison teachers (350 students) participated. The 2008 study used infusion lessons that were more refined than those used in the 2007 study. Additional teacher PD focused on math content knowledge and pedagogy, and student assessment.

Proof-of-concept Study 1 – fall 2007. The fall 2007 lessons primarily infused three mathematics concepts—ratio and proportion, measurement, and graphing—into science lessons addressing the scientific method, mass, volume, and density. Despite initial concerns that science teachers would resist the math-infusion model, participating teachers reported that they indeed valued the role of the math teacher and supported math infusion into their science units. Results indicate that the model embedding 20 days of math infusion is feasible and can be implemented within regular 7th and 8th grade science classes. Science teachers were confident in their ability to teach the math; lessons were doable within science units; and students were open to learning math within science. Even though teacher logs indicated the actual amount of direct exposure to math instruction was minimal (four to eight hours over the 20 days), infusion students demonstrated increased knowledge of math concepts and improved affect toward math (see detailed description below).

A/B Workshop Professional Development Model

MSTP implemented a unique and innovative PD model that provided teachers with a way to synthesize their knowledge of STEM content and pedagogy by developing exemplary lessons.

The model invited participating schools to convene monthly sets of half-day A/B workshops targeted toward developing and refining lessons that infused mathematics into STEM topics; enhanced pedagogy; and aligned content to standards. The procedure used a research-based lesson planning template that guided inclusion of standards-based content, pedagogy, and diversified assessment. The template itself was reviewed by expert curriculum consultants and school administrators, field tested, and revised.

The A workshop was scheduled at the beginning of the month, the B workshop toward the end of the month. During the A workshop, teachers (in STEM teams) drafted lesson plans, engaged in peer collaboration, optimized mathematics infusion, and drafted assessment rubrics. Between the A and B workshops, teachers individually implemented lessons with classes, collected and scored student work, and reflected on possible improvements. During the B workshop, teachers engaged in collaborative peer review within and across disciplines to further enhance their lessons based upon examination of student work for evidence of understanding. During the workshops, support to participating teachers was provided by the district's Collaborative School Support Team. Over 700 mathematics, science, and technology education template-based lessons were developed.

Student mathematics achievement in this study was measured by a 19-item pre-post assessment adapted from validated NYS 8th grade math assessment items. Of the 13 multiple choice questions, six revealed statistically significant ($p < .05$) pre-post improvements (McNemar test) in the number of students with correct responses in the infusion classes, while three showed a similar shift for students in the comparison classes. Of the six open-ended questions that measure more conceptual understanding, matched paired t-tests showed statistically significant higher means ($p < .05$) on the post measure than the pre measure for the infusion classes. A t-test with independent samples was then used to compare post responses for the infusion and comparison classes. For the 19 items, three were statistically significant ($p < .05$), indicating the infusion classes performed better on these items than the comparison classes.

Attitudes of students toward math, connections between math and science, and how they perceived themselves as math students were assessed using a five-point Likert-type scale. Statistically significant ($p < .05$) pre-post t-test differences were found for the infusion students on eight of the 17 items. In all cases, the post scores reflected more positive attitudes. For example, students more strongly agreed on the post administration that: understanding math makes learning science easier; it is important to be able to solve math problems to do well in science; math and science careers are interesting; math is not boring; math is important in everyday life; and complex math problems are solvable. Statistically significant differences between the infusion and comparison students' post scores were found on four items dealing with enjoyment of math during science, interest in math, math not being a waste of time, and math not being boring. In all cases, the infusion students expressed more positive attitudes than the comparison students.

Proof-of-concept Study 2 – fall 2008. The fall 2008 study primarily focused on infusing algebraic equations, percents, rate of change, unit conversions, and graphing into science lessons addressing density, astronomy, weather, heat, and properties of matter. The mathematics in the second study was at a more advanced level than that in Study 1, and the science lessons were more inquiry-based and complex. Despite making the mathematics and science "harder," infusion was again found to be feasible. Teacher logs indicated that as in Study 1, between four and eight hours of mathematics was infused over the 20 days of instruction. Classroom observations further indicated that as a result of the enhanced PD, Study 2 teachers were better able to deliver the infused lessons using inquiry-based approaches as compared to infusion teachers in Study 1. Student achievement and attitudinal results in Study 2 replicated the Study 1 results. Student achievement results are briefly reviewed below.

On the multiple choice mathematics achievement items, two of the eight revealed a statistically significant ($p < .05$) pre-post change in the number of students with correct responses in the infusion classes after participating in math infusion lessons, while one item showed a similar shift for students in the comparison classes. On the open-ended questions, matched paired t-tests showed that infusion students demonstrated greater mastery of the material on five of the six items on the post measure than the pre measure. Finally, a t-test with independent samples was used to compare post responses for the infusion classes and comparison classes. For the 14 items, three were statistically significant ($p < .05$), indicating that math infusion classes performed better on those questions than the comparison classes. A problem-solving scale was also computed that averaged scores on the five open-ended questions. An analysis of covariance (ANCOVA) was performed to determine if the infusion students' achievement scores were higher than the comparison students' after adjusting for initial differences. The ANCOVA was significant: $F(1,828) = 4.34$, $p = .038$. This indicates that the infusion students performed significantly better on the problem-solving scale than the comparison students when the post-test means were adjusted for initial differences. In additional analyses of the Study 2 data set, lower performing students demonstrated greater gains than higher performing students, suggesting a potential differential impact based on students' academic level.

In summary, although the effect sizes in the proof-of-concept studies were small, results are encouraging. Even though infused lessons were developed by teachers with support from experienced consultants, the professional development was not fully optimized. Yet the studies demonstrated that math of varying levels of difficulty can be infused into a wide range of 8^{th} grade science topics. Post-lesson reflections of teachers indicated that the math they introduced fit naturally within science topics and that students expressed few of the anticipated frustrations with the introduction of math into science. Science teachers reported that they would by choice continue to embed math despite their initial resistance to give up science teaching time. Student achievement and attitudinal shifts were documented even though time devoted to mathematics was still relatively limited.

Examination of the pre-post achievement data showed that the observed change was greatest on open-ended questions, questions hypothesized as assessing conceptual learning. Social benefits were also noted. For example, one teacher with many special education inclusion students noted that when a student with special needs found the math easy, the student often gained a new respect from peers.

Focus on Algebra

M$_i$SP will emphasize infusion of algebra into 8th grade science contexts. Algebra is an area shown to be difficult for students nationally and represents almost one-half of NYS 8th grade assessment items. It is the area of mathematics in which M$_i$SP students score lowest.

Based on the positive and encouraging findings from both the A/B workshop infusion initiative and the proof-of-concept studies, a more rigorously developed mathematics infusion model is being proposed that will employ expert curriculum developers as well as teachers and result in an M$_i$SP curriculum that is three times the length of the 20-day curriculum used in the studies. In addition, more extensive training and support will be provided to science teachers for them to optimally deliver the curriculum with less variability. Finally, as detailed in the subsequent sections of the proposal, the mathematics content targeted for infusion will be the highly important and problematic content area of algebra. The collegial support provided by math teachers will continue and be enhanced and supported by building principals. The Project being proposed will be guided by a set of M$_i$SP decision rules.

M$_i$SP CRITERIA-BASED MATH INFUSION DECISION RULES

The model for infusion of mathematics initiated in MSTP Phase I will be fully optimized in M$_i$SP. Science curricula will be infused with the mathematics most needed by students. The focus will be on linear functions, an area of algebra that the National Math Advisory Board identified as critical for advanced math understanding and an area that students often find difficult to master. M$_i$SP will apply and study the math infusion model in 180 experimental and 60 control classrooms (see p. 10). The model operationalizes a set of Project *decision rules* that will serve as **infusion model criteria** to guide curriculum, instruction, PD, and the development of prototypical materials. These criteria are described below.

▪ ***Mathematics content selection criteria.*** Selected mathematics content must be important, present difficulty for students, and facilitate science learning. **Important** content is based on the weight of curricular emphasis, includes math from prior grades essential for mastery of the targeted subject matter, and reflects mathematics necessary for success in more advanced courses. Content that presents **difficulty** is selected based on standardized math assessment scores, and designation by knowledgeable math educators. Content that will facilitate **science learning objectives** and inform science learning is specified by expert science teachers and consultants. For M$_i$SP, the algebra content will build in complexity during the academic year, allowing students opportunities to revisit and practice basic skills several times before moving to a more difficult level where they can develop deeper understanding (see table 1, p. 8). The different levels of math within this progression of increasing complexity fit well within the targeted science topics, especially the hands-on inquiry science activities that may be taught at different times of year by different teachers.

▪ ***Instruction criteria.*** These include sequencing instruction, incorporating inquiry/reform-based pedagogy, and using formative assessment. **Sequencing** involves targeting mathematics that the math instructor will address prior to the math-infused science lesson. Science lessons will be **inquiry-based** and science will employ **reform-based mathematics pedagogy** (as opposed to formulaic presentation of mathematics). **Assessment** will be embedded within instruction. Formative assessment will help guide instruction in both science and mathematics, and comprehensive samples of student work will make student thinking visible. Math infusion will occur within inquiry-based science labs, where the sequencing of mathematics can build in complexity without limiting student learning at the more introductory levels.

▪ ***Professional development criteria.*** These will ensure that PD enhances the participating science teachers' **mathematical content knowledge**, **skills**, and **pedagogical content knowledge**. PD will relate to 1) targeted mathematics content and reform-based mathematics pedagogy related to the math to be infused; 2) diversified assessment; inquiry-based science pedagogy; 3) the use of model infusion lessons; and the development of new or adapted units using the Project infusion model criteria and decision rules**.**

MiSP professional development will further teachers' understanding of linear functions and their applications in science, and also help them promote the learning of these concepts using reform-based mathematics pedagogy. A key element of the PD will be the professional ongoing support and connections given to science teachers by math teachers within their schools and by IHE STEM faculty consultants.

Mathematics Infusion versus Integration. A search of the Eisenhower National Clearinghouse revealed a plethora of terms referring to math/science "integration": connections, cooperation, coordinated, correlated, cross-disciplinary, fused, interdependent, interdisciplinary, interrelated, linked, multidisciplinary, transdisciplinary, and unified [31]. M_iSP *infuses* mathematics into science, rather than *integrates* science and mathematics, and the Project approach illuminates the distinction between infusion and integration in an educational setting. Whereas an integration model would combine mathematics and science into a curricular whole, an infusion model introduces a modifying element (grade-related mathematics) that enhances understanding through frequent reiteration in various topical contexts. The M_iSP model is not designed to develop an integrated curriculum; within M_iSP, each subject maintains its own unique perspective.

PHASE II (M_iSP) MISSION AND GOALS

The primary mission of M_iSP is to improve middle school student achievement in mathematics. The Project will accomplish its mission by rigorously developing, implementing, and researching an instructional model and prototypical materials to infuse mathematics into middle school science education that builds extensively on MSTP, the Phase I MSP project. While the program model will be implemented and institutionalized in eight low-performing Long Island schools, M_iSP will inform middle school STEM reform and teacher development across NYS and nationally, through dissemination by NYSED and commercial publisher Pearson/Prentice Hall, Inc. To achieve its mission, M_iSP projects the following goals:

1. To enhance student learning by refining and further improving the math-into-science infusion model.
2. To enhance the operational features of the infusion model by applying M_iSP criteria to the development of prototypical lessons and to the associated professional development.
3. To implement M_iSP in authentic middle school science settings in eight low-performing schools.
4. To conduct an experimental study in relation to the infusion model that (1) collects evidence of the feasibility of implementing M_iSP; (2) assesses Project impact on teacher knowledge, instructional behaviors, and attitudes; (3) assesses Project impact on student attitudes and academic achievement; (4) refines the conceptual and operational features of M_iSP; and (5) in general, develops new knowledge regarding contextualizing mathematics in real world problems.

Quantitative outcome goals, objectives, and annual benchmarks are provided in Section J, Appendix 3.

IMPLEMENTATION, RESEARCH, AND EVALUATION FRAMEWORK

M_iSP will build on interventions developed in MSTP and further develop the instructional model and prototypical materials for infusing mathematics into science education in eight targeted middle schools that participated in the Phase I Project. A rigorous research agenda will inform the Phase II model and the mathematics into science curriculum development process.

Mathematics and Science Topic Selection for M_iSP. The math to be addressed in M_iSP will be algebra, as the National Mathematics Advisory Panel notes that algebra is "a demonstrable gateway to later achievement" (p. xiii). Understanding and applying linear equations (a major topic of school algebra that the panel recommends should be considered when revising mathematics standards) will be the focus of Project efforts. This topic meets the math infusion model criteria of being important and difficult, and fits within and contributes to the science curriculum.

The yearlong progression of the contextualized math, roughly broken into four semesters, will offer students opportunities to revisit math ideas in increasing complexity. Table 1 depicts the math that a student experiences within a given level, independent of the science topic.

Table 1: Algebraically representing and analyzing situations at different levels of complexity

Level 1	Level 2	Level 3	Level 4
Graph points that represent data. Identify, represent, and interpret patterns of change for linear relationships in a table.	Write and interpret linear equations to represent findings in lab experiments. Graphically represent data and interpret graphical representations of linear relationships.	Use data to represent linear equations. Solve linear equations.	Determine the slope of a line and interpret slope as a rate of change.

The math progression will be infused into the regular sequence of science topics over the course of 8th grade. Project teachers will introduce the same progression of math topics within whatever science topics they are teaching. The more complex math topics will build upon prior understanding and facilitate student progress. Since the order in which science topics are introduced varies across schools, math infusion lessons that reflect four levels of math complexity will be developed for each targeted science topic.

Selection of science topics involved examining NYS and national science standards, review of 8th grade science topics addressed by M$_i$SP schools, consultation with science and math experts and experiences with MSTP. Possible topics within which mathematics can be meaningfully infused are listed in table 2.

Table 2. Examples of 8th Grade Science Topics in Targeted Schools Tentatively Identified as Amenable to Math Infusion

Earth Science	Physical Science	Life Science
Solar System	Matter: Volume, Mass, Density	Genetics
Geologic Time Scale	Energy and Power	Bacteria & Viruses
Climate Change	Forces and Motion	Changes over Time
Weather Patterns	Work/Machines	
Mapping, Latitude/Longitude	Electrical Charges and Current	
Rocks and Minerals	Wave Characteristics/Light	

In response to National Math Panel recommendations, mathematics will be embedded in science topics that have real world applications and are amenable to inquiry-based pedagogy. M$_i$SP will develop math-infused lessons for up to 15 science topics with four levels of math in each, for a total of 60 units. Some units will be enhanced from those developed during Phase I. Teachers will be able to select from among eight topics in the order that fits within their district curriculum.

Each of the topical science units will include four levels of math that teachers can choose to infuse, depending upon the time of year they teach the science unit. Some math would logically be taught at the beginning of the year, some toward the end of the year. Although the science topics may be taught at different times by different teachers, the math to be infused will be consistent across all teachers during any particular time of year.

The infused mathematics will also help transform the primarily descriptive instruction currently used in middle school science into more inferential and analytical instruction, and will therefore inform science understanding. Mathematics will be taught for understanding using reform-based pedagogy that meets NCTM standards for both instruction and time on task. Infused mathematics instruction of the targeted mathematics topics by science teachers who received professional development would closely approximate the instruction delivered by a mathematics teacher who is well trained in reform-based mathematics.

IMPLEMENTATION ACTIVITIES

Implementation Overview. Mathematics-infused science lessons (the M$_i$SP curriculum) will be developed and delivered over 60 days of the academic year (approximately one-third of the school year) to 8th grade science students in eight middle schools in high-need Phase I districts.

The M$_i$SP curriculum will consist of 20 days of introductory math-infused science lessons (to be developed as a common core for implementation at the beginning of the school year) and eight additional one-week math-infused topical science units to be implemented throughout the academic year. The function of the start-up unit, in addition to enhancing mathematics and science learning objectives, is to establish within science classes an orientation toward addressing contextualized mathematics and reinforcing its functionality and connections to the real world.

As noted previously, over the course of the academic year the math will follow a progression from graphing data to solving linear equations. Initially, students will learn and practice graphing and labeling coordinates. This will be revisited several times in different science contexts/lessons, allowing student to master graphing and representation before moving on to more complex math. Since each of the eight science topics includes four mathematical levels of complexity, participating teachers can choose to introduce a specific science topic at any time during the year, in order to align the math infusion to the math being addressed in their 8th grade mathematics class. Participating teachers will therefore be able to adapt the units to reflect nuanced district differences in the order in which science topics are addressed.

Following Project curriculum and professional development activities in Project Year I, 30 8^{th} grade science teachers will deliver the M$_i$SP curriculum over a two-year implementation period. They will be supported by their principals (who will provide support needed to implement the project) and a partner math teacher (who will provide ongoing support and help ensure the math is taught in a way that is congruent with what is taught in math classes).

As part of the Project's experimental research design (see p. 11), 15 of the science teachers will be randomly assigned to implement the curriculum with their 8^{th} grade science classes in Project Year II, while the remaining 15 (waiting list controls) will deliver their regular science curriculum. During Year III, the waiting list control teachers will then implement the M$_i$SP curriculum with their classes and the Year II infusion teachers will also again implement the M$_i$SP curriculum (with a new cohort of 8^{th} grade science classes).

Context for Research and Implementation Activities: A Focus on Diversity

All eight M$_i$SP sites are high-poverty, low-performing middle schools that were involved in MSTP. The schools have an average 8^{th} grade enrollment (the targeted grade) of 380 students that averages 76% minority (the range is 29% to 100%). Free or reduced lunch eligibility ranges from 10% to 74%, with an average of 53%. An average of only 52% of M$_i$SP students met or exceeded standards on NYS 2007 8^{th} grade math assessments.

Participating teachers (n = 30 science, 8 math) will be NYS certified in their disciplines and have master's degrees. Science teachers will have an undergraduate science major, appropriate education courses, and a master's degree. Mathematics teachers will support implementation as on-site consultants. They will be lead MSTP math teachers in their schools. Principals of each middle school will support implementation and data collection activities. (See Section J, Appendices 1 and 2.)

As summarized in the research overview that follows, approximately 180 8^{th} grade science classes and 4,500 students using the M$_i$SP curriculum will be compared, in terms of achievement and attitude measures, to 60 8^{th} grade science classes and 1,500 students who are taught using their regular science curriculum.

Research Overview. <u>Project research and evaluation activities are isomorphic</u>. Research will be guided by seven explicit research questions (see p. 12). Careful documentation of all Project activities will lead to improved and enhanced math-infused science lessons. The research will deepen understanding of essential infusion model elements and their impact on students and teachers, and address the overall question of the efficacy of infusing mathematics into real world problems. An experimental pre-post design will be used with wait list controls. Multimethod approaches will help ensure that subtle changes are not overlooked while methodological demands for rigor, including random assignment and pre-post controls for initial differences in student assessments, are addressed. Content knowledge in mathematics and science will be examined using standardized state test results and assessments that include validated math questions from prior middle school tests. Additional assessment methods will include relevant hands-on math problems, embedded assessments, expert reviews, teacher and student feedback, self-efficacy and attitudinal surveys, classroom observations, interviews, and focus groups.

Development Overview. The model math-infused units will be developed by a four-person development team of nationally known mathematics and science experts, and lead MSTP science and mathematics master teachers representing participating schools. The team will be actively supported by the M$_i$SP co-PIs (see partnership management/governance plan, p. 15). Curriculum units will include daily lesson plans that meet NCTM and NSTA standards for detailed explication of objectives, instructional activities, and formative/summative assessment procedures; and will use the revised MSTP Phase I mathematics infusion lesson plan template as a guide. As units are developed, they will be reviewed by the M$_i$SP Project team and evaluators as well as an Academic Advisory Board (see text box, p. 12). The development team and co-PIs will then conduct extensive PD for participating science and mathematics teachers to enable them to deliver the mathematically infused science lessons in pedagogically sound ways.

STRATEGIC ACTIONS / WORK PLAN FOR IMPLEMENTATION AND RESEARCH

Based on strategic actions undertaken, significant improvements in student and teacher outcomes are predicted. The Project work plan follows.

▪ **During Project Year I** (September 2009–August 2010). **Research and evaluation activities** will include gathering student performance data on prior year state testing in math and science; recruiting and selecting teachers; randomly assigning teachers to experimental (cohort 1) and waiting list control (cohort 2) conditions; orienting all teachers to data collection protocols; carrying out data collection, observations, and interviews during summer PD; evaluating math infusion lessons; and developing/refining assessment tools.

Development and implementation activities will include developing the 20-day math-infused science core focusing on scientific method, common among all districts (a refinement of the MSTP units in the proof of concept studies), developing the eight additional one-week topical units, and developing assessment items. An Academic Advisory Board consisting of expert mathematics and science faculty and classroom teachers will review materials. The two-week summer 2010 PD program for 15 cohort 1 science teachers (experimental group) will be conducted (see PD text box). Partner principals and math teachers will participate for at least two days, providing guidance and support, and helping ensure connections with the ways in which math is taught. PD will focus on enhancing the teachers' ability to adapt and implement the infusion units, and will be driven by the content and instructional design of the units. The PD program will reflect the Project's PD criteria (see p. 7) and ensure that teachers have the content and pedagogy skills necessary for lesson implementation.

Overview of Professional Development Program

The M_iSP PD program will focus on:

- Mathematics content related to infusion units
- Pedagogical content knowledge of mathematics related to the infusion units
- Inquiry-based science pedagogy related to the infusion units
- Formative assessment using student work
- Adapting the infusion units to fit/support district curriculum
- Procedures for implementing the M_iSP infusion curriculum
- Data collection procedures for students and teachers
- In summers 2011/2012, enhancing M_iSP operational features and infusion units, and providing additional PD as needed

While these components are shown as being discrete, they will be integrated within the PD program.

Project Year II (September 2010–August 2011). **Initial Rollout.** Experimental group teachers will each implement the initial 20-day core unit during the early fall 2010 semester with four 8^{th} grade science classes of about 25 students each (n = 1,500 students). A like number of science classes and students (n = 1,500 students) will be taught by the waiting list teachers using their regular science curriculum. Principals will convene bimonthly meetings in each middle school for science teachers and math consultant partners, and math teachers will provide ongoing support. The M_iSP Web site will be launched.

Research and evaluation activities will include examining fidelity of implementation, ongoing data collection and analysis, collecting and providing feedback to the experimental group and Project management for program improvement, and discussing data collection procedures with the control group.

Development and implementation activities will include implementation of the 20 days of introductory science-infused lessons and of the eight subsequent units by experimental group teachers; summer 2011 refinement of infusion units by the development team; and further professional development of experimental group teachers to optimize implementation. Principals will continue to convene bimonthly meetings for participating science teachers and their math consultant partners, and the Academic Advisory Board will review materials. The cohort 1 experimental science teachers and their math teacher partners will meet for two days in the early summer of 2011 to review all aspects of implementation, and pedagogical improvements, and discuss the Project Year III procedures, which include an enhanced replication of Project Year II implementation. Based on their recommendations and those of the advisory board, the development team and co-PIs will enhance the units and the PD procedures. In the summer of 2011, the 15 waiting list teachers will also participate in a ten-day PD program modeled after the Year I summer workshop and revised using cohort 1 teacher input.

Project Year III (September 2011–August 2012). In the fall 2011 semester, all cohort 1 experimental and cohort 2 waiting list teachers will implement M_iSP units with new classes of students (n = 3,000).

Research and evaluation activities will include gathering student performance and teacher implementation data; observing both cohorts of teachers; examining fidelity of implementation with both cohorts of teachers; and analyzing and disseminating research results to NYSED, partner districts, BOCES, and STEM professional association partners.

Development and implementation activities will include implementation of math-infused lessons by 30 teachers (both cohorts); analysis of research results and transferable implications; debriefing with all teachers to reflect on Project effects; and final enhancement of the Project model. Principals will continue to convene bimonthly meetings for math and science teachers and the Academic Advisory Board will validate all materials. A written curriculum and supporting training materials will be finalized and disseminated.

Reflection and Final Revisions. All participating science and mathematics teachers and school principals will convene over a two-day summer 2012 retreat to debrief the implementation and make final recommendations to inform the Mathematics into Science Infusion Model, the M$_i$SP curriculum, and the M$_i$SP training program. The M$_i$SP Project team, curriculum development team, evaluation team, and local school administrators will be included. Final revisions will be made by the development team and the materials will be readied for publication. A primer will be published describing how curriculum specialists can generalize M$_i$SP methodologies to revise other science curricula at MS and other grade levels.

RESEARCH AND EVALUATION ACTIVITIES

Research and evaluation will address seven questions related to process and outcomes. Overall, the answers to these research questions will contribute to new knowledge development dealing with the general question of contextualizing mathematics in real world problems. **Formative and process research questions** that will inform implementation fidelity include: (RQ1) To what degree are the M$_i$SP lessons of high quality in that they reflect the M$_i$SP math infusion model characteristics and embed suitable mathematics and science content and pedagogy as judged by math/science experts and teachers? (RQ2) How well does the PD for science teachers adequately allow for implementation of the M$_i$SP curriculum? Which aspects of the training are most essential for teachers? (RQ3) To what degree does implementation of the M$_i$SP curriculum fulfill model specifications and is it taught in an inquiry-based way? How much math is taught, of what type, and in what manner? **Outcome research questions** include: (RQ4) How does participation in M$_i$SP affect science teachers' knowledge and skills in relation to mathematics knowledge, math and science pedagogy, and mathematics into science infusion methods? (RQ5) How does participation in M$_i$SP affect teachers' attitudes toward reform-based mathematics, inquiry-based science, and infusion of mathematics into science? (RQ6) How does participation in M$_i$SP affect students' knowledge of math and science? (RQ7) How does participation in M$_i$SP affect students' attitudes and self-efficacy related to math and science?

> **Academic Advisory Board Evaluation Activities**
>
> In addition to the external research and evaluation team, the Project will convene an Academic Advisory Board of STEM experts to ensure that M$_i$SP activities are aligned with goals. Board members (see p. 15) will work with Project teams to review draft materials, infusion criteria, implementation and research procedures, data, and research results to help document, optimize, and assess Project activities. The board will consider issues related to relevance and implementation and provide guidance for enhancing and expanding procedures and products, and provide support during revision and dissemination activities.

Student and Teacher Sample. The sample will include 30 stipended, volunteer middle school science teachers from eight high-need districts on Long Island. The 30 teachers will be randomly assigned to one of two groups: **novice experimental (NE)** implementers, or **waiting list controls (WLC) (**see experimental design below**).** Thus, teachers—not students—are assigned to conditions. After PD, the NE teachers will teach the math-infused lessons for one academic year (Project Year II) to all of their 8^{th} grade science students (see description of students in text box on p. 10). The WLC teachers will not change their current curriculum, but rather teach their regular "business as usual" curriculum for one academic year to their 8^{th} grade science classes. All teachers will provide data about themselves, their classes, and their students. In the following year (Project Year (III), the 15 NE teachers (initial implementers) will become the **expert experimental (EE)** teachers, and the WLCs will become a NE sample so that all 30 teachers will deliver math-infused lessons for one year (NEs and EEs).

Formative Evaluation and Process Research (RQs 1 and 2): In addition to the work of the Academic Advisory Board, the formative and process evaluation will examine the math infusion into science units, their congruency with the M_iSP model, and their usefulness for science teachers. Using a structured rubric developed during MSTP, experts and teachers will review the lessons to provide data about the lessons as they are implemented. Feedback about teacher workshops, as well as data about ongoing technical support to teachers and ease of implementation, will be collected. Student and teacher reactions will be used to assess the process and implementation characteristics of the infused units. The evaluation team will work closely with Project management to use ongoing findings to guide revisions or adaptations if needed to the lessons, PD program, and technical support in a way that does not compromise the research.

Fidelity of Implementation Evaluation (RQ3): Prior MSTP math infusion efforts revealed that ensuring the fidelity of implementation was critical for success. Classroom observations, weekly online teacher feedback, and teacher surveys will be used to determine if the lessons adequately address (1) the identified math topics using infusion model criteria; (2) the quality and quantity of math delivered; and (3) the level of inquiry-based instruction in the lessons. During the initial delivery of infusion units, Project management will use feedback from the evaluation and research team after the initial 20 days to make adjustments or expand technical assistance. Support provided to teachers will be documented.

Experimental Design. Research and Summative Evaluation (RQs 4, 5, 6, and 7) will be addressed using a waiting list experimental design to examine the outcome research questions, as described above. The design will allow for a combination of comparisons between experimental and control teachers and classes (i.e., NEs or EEs with WLCs), and between two cohorts of teacher implementers who have different amounts of training and implementation experience (NE-1 with NE-2 and NEs with EEs). Data will be collected from students and teachers in all experimental conditions at multiple times during the year to document Project impact. Data collection is described below.

DATA COLLECTION AND ANALYSIS

Data will be collected from and about students and teachers and analyzed by the evaluators as follows:

- **Student Data.** Each year all students (in experimental and control classes), except as noted, will complete math content knowledge, attitude, and self-efficacy assessments at the beginning, middle, and end of the school year. **Student Achievement Data.** For each 8th grade student in the study, <u>a specially constructed (math and science) content test</u> aligned with the math infusion lessons will be developed and administered pre-post to students in both the experimental and control groups The assessment will be adapted from existing validated assessments (e.g., NYS and NAEP 8th grade math and science tests), with the majority of items being open-ended questions to allow for maximal demonstration of conceptual understanding. As needed, existing scoring rubrics will be expanded to allow for finer gradations than needed when evaluating schoolwide progress. All students, regardless of condition, will complete the specially constructed content knowledge pre and post assessments each year.

To better align assessments with lesson content and the inquiry-based pedagogy of the infusion model, and to explore how content knowledge increases as math exposure increases, <u>math unit embedded assessments</u> will be administered to the infusion (experimental) students only. Before and after each unit is taught, two teachers will administer a hands-on lesson assessment. Although different students will be completing the assessment, the burden on teachers is reduced and data will be statistically compared to explore changes in student knowledge.

Student attitudes toward math. The student attitude survey developed in MSTP will be revised for M_iSP. The three assessment scales (interest in math, connection between math and science, perception of self as a math student / math self-efficacy) had internal consistency (alpha reliabilities ranging from .62 to .82). Items that failed to differentiate among students will be dropped and additional items included. This measure will be administered to all students (experimental and control) at the start and end of the AY.

Student feedback about the math infusion experience. Students will complete surveys at the start of the year about prior expectations with science and math class, and at midyear and end of year about their science class experiences. They will be asked about the importance of math for science learning, types of learning they experienced (e.g., perceptions of inquiry-based learning), and overall ease of learning. These data will be collected from both experimental and control students.

▪ **Teacher Data.** Teachers will provide data about their experiences, knowledge and attitudes, and perceived student changes. Research shows that **teacher content knowledge** is a critical factor in student learning [32]. However, directly assessing science teacher math content knowledge without provoking negative teacher reactions is challenging. As such, all M_iSP teachers (experimental and control) will be asked to anonymously solve content-specific math problems at the start and end of the summer PD and then again at the end of the school year. These data will be used to guide PD for teachers as a group (by identifying areas of weakness and the ways teachers solve problems). The data will also provide aggregated pre-post indicators of teacher content knowledge change. PD activities, as well as teacher self-reports, will provide additional indicators of math ability and will be collected at the start and end of each year.

Teacher attitudes toward math. The student-attitude-toward-math survey will be adapted for use with teachers. Additional items will explore teachers' valuing of math infusion into science. All teachers will complete this assessment at the start of the Project, after Project Year I, and again at the end of the project.

Teacher perceptions. Following implementation, all teachers will be asked to report on observed changes in relation to students' math ability, math attitudes, and overall approaches to learning and doing math. These class-level data will provide a general indication of class math climate and student change.

Contextual data. Contextual data provides the basis for understanding student, teacher, and classroom change. Demographic data from students and teachers; information about the school's approach to math and science; teacher background, experience, and math interest/knowledge; and historical data on past performance on state tests will inform understanding and application of the model. Classroom observations and teacher focus groups will provide additional data. Some data will serve as both independent and dependent variables depending on the analyses. For example, change in teacher attitudes will be examined as a dependent variable but teacher attitudes also may be used as a context variable to help explain change in student content knowledge.

▪ **Data Analyses.** Data analyses will rely on univariate, multivariate, and nonparametric statistical procedures. Results will be interpreted and enriched using contextual data and feedback from teachers, students, and experts. When appropriate, summed scale scores will be computed and internal consistency computed. Item analyses of content assessments will examine item response patterns. Individual and scale-level analyses will examine change over time through ANCOVA and discriminate analyses. Various covariates will be used to control for initial differences, including scores from mathematics pretests, and 7^{th} grade state math scores. Class differences will be examined relative to student and teacher change. Logistic regression will be used to predict the dichotomous dependent variable (in this case correct/incorrect) on the basis of continuous and categorical independents and to determine the percent of variance in the dependent variable explained by the independents. Examination of the analysis will help rank the relative importance of independent variables to explore for interaction effects; and to include covariate control variables (e.g., pre-scores). Thus, logistic regression will be used to estimate the probability that students get an item correct given a variety of conditions (e.g., math achievement on the 7^{th} grade state math test, gender, prescore on the math assessment, teacher, school, and other contextual indicators related to the infusion experience). A total test score will be computed on the basis of student assessment data. This total score will also be examined using a multiple regression model.

DISSEMINATION AND INSTITUTIONAL SUSTAINABILITY

Math-infused units and results will be published and disseminated nationally by Pearson/Prentice Hall, Inc. Core partner NYSED, and BOCES and STEM professional association supporting partners, will broadly disseminate Project models, products, and research findings including a primer on how to revise existing science curricula to include mathematics. Partner districts and NYSED will sustain M_iSP math-infused science curriculum if proven effective. Articles will be submitted for publication by co-PIs and development/research/evaluation team members in refereed professional journals, and presentations will be made at STEM education and research conferences. NYSED will convene a one-day statewide dissemination conference where M_iSP teacher representatives, the Academic Advisory Board, the research and evaluation team, and Project co-PIs will meet with STEM professional association and administrative organization leaders and NYSED staff to discuss results and implications.

PARTNERSHIP MANAGEMENT/GOVERNANCE PLAN

The Project management team comprises national leaders in STEM content and pedagogy, research and evaluation, and NSF project management. Core partners are listed on page 1 and have all agreed to submit yearly data to the NSF Management Information System. Co-PIs represent all core partner groups.

Dr. David Burghardt (PI) and **Michael Hacker** (PC) co-direct the Hofstra CTL. Burghardt was PI and Hacker co-PI/PC on the Phase I project. They have jointly managed eight large NSF projects. Burghardt will ensure that goals/timelines are met, administer the Project budget, and assist with research and evaluation. He is a professor of engineering and teaches in the Schools of Education and Engineering.

In 44 years in education, Hacker was a middle school teacher/chairperson, a university educator and administrator, and a NYSED curriculum supervisor. He will oversee Project coordination and serve as a pedagogical expert. Burghardt and Hacker will actively support development and evaluation team activities.

Dr. Allan Gerstenlauer (co-PI) is superintendent of schools in the Longwood CSD, one of the participating M$_{i}$SP districts, and was a Phase I co-PI. He has expertise in school reform, curriculum, instruction, and staff development, and will represent partner districts on the management team.

M$_{i}$SP Development Team Members (See vitae.)

The diverse development team brings expertise in STEM content and pedagogy, instructional materials development, and design of learning environments. The team will develop and (after testing) refine the math-infused science materials. Members include:

Science Expertise

- **Dr. Beverly Clendening** is associate professor of biology at Hofstra University and co-PI.
- **Kathleen Chapman,** K-12 science coordinator for Oceanside School District, brings 30 years of science experience to the team. She is an adjunct faculty member in the Hofstra School of Education and was a lead member on the MSTe grant that interconnected STEM in the elementary grades.

Mathematics Expertise

- **Dr. Sylvia Silberger** is associate professor and chair of mathematics at Hofstra University and co-PI.
- **Linda Walker** has over 40 years of mathematics teaching and consulting experience for the Florida Department of Education, Connected Math, and MSTP Project.

The team will be actively supported by **PI Burghardt** and **PC Hacker**, Hofstra CTL co-directors.

Dr. Beverly Clendening (co-PI) is an associate professor of biology and co-directs the secondary education science program at Hofstra. As an MSTP faculty member, she facilitated the teacher professional development and alignment of middle school science to science standards in the Roosevelt UFSD.

Dr. Sylvia Silberger (co-PI) is associate professor and chair of the mathematics department at Hofstra University. She was one of the key math STEM faculty on the MSTP project in supporting improved math instruction and deepening teacher math content knowledge.

Dr. Deborah Hecht is associate director, and **Dr. Bert Flugman** is director, of the Center for Advanced Study in Education at the CUNY Graduate Center. For decades they have served as researchers and evaluators on numerous large-scale NSF and USDOE projects and served as external evaluators/researchers on the Phase I project. Along with postdoctoral associates and graduate students, they will lead research and evaluation activities.

Jean Stevens (co-PI) is NYSED associate commissioner for the Office of Instructional Support and Development. She was a co-PI on the Phase I project and will leverage NYSED resources to ensure that M$_{i}$SP Project activities align with NYSED priorities. She will oversee NYSED dissemination activities.

Academic Advisory Board Members. The Project will establish a diverse Academic Advisory Board with the following expert members: Dr. Alan Tucker, distinguished teaching professor of applied mathematics, Stony Brook University; Dr. Donna Berlin, professor of mathematics education, Ohio State University; Dr. Michal Lomask, director of science certification, Connecticut Department of Education; Gina Talbert, principal, Wyandanch Middle School; Claudia Toback, past president, National Middle Level Science Teachers Association.

A Disciplinary Partners table in Section J, Appendix 8, includes a list of disciplinary faculty involved in M$_{i}$SP, along with their roles and responsibilities.