Statement of Need

Trends reported by the National Science Board reveal that there are not enough students in the pipeline today to support the Science Technology Engineering and Mathematics (STEM) workforce of tomorrow (National Science Board 2003, 2004). US undergraduate enrollment in engineering is in decline and, combined with the graying trend in the federal and academic workforces, this poses a significant limiting factor for future US industry and research. In contrast, countries such as India and China are producing unprecedented numbers of engineers and scientists (National Research Council 1996). The causes of the shrinking US STEM pipeline may be complex and are the subject of much research, however some fundamental problems are well recognized and supported by statistical evidence.

1) Conventional K-12 science and mathematics curricula often inadequately prepare students for scientifically rigorous engineering higher education and training. TIMSS (Trends in International Mathematics and Science Study, US Dept. of Education, 2006) and other reports document the underperformance of U.S. students in mathematics. Educational research (e.g. Halloun, 1985, Hestenes, 1992) has established that students do not properly understand many fundamental science concepts, and that conventional K-12 instruction produces little change in students' understanding and predominantly fails to remove major misconceptions.

2) Too few students are enrolling in engineering degree programs. In addition to preparation issues, there has been a lack of effort to positively promote awareness and understanding of the nature of engineering careers. Female students, in particular, are less likely to take higher levels of math and science, such as calculus, computer science, or physics at the high school level, (National Academic Press, 2006, 2007) leading to their under-representation in university level science and engineering courses.

3) Attrition rates. For the few students that do enroll in engineering and STEM degree programs there is a very large attrition rate. This situation might be helped by the integration of innovative teaching methodologies. However, much of the pioneering educational innovation in recent years has been focused at the K-12 level and the incorporation of these methods into university level teaching has been comparatively slow.

Enrollment in US higher education institutions rose from 12.6 million students in 1983 to 15.7 million in 2001, partly due to an increase in the college age population. In contrast, over the same period the number of those enrolling in engineering degree programs declined from around 440,000 to 420,000, i.e. engineering enrollment declined from around 3.5% of college students to only 2.7% over the past 20 years.

However, of the small numbers who do enroll in engineering programs, far fewer complete them, and this trend is worsening. Only 16% (of the 440,000) who enrolled in 1983, completed their engineering degrees. In comparison, only 14% of the 2001 enrollments achieved engineering degrees. These statistics are even more worrying when one considers that an increasing proportion of these degrees were awarded to foreign students (those on temporary visas). Foreign students accounted for 7% of all awarded US bachelors degrees in engineering in 2002 (as compared to only 4% of all science and engineering degrees) and 55% of all engineering doctorates awarded in 2003 (2006 Science and Engineering Indicators).

Response to Need

This project proposes to enhance high school science curricula with a series of engineering related project based learning modules. A cohort of graduate engineering students (GK-12 Fellows) will collaborate with high school teachers to design and implement these modules,

based on the Fellows' research topics but closely mapped to core STEM curricula and educational standards. NJAEE will link fundamental concepts and topics, in the high school science curricula, to exciting, relevant, and real-world engineering problems. Bringing engineering concepts (and young engineers in person) into high school classrooms will increase awareness and interest among high school students in engineering, technology innovation and its impact on society. Presenting traditional science subjects in the context of topical engineering problems will make science and mathematics more meaningful and engaging. Thus this project (figure 1) will help increase the numbers of high school graduates who are both interested and adequately prepared to pursue STEM careers. At the same time, the GK-12 Fellows will become actively involved in education, thus training the next generation of engineering professors in pedagogy and the latest innovations in teaching methodology, helping improve future retention rates at the undergraduate level. As an additional benefit, by learning how to explain their research areas to non-experts in simple terms, Fellows will reinforce their own understanding of these subjects, and have an opportunity to share their research findings with a larger audience. The NJAEE project is driven by the philosophy of Technogenesis [TM], pioneered by Stevens, where faculty, students and industry jointly nurture research concepts to commercialization and back to the classroom. This is part of the Stevens educational experience and creates a climate of innovation and enterprise across the campus.

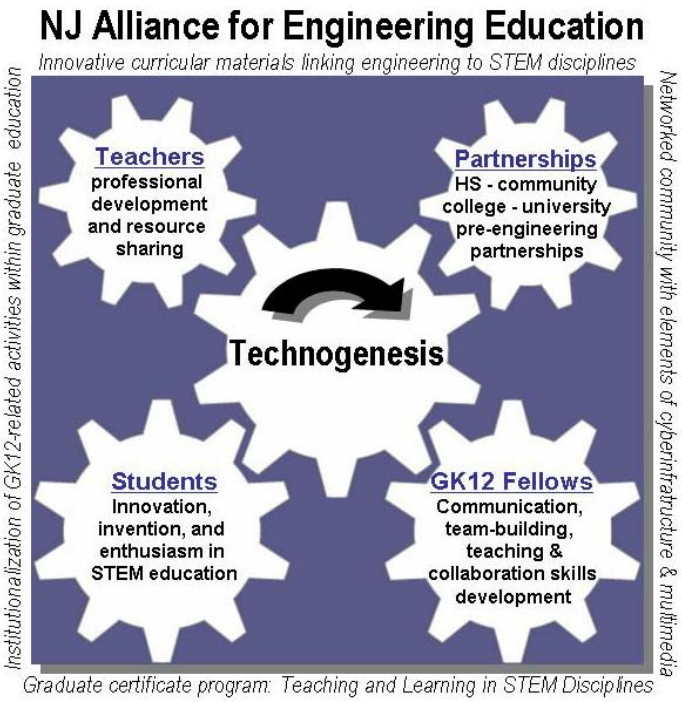

Figure 1. Proposed NJAEE project.

Participants

The proposed program brings together a diverse set of high schools throughout New Jersey with educators at Bergen Community College and Montclair State University and with faculty, researchers, and graduate students from Stevens Institute of Technology, and the Center for Innovation in Engineering & Science Education (CIESE) at SIT (see Figure 1). The Fellows and HS teachers will be exposed to research-based instructional strategies courses that will form the basis for the new Graduate Certificate Program *Teaching and Learning in STEM Disciplines* to be developed, piloted, and institutionalized through this program. This certificate program is being developed in direct response to our Institute's desire to provide our graduate students with a strong set of complimentary skills to augment the research training typical of a traditional graduate degree. The project will be

Figure 2. NJAEE schools

enhanced by an external assessment and evaluation program and an external advisory board made up of leaders in engineering and K-12 STEM education and industry (Verizon, Stryker).

Primary stakeholder benefits Table 1 outlines the benefits for each stakeholder:

Pedagogical & Professional Development of GK-12 Fellows	• Training in communicating technical information to diverse audiences • Exposure to constructivist educational strategies • Grad. certificate in **Teaching and Learning in STEM Disciplines**
High School (HS) Student Learning and Development in STEM Disciplines	• Enhanced STEM education through participation in innovative curricular materials • Increased awareness of what engineers do and engineering career and training opportunities • Engagement in creative design/problem-solving activities
Professional Development of Teachers in STEM Disciplines	• Graduate credit or research opportunities and a stipend • Improved understanding of engineering applications and principles as related to science • Support collaboration with Fellows in planning/delivery of classroom instruction
Professional Development of Current and Future University Faculty	• Increased awareness/adoption of innovative teaching strategies • Exposure to pedagogical strategies to address the needs of students with diverse learning styles • Communicating Engineering Science and the new Communicating Engineering courses
Participating Institutions	• Communication/collaboration among partners regarding "pre-engineering education" • Model for sustained involvement by SIT faculty and graduate students in "pre-engineering education" at the K-12 and community college level through the Graduate Certificate program • National model linking high school – community college – university within STEM education
STEM Educational Community at Large	• National model institutionalizing use of GK-12 STEM-related activities within graduate education: *Graduate Certificate Program*: **Teaching and Learning in STEM Disciplines**

Table 1: Primary stakeholder benefits

Relevant prior NSF support

- *Minority Access/Graduate Networking in the Sciences, Technology, Engineering, and Mathematics (MAGNET-STEM II), NSF HRD-0450360, $2.4M, 10/04-9/09.* MAGNET-STEM II (CUNY, SIT, NJIT, and Polytechnic), in its second 5-year funding phase, supports minority Ph.D. students pursuing academic STEM careers. Four students have completed Ph.D. degrees; one is currently Assistant Professor of Physics at a minority institution (St. Peter's College, Jersey City, NJ), two are post-doctoral researchers in universities, and one is in industry.
- *BUILD IT - Using Underwater Robotic Vehicles to Build IT and Pre-Engineering Skill, NSF DRL-0624709, $1.2M, 2006-2009.* BUILD IT is a program in which 2600 students and 72 teachers from NJ middle and high school construct underwater remotely and autonomously operated robots using LEGO and other simple materials. BUILD IT fosters an active learning environment that integrates the application of many IT, scientific, and engineering principles; conceptual and skill-based learning; and collaborative learning and cooperative group skills.

BUILD-IT will serve as one of several proven innovative curricula for which the Fellows will support HS implementation during the Fellow introductory training period.

- *ITR: An Infrastructure for Designing and Conducting Remote Laboratories, NSF ITR-0326309, $1,905,708, 2003-2008.* This project integrates a variety of online laboratory resources so that users can run remote or virtual experiments involving multiple resources in different labs in different locations. Users can perform collaborative experiments with multiple participants or combine experiments and simulations in an integrated lab experience. Potential **Fellow activities could leverage the ITR framework to bring university laboratory experiments into the high school and community college classroom curriculum.**
- *Collaborative Research of Mid-Atlantic COSEE: Center for Ocean Science Education Excellence, NSF OCE-0215399, $492k, 08/02-08/07.* COSEE-Mid-Atlantic uses Coastal Observing Systems to promote awareness and understanding of our oceans. It integrates research and education programs to encourage lifelong learning among K-12 educators, students (K-16), coastal managers and underserved audiences. **Some Fellows could support HS implementation of these materials during the Fellow introductory training period.**
- *NUE: Virtual Research Experiences for Undergraduates in Nanotechnology (VREUN), NSF EEC-053255, $200k, 09/01/05-08/31/07.* Faculty from various departments across the School of Engineering and CIESE are developing modules to introduce undergraduates to nanotechnology within the context of undergraduate nanotechnology research. Each module introduces students to nanotechnology in the context of research being done on campus. Here **GK12 Fellows could provide module extensions and appropriate teacher supports of existing modules during the Fellow introductory training period; in addition, the framework may also be used by the HS teacher – Fellow teams developing *new* nanotechnology modules.**
- *NIRT: Self-Assembled Nanohydrogels for Differential Cell Adhesion and Infection Control, NSF DMR-0708379, $1M, 2007-2011.* This project explores a new mechanism to create synthetic surfaces that are adhesive to eukaryotic cells but simultaneously repulsive to bacterial cells. CIESE is building two new educational modules that introduce nanotechnology to high school chemistry and biology curricula to complement the research. **This effort demonstrates translating cutting-edge research into K-12 classroom materials. Fellows will provide the content-specific support both in classroom and through the online learning community.**

Additional support of $2.5M is being provided by the Verizon Foundation "Engineering Our Future NJ", the NJ Commission on Higher Education for Teacher professional development, and the NJ Department of Treasury to develop the NJ Community College Strategic Partnership.

Project plan: Leveraging the resources outlined above with the NJAEE project plan, the team expects to achieve the following project objectives and goals, as shown in Table 2:

Goals	1. Increase the number of students enrolling and persisting in engineering education 2. Develop a national model to develop innovative pre-engineering curricula
Objectives	1. Exposure of Fellows to hands-on classroom teaching and learning 2. Teacher professional development 3. Pre-engineering education module development 4. Pedagogy and technical communication training for graduate Fellows 5. Creation of new "Communicating Engineering" course. 6. Graduate certificate program ***Teaching and Learning in STEM Disciplines*** 7. Cyber-collaboration through an online learning community 8. Promotion of engineering awareness among high school students.

Table 2: Project Goals and Objectives

The project tasks associated with the objectives listed above are given in Table 3 and further illustrated below (For a project timeline outlining the various project activities refer to Table 5 at the end of this section) :

Task 1: Build teacher-Fellow teams – The **Internal Advisory Panel,** which will be meeting monthly for the duration of the program, will meet with the STEM-discipline coordinators from the partner high schools to assess the needs of the schools and the teachers. Its membership consists of PI/Co-PIs (Chassapis, Fisher, Stolkin, McGrath, Hotaling), P.J. Riccato representing Bergen Community College, and the Science Coordinators from Jersey City High Schools and Bergen Academies (one from each). Teachers will be grouped into teams on the basis of school and/or discipline, e.g. several math teachers from different schools could collaborate to create a math module, or alternatively several teachers from different subject at the same school might form a team to create an interdisciplinary module. The Internal Advisory Panel will assign Fellows to teacher teams based on the research/expertise area of the Fellow and the subject areas addressed by the team. The IAP will meet on a monthly basis to review the progress of the project: recruiting and selecting participants, reviewing module development, collecting and reviewing feedback from the NJAEE participants and the external evaluator.

		Objectives							
		1	2	3	4	5	6	7	8
Tasks	1. Assign Fellows to teachers – Internal Advisory Panel	X							
	2. Convene External Advisory Board	X	X	X	X	X	X	X	X
	3. Summer Institutes (2008, 2009, 2010, 2011)	X	X	X	X				
	4. School-year professional development opportunities	X	X	X	X				
	5. School-year activities	X	X	X	X	X	X	X	X
	6. Module Development	X	X	X	X			X	X
	7. Development and delivery of "Technogenesis ^{TM}" workshop		X	X			X		
	8. Fellows undertake literature patent and product searches			X	X		X		X
	9. Development and delivery of Communicating Engineering				X	X	X		
	10. Development and delivery of Teaching and Learning Certificate		X						
	11. Development of online classroom visit reporting tool	X							
	12. Development and implementation of online learning community		X	X				X	
	13. NJAEE Spring Showcase (2009, 2010, 2011, 2012)	X	X	X	X				X
	14. Design and maintain project web site			X				X	X
	15. Design and maintain web-based module repository			X				X	
	16. Project evaluation	X	X	X	X	X	X	X	X
	17. Dissemination of NJAEE project results								X

Table 3: Tasks and Objectives

Task 2: Convene External Advisory Board - The **External Advisory Board** (EAB) will be convened once a year to review and critique the progress of the Alliance. Eight individuals have been approached and expressed interest in serving on the EAB. **Mark Bocchieri,** Director of External Affairs, Verizon New Jersey; **Norman Fortenberry**, Director, Center for the Advance. of Scholarship on Eng. Education (CASEE); **Susan Lowes**, Director of Research & Evaluation, Institute for Learning Technologies, Teachers College/Columbia University; **Susan Metz**, co-founder and past-president, WEPAN (Women in Engineering Programs & Advocates Network); **Jeffrey V. Osowski**, Vice President, Learning and Teaching, Liberty Science Center (Jersey City, NJ); **Cary Sneider**, Vice President for Educator Programs, Museum of Science, Boston;

Connie Walde, Office of Career and Technical Education, NJ Department of Education; and **Joseph Zitelli**, Manager, Orthobiologics Group, R&D, Stryker Corporation.

Task 3: Summer Institutes (2008, 2009, 2010, 2011) - Beginning in Summer 2008, an annual two-week Summer Institute (8 days, 6 hours/day = 48 hours) for 20 teachers and 9 Fellows (8 in year 1), will be comprised of the following components:

Graduate Coursework (offered by Montclair State University at the Stevens campus): Two, three-credit courses will form the basis our Summer Institute. ***Innovations in Teaching (CURR 522)*** and ***Pedagogy: The Art and Science of Teaching and Learning (EDCO 803)*** will involve 24 hours (total of 48 hours) of face-to-face work for each course, to be complimented by online support for a total of 42 hours (21 hours for each course) over the school year. The courses are designed to prepare participants to recognize and adapt to different ways of learning, and to provide them with tools that will ensure successful collaboration in the design, development, and implementation of innovative educational materials. **In this manner, motivated students, enthusiastic engineering faculty and knowledgeable teachers can form the foundation for a healthy engineering education pipeline.**

***Research Laboratory Experiences*:** Six hours of the Summer Institute will be devoted to orientation seminars at selected engineering research centers at SIT, including: The Center for Maritime Systems, The Cyber Security Research Center, the Design & Manufacturing Institute, the Center for Environmental Systems, the Highly Filled Materials Institute, the NJ Center for Microchemical Systems, The Center for Intelligent Networked Systems, and CIESE. It is through this orientation that participants will become more familiar with research activities and prior developments at these centers, which will enrich module content.

Task 4: School-year professional development opportunities – As outlined above, in addition to the summer institute, teachers will need to complete additional assignments during the school year in order to complete their two graduate courses through Montclair. Furthermore, teachers will participate in **seven 6-hour workshops,** totaling 42 hours. These workshops will be used for training on previously developed modules, new module content development, Technogenesis ™ workshops, spring showcase, lab tours and exposure to cutting edge engineering research. Research reveals that effective professional development requires time (Duschl, Schweingruber, and Shouse, 2006, Loucks-Horsley et al., 2003). Some researchers argue that over 80 hours of professional development, spread out over an extended period, is the most effective way to sustain teacher change (Basista et al., 2001; Mouza, 2005). **The two 45 hour-each Montclair courses, the 6-hour research laboratory experience and 42 hours of workshops along with the additional time spent interacting with Fellows to develop modules, will total well in excess of the 120 contact hours recommended by NSF (e.g. NSF ITEST solicitation 2007).**

Task 5: School-year activities - ***Identification of Team Goals, Benchmarks, and Measures of Success*:** With guidance from the evaluator, teachers and Graduate Fellows will identify goals and benchmarks for their professional growth and their students' accomplishments for the coming year. Teachers will create a timeline, benchmarks, and indicators of success that will be used to measure progress and identify remaining challenges. ***Team (Teacher-Fellow) Joint Planning & Curriculum Development*:** Each team will produce a yearly plan for the Fellow's work to support classrooms, along with a monthly set of lessons and activities for implementation in the NJAEE schools. ***Classroom Implementation and Support*:** Fellows will

work with teachers to implement lessons, design experiments, team teach, mentor students and teachers in subject matter content and become exposed to instructional strategies and classroom situations. School-year activities will involve a minimum of 10 hours per Fellow in the classrooms of their partner teachers, plus a minimum of five hours per week of preparation. Where appropriate, Fellows will also support student participation in extracurricular academic activities, in addition to being a valuable resource to High School college guidance counselors.

Task 6: Module Development - Teacher teams and Fellow(s) will develop and implement one- to two-week modules (four/five lesson plans) which relate to the Fellow's area of engineering research, and can be readily incorporated into existing, required science, mathematics, and technology courses (see Table 4). The modules will also enable students and teachers to gain hands-on skills, expertise, and understanding of IT tools and concepts consistent with the National Science Education Standards, ITEA Standards for Technological Literacy, ISTE standards, and 21st century workforce skills (North Central Regional Education Laboratory, 2003) including communications and experimental design and techniques. This collaborative approach is essential to enable a two way cross fertilization – teachers will benefit from the Fellows' scientific research background and perspective and Fellows will gain from the teachers' educational expertise and classroom education experience. Stevens engineering faculty and CIESE education experts will interact in this process as facilitators, advisors and mentors. Completed modules will be made available on the project web site and in print form, with a teacher's guide. Teacher-Fellow teams will first outline their module and submit a proposal to the Internal Advisory Panel. The IAC will assess each module, make recommendations and approve modules for development and implementation. Approved modules will require:

- Alignment with NJ and National standards for Science (Appendix Table S1);
- Linking of a required STEM 9-12 course with a topical area of engineering;
- Emphasis on innovation and inventiveness;
- A clear plan for assessment and evaluation.
- The created modules will emphasize engineering, innovation and inventiveness.

While the limits of traditional lecture-based teaching are now well-recognized, **Project-based Learning (PbL)** and discovery-learning approaches (Berlyne, 1965, Bruner, 1966) will be utilized to facilitate active learning, to provide students with broad context for understanding, which is likely to improve knowledge retention and integration (Wood, 1998, 200, Richardson, 1998). Increasingly, PbL has gained acceptance within the STEM community. This will provide Fellows with the opportunity to practice their technical communication skills as they work alongside teachers and educators on developing modules steeped in the latest educational theory for the benefit of all students. An integral part of each module will be a requirement that each student team delivers a written report and/or an oral presentation, which will highlight what the students consider to be novel aspects of their design, advantages/disadvantages and similarities/differences as compared to existing/previous work and the work of other student teams in the classroom. This does not necessarily have to be competitive – the emphasis should be on showing the students the importance of putting their own work in context. Inter-school or intra-school district teacher collaborations will be encouraged where it is deemed appropriate by the Internal Advisory Panel. For example, a team of math teachers from several different schools collaborating to develop a module. Fellows will take on the role of facilitators and go-betweens to reinforce these collaborations. Cyber-collaboration will be employed for Fellows and teachers

to interact and build their modules. CIESE will lead the effort to ensure that all materials align with state and national standards to ensure widespread applicability. Aggressive dissemination will maximize their impact on STEM education.

Major area of Stevens research - potential basis of modules -	High School Courses						
	General Science	Biology	Chemistry	Physics	Env. Science	Math	Computer Science
Nanotechnology (Nanotechnology Program) Chem. & bio. micro-systems, NEMS/MEMS	X	X	X	X	X	X	X
Robotics & AI (Maritime Systems, Elec. Eng.) Underwater robots, robotic vision	X			X	X		X
Sensor Systems (Center for Maritime Systems) Coastal ocean, harbor protection, navigation	X	X		X		X	
Environmental Engineering (Center for Env. Systems) Fate & transport of toxins, pollution control	X	X	X		X	X	
Ocean Engineering (Center for Maritime Systems) Sediment transport, rip currents, vessel design	X			X		X	X
Biomedical Engineering (Biomedical Eng. Program) Pain management, implants, nanogels		X	X				
CyberInfrastructure Cryptography, network security, remote laboratories	X	X	X	X	X	X	X

Table 4. Potential subjects for pre-engineering education modules.

Task 7: Development and delivery of "Technogenesis" workshop - To facilitate the incorporation of innovation, inventiveness and entrepreneurship into the new modules, Dr. Thomas Lechler (School of Technology Management) will develop and deliver a workshop on Technogenesis. Fellows and teachers will participate in the workshop as part of their school-year professional development. Technogenesis ™, pioneered by Stevens, where faculty, students and industry jointly nurture research concepts to commercialization and back to the classroom. The information and guidance provided by Dr. Lechler will assist Fellows and teachers integrate the spirit of Technogenesis ™ or "how to bring a product to market" into their modules and create a climate of innovation and enterprise in the classroom.

Task 8: Fellows undertake literature, patent and product searches - In order to understand the "big picture" of their research area, further appreciate the spirit of Technogenesis ™ and master the ability of integrating aspects of "how to bring a product to market" into their modules, Fellows will conduct an extensive search on the area that most closely relates to current and future product commercialization opportunities/implementations of their research topic. The activity will include tasks such as a literature survey, a patent search and a survey of publicly and privately held companies with considerable activity in Fellow's research area. Students will conduct this work under the guidance of their research advisor and with the assistance of Dr. Lechler. Additional outcomes through this process - especially valuable to the graduate student,

the faculty research advisor, and the research community - could lead to peer-reviewed: 1) state-of-the-art reviews for a standard technical journal; 2) extensive patent searches and analyses publishable in journals such as the *Journal of Recent Patents in Engineering*; and 3) analyses of the existing commercial technology and product case studies publishable in journals such as *Harvard Business Review* and *Product Development Management Proceedings*.

Task 9: Development and delivery of "*Communicating Engineering*" - Lawrence Hall of Science (LHS), the University of California at Berkeley's public science center, is recognized for its expertise in instructional materials development for the K–12 audience. A pioneer in the inquiry-driven, direct experience approach to pre-college science instruction, LHS projects include the Full Option Science System (FOSS), the Science Education for Public Understanding Program (SEPUP), the EQUALS/Family Math programs, and the Great Explorations in Math and Science (GEMS). Of interest here, LHS and UC Berkeley's College of Chemistry have developed a semester-long college science course entitled Communicating Science which introduces chemistry, physics, and astronomy majors to the skill and excitement of introducing their subject areas to children (see attached letter of support). Within the current project the NJAEE will collaborate with LHS staff to create "*Communicating Engineering*" – a new course for undergraduate and graduate engineering students. *Communicating Engineering* will be based on the Communicating Science framework but use Stevens Faculty and GK12 Fellow research to create K-12 engineering education exemplars to weave into the framework creating relevant experiences for graduate and undergraduate engineering students. Following attendance of a workshop at LHS, two Stevens PIs will begin developing engineering exemplars and through electronic collaboration and teleconferences collaborate with LHS staff to weave in examples. LHS staff will travel to Stevens to finalize course content(see discussion in Budget Justification section). In addition, the LHS staff will offer a workshop to Stevens faculty regarding the importance of understanding the science of how people learn to effectively communicate engineering topics and cutting-edge engineering research to non-expert audiences, thereby providing the opportunity for the entire Stevens faculty to come up with additional exemplars. The final *Communicating Engineering* course will be mandatory for all GK-12 Fellows, offered as an elective to all Stevens graduate and undergraduate students and will be made available to teachers interested in obtaining the **"Teaching and Learning in STEM"** certificate.

Task 10: Development and delivery of the "Teaching and Learning in STEM" Certificate - As a result of the activities listed above, a graduate certificate program ***Teaching and Learning in STEM Disciplines*** will be created. The coursework will be mandatory for the GK-12 Fellows, optional for the NJAEE teachers and made sustainable as a permanent graduate certificate offered to all Stevens graduate students beyond GK-12 funding. The certificate will consist of:

1) Three courses - *Innovations in Teaching (CURR 522), Pedagogy: The Art and Science of Teaching and Learning (EDCO 803),* and Communicating Engineering (E 5xx)
2) One semester practicum in a K-12 classroom[1]
3) Development of a K-12 module on engineering research

Task 11: Development of online classroom visit reporting tool - Project PIs and the Program Administrative Assistant will monitor Fellow classroom visitations through an online reporting

[1] This requirement will apply to all students interested in pursuing the certificate. The GK12 Fellows will have clearly satisfied this requirement by being part of the NJAEE program.

tool. Fellows will be required to visit classrooms a minimum of 10 hours per week. Fellows will complete a "Classroom Visit" report at the conclusion of each classroom visit, where they will report on the activities that occurred, time spent at the location, and any other noteworthy occurrences. CIESE will be responsible for creating and maintaining this online tool. The "Classroom visit" reports will be included in the Fellows' evaluation.

Task 12: Development, implementation and management of online learning community - CIESE will initiate and maintain an electronic learning community (or community of practice) for all of the teachers and fellows. This electronic learning community web space will house a listserv distribution mechanism, a discussion forum, "ask-an-expert" area with Stevens researchers available to answer specific questions on subject matter, house an electronic library of all classroom materials created by the teachers and fellows, project announcements and other news.

Task 13: NJAEE Spring Showcase (2010, 2012) - Starting Spring 2010 Stevens will host the NJAEE Summer Showcase, a statewide forum for STEM educators where Fellow-teacher teams will make presentations of curriculum modules implemented during the previous year(s), highlighting key components of the modules, design projects and student experiences. These sessions will be open to high school teachers and administrators from the tri-state area.

Task 14: Design and maintain project web site - The NJAEE project web site will be developed and online during Spring 2008. The web site will remain under constant construction throughout and beyond the duration of the GK-12 funding cycle. The web site will house general project information and announcements, the online learning community, the module repository, the classroom visitation reporting tool, promotional materials about the project, including publications and hand-outs.

Task 15: Design and maintain web-based module repository - The module repository will be housed on the NJAEE project web site. The module repository will contain the completed modules (developed by Fellows and teachers, and quality-controlled by the Internal Advisory Panel) in electronic, printable form and link to a teacher's guide. The module repository will be open-access and promoted through listservs, conferences and papers.

Task 16: Project evaluation - Program evaluation will be conducted by Lynn W. Gregory, Executive Director of Partnerships for Creative Action (PCA), an independent consulting organization. (Table 5 provides the timeline associated with the various activities in this task.) Over the past 32 years, PCA has conducted evaluations of a wide variety of educational programs including many school-university partnerships and programs focused on improving STEM education. In recent years, these have included three GK-12 Fellowship programs: two (Rutgers University-Newark, tracks 1 and 2) and a third (Columbia University). *PCA* is currently conducting evaluations of three NSF-funded programs: the *Rutgers University-Newark/Newark Public Schools Track 2 GK-12 Fellowship Program*, the Educational Equity Center/Academy for Educational Development, *Great Science for Girls Extension Services for Gender Equity in Science through After-School Programs* and the Rutgers University-Newark *Opportunity for Enhancing Diversity in Geosciences Program.* The goals of the proposed program focus on impacting the GK-12 Fellows, HS teachers and their students, SIT faculty, and the partner educational institutions as well as contributing to the 9-20 field of STEM education.

The program is specifically designed to create knowledge bases, processes and products that will improve science education in the partner institutions beyond the life of the program. The evaluation will include methods to monitor the process by which these goals are achieved (formative evaluation) and assess the extent to which they are accomplished (summative evaluation). Data collection will be designed to address:

GK-12 Fellows. In what ways and to what extent are…

- Fellows trained in innovative teaching strategies?
- Fellows trained in pedagogical strategies to assess and address needs diverse learning styles?
- Structures/opportunities provided to assist GK-12 Fellows to communicate, organize and present ideas? To what extent are they able to apply those lessons?

High School Student Learning & Development in STEM Disciplines. How…

- Does the program increase interest in STEM course work and related careers?
- Does innovation and inventiveness as a strategy serve to motivate/engage students?

Professional Development of Teachers in STEM Disciplines. How are…

- Participating teachers prepared to implement pre-engineering modules in their classroom?
- Teachers developing pedagogical strategies to assess/address diverse learning styles?
- Structures/opportunities provided to assist participating teachers to communicate, organize and present their ideas? To what extent are they able to apply those lessons?
- Planning/delivery of classroom instruction supported through GK-12 interactions?
- Teachers able to utilize increased knowledge of engineering principles and practice?
- The trained HS teachers able to serve as peer leaders of exemplary science instruction, and facilitate and support others teachers in developing these skills in their school districts?

Partner Educational Institutions. In what ways / to what extent do:

- SIT faculty adopt innovative teaching strategies based on their exposure to NJAEE fellows?
- SIT faculty develop pedagogical strategies to assess and address diverse learning styles?
- Does the program deepen institutional relationships between SIT and its high school partners?
- Does the program create a model for sustained involvement by SIT faculty and graduate students in K-12 education? What is the nature of that model?
- Does the program foster collaboration resource-sharing between the institutions?

STEM Educational Community

- What processes are used for the adaptation and wider dissemination of instructional modules, curriculum content, and classroom activities that promote student engagement in application of engineering process and exposure to real world design and problem-solving?
- What benefits are realized by the high school – community college – university partnership in pre-engineering education? What obstacles must be addressed to realize such a partnership?

For data collection analysis, both qualitative and quantitative research methods will be utilized. Process and outcomes questions will be addressed through a multi-method approach combining observations, formal and informal group and individual interviews, questionnaire administration, and maintenance of records of program-related meetings and activities. Throughout the implementation years, examples of all program activities will be observed. At the end of each school year, comprehensive surveys to Fellows and teachers will be administered to obtain information regarding their experiences with the program, their perceptions of how it has impacted their practice, and strengths and challenges of the program. Participating HS

students will complete pre- and post-surveys to measure changes and obtain their perceptions regarding the effects of working with college students, and the projects themselves, on: their knowledge; interest in engineering, science and mathematics; understanding of real-world applications of their learning experiences; and future academic and career goals. Key administrators will be interviewed annually to address questions regarding lessons learned, alterations made to improve the program and other program development issues, and their perceptions of the ways in which the program has affected the relationship between and among the partner institutions. Led by *PCA*, feedback between the evaluation team and program administrators and participants will be built into the assessment process.

Task 17: Dissemination of NJAEE project results - Dissemination will occur at the local, state, and national levels via: (1) internal dissemination at SIT of research-based teaching strategies through CIESE-led workshops; (2) science, technology, and engineering journals and publications; (3) conference presentations at the National Science Teachers Association, the American Society of Engineering Education, the National Education Computing Conference, and other relevant forums; (4) the CIESE website, which had 700,000 unique visitors in 2006 along with the NJAEE website; (5) CIESE's teacher professional development programs and listservs, which have impacted a very large number of educators throughout the U.S.; (6) submission to MOS and other online repositories of engineering curricula; (7) the statewide NJAEE Summer Showcase; and (8) participation at local events hosted by the partner institutions.

Utilization of Cyberinfrastructure for pre-Engineering Education

In addition to the online learning community, two current NSF projects, Nanotechnology Undergraduate Education (NUE) and *Information Technology Research (ITR): An infrastructure for designing and conducting remote laboratories. NSF-ITR Grant No. 0326309* grants, immediately provide a framework necessary for NJAEE to extend these tools for high school STEM education. Fellows will learn of additional tools and techniques to incorporate and apply remote laboratories and/or multimedia-based learning environments towards their future research and educational activities. More importantly, each of these projects will provide fellow members of the Alliance with 'virtual' access to the Stevens engineering research and education environment, whether it be remote access to the same laboratories used within the Stevens undergraduate engineering curriculum or a suite of self-contained multimedia learning modules based on ongoing cutting-edge undergraduate and graduate research at Stevens.

Additional Curriculum Materials

In addition to the modules described above, we will seek to use/promote existing exemplary engineering curriculum resources, particularly the *Build IT* (NSF DRL-0624709) project developed by CIESE, and the *Engineering the Future (ETF)* curricula developed by the National Center for Technological Literacy at the Museum of Science (MOS) in Boston.

Recruitment and Selection

The PI, Co-PIs, and Faculty Participants will oversee the ***recruitment and selection of the Fellows***, working in partnership with a team of SIT department heads and faculty advisors from the participating departments with input from the school administrators. A set of criteria, including academic standing, GPA, interpersonal skills, communication skills, and expressed interest and/or previous experience in teaching or working with K-12 students and/or teachers will be considered. Nominees will be required to complete a formal application and two personal

interviews: one with members of the IAP and a second with the potential HS teachers. *There will be an effort to recruit Fellows with diverse backgrounds, as it has been noted that K-12 students respond particularly well to college students as role models when they share gender, ethnicity, and/or cultural backgrounds*. In particular, we will partner with such organizations as Women in Engineering Program and Advocates Network (WEPAN), the National Action Council for Minorities in Engineering (NACME), and Alliances for Graduate Education and the Professoriate (AGEP) to leverage our access to a national database and network of minority undergraduate and masters' students for recruitment purposes.

The ***Teacher selection*** will be based on individual interest and commitment to the objectives of the program; leadership/dissemination skills; recommendations by the department head, coordinator and/or principal; and probability of success provided the teacher receives sufficient professional training and support. An additional major selection criterion will be the likelihood of continual participation (NJAEE counts on teachers staying with the program and providing support, as illustrated in Table 5 under the "GK-12 Teacher Alumni Support Provider Activity") and communication within the online learning community cyberinfrastructure. A professional development contract will be developed delineating the benefits, terms, and conditions of participation in the program. In addition, lessons learned from previous GK-12 programs indicate that ***the matching of fellows with teachers*** plays an important part in the success and effectiveness of the program. A working group comprised of school system administrators and GK-12 university faculty will orchestrate these Fellow-teacher pairings with the aim of achieving the greatest educational impact and professional accomplishment for Fellows and teachers.

Organization, Management, and Institutional Commitment

PI Constantin Chassapis, will oversee the GK-12 Fellows program, convene monthly meetings on project progress (IAP), including the yearly EAB meeting, oversee Fellows' activities, and be responsible for the organization of the annual two-week Summer Institute and the school year workshops. He will work closely with the IAP and the rest of the participants in the first part of Year 1 to organize the program. He will also oversee the work of the external evaluator and ensure that formative data is used to improve program implementation. *Christina Connors* will serve as the *Program Administrative Assistant*. Connors will serve as the point contact for the GK-12 program at Stevens for Fellows and teachers. Connors will be responsible for collecting Graduate student applications for the GK-12 program, monitoring the classroom visitation reports, coordinating Summer Institutes, school-year workshops, and Spring Showcases. Connors will receive funding from the GK-12 program for Years 1 and 2. Subsequent funding will be provided through the Mechanical Engineering department. *Co-PI Beth McGrath*, Director of CIESE, will serve as primary liaison with the K-12 partners. *Co-PI's Rustam Stolkin, Frank Fisher and Sven Esche and Liesl Hotaling* will coordinate the matching of Fellows and teachers, continuously monitor the activities of the teacher-Fellow teams to ensure that the jointly developed annual plan is being met, oversee Fellows' activities relating to project/module content, and coordinate with their academic advisors. *Thomas Lechler* will work within the Alliance to incorporate invention and innovation leading elements into the materials.

List of Faculty Participants

R Besser (Chem. Eng.); C. Christodoulatos (Env. Eng.); S. Hassiotis (Civil Eng.); M. Libera (Materials Eng.); H. Man (Electrical & Computer Eng.); Art Ritter (Biomed. Eng.); S. Wetzel (Computer Science); R. Stolkin (Ocean Engineering); C. Chassapis, S. Esche & F. Fisher (Mech. Eng.).

Faculty participants have been carefully selected from a wide span of disciplines to serve as the research mentors of the GK-12 Fellows. Each research mentor is committed to the overall goals of NJAEE and will champion the benefit of this program for their potential graduate students. Advisors will assist in Fellow recruitment/selection, work with the Fellow-teacher Teams on identifying an appropriate aspect of the research project to serve as the basis for the module, and assist in module background development. These advisors will critique the module design, provide feedback to the Teams as the modules are developed, and review the content of the developed materials once completed. Furthermore, they will provide feedback to the external evaluator relating to the fellow's progress in his/her dissertation topic. They will also provide orientation sessions of their research projects during the annual summer institutes, and actively contribute to discussions regarding future module development. They will also work with the evaluator in assessing how participation in NJAEE and courses from 'Teaching and Learning in STEM Disciplines' have facilitated the development of the Fellow's professional skills.

School Involvement

Several schools have eagerly volunteered to participate in the NJAEE (see Supplemental Documents). However due to space limitations, all Letters of Support could not be included. Schools currently identified for NJAEE include Bayonne Public Schools, Jersey City Public Schools, Hoboken Public Schools, North Brunswick Public Schools, Alpine Schools, Bergen Academy, Great Meadows Pubic Schools, Washington Township Public Schools, Ridgewood High School and Bergen Community College. As described in BCC's Letter of Support (see Supplemental Documents), **Bergen Community College** has initiated a program with **Ridgewood High School (RHS)** to develop an Engineering Academy within the high school. The NJAEE will benefit from an ongoing examination of the RHS science curriculum with an eye toward introducing engineering concepts into science courses across the board, in order to facilitate the Engineering Academy option. The integrative role of BCC in this GK12 project has the potential to provide a model for high school–community college–university partnerships (2+2+2) to complement the "traditional" HS-university (2+4) approach for students to pursue an undergraduate degree in STEM. This alternative (2+2+2) pathway enabled by the community college can serve as a critical "safety net" for recruiting and retaining under-represented minorities and women in science, engineering, and engineering technology programs, and in particular for those students from disadvantaged economic backgrounds.

Program Sustainability

This program will serve as a test bed for a **Graduate Certificate Program** on ***Teaching and Learning in STEM Disciplines*** being developed at SIT in response to the Institute's desire to compliment traditional graduate research training. As described in the support letter from Dr. Korfiatis, Provost at Stevens, this program is well-aligned with the "education rooted in Technogenesis™" vision at Stevens and will provide a continuous stream of graduate students available to work with STEM teachers. Our partners in the NJAEE have embraced this model. Beyond the GK-12 funding cycle, the following products, which also represent academic requirements for the Graduate certificate on **Teaching and Learning in STEM Disciplines**, will be sustained at Stevens through institutional and industrial partner support:

- Communicating Engineering course
- Graduate student K-12 classroom practicum
- Maintain and promote K-12 pre-engineering modules on the project web site

Project Task	Year 1			Year 2			Year 3			Year 4			Year 5	
	6/08-8/08	9/08-2/09	2/09-6/09	6/09-8/09	9/09-2/10	2/10-6/10	6/10-8/10	9/10-2/11	2/11-6/11	6/11-8/11	9/11-2/12	2/12-6/12	6/12-8/12	9/12-12/12
NJAEE Participant Training (Summer Prog.)											`			
- Course A: Innovations in Teaching	**X**			X			**X**			X			**X**	
- Course B: Art and Science of Teaching	X			**X**			X			**X**			X	
Technical workshops (7 days/year)		X	X		X	X		X	X		X	X	X	X
- NJAEE Summer Showcase							X						X	
Internal Advisory Panel Meetings (monthly)	X	X	X	**X**	X	X	**X**	X	X	**X**	X	X	**X**	X
External Advisory Board Review				**X**			**X**			**X**			**X**	
GK12 Fellow Activity														
- Hands –on classroom teaching & learning		X	X		X	X		X	X		X	X		X
- Pedagogy & technical communications training	X			X			X		X				X	
- Pre-engineering Education module development		X	X		X	X	X	X	X	X	X	X	X	X
- Assisting of HS teachers in classrooms		X	X		X	X		X	X		X	X		X
-Promotion of engineering awareness among high school students		X	X		X	X		X	X		X	X		X
Creation & Formal Approval of the Grad. Certificate						X	X							
Communicating Engineering (course develop.)					X			X						
GK12 – Teacher Alumni Support Providers					Alum 1			Alum (1+2)			Alum(1+2+3)			Alum(1+2+3+4)
Program Evaluation Components														
- Instrument Design/Refinement/Planning	X			X			X			X			X	
- Monitoring Program Activities	X	X	X	X	X	X	X	X	X	X	X	X	X	X
- Survey Administration	X		X	X		X	X		X	X		X	X	
- Interviews			X			X			X			X		X
- Student Record Data Collection	X			X			X			X			X	
- Data Analysis / Report Writing				X			X			X			X	
- Formative Feedback	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dissemination														
- Conferences (ASEE, NSTA, AERA, etc.)			**X**			**X**			**X**			**X**		**X**
-Websites & Material Repositories		X	X	X	X	X	X	X	X	X	X	X	X	X
- NJAEE Summer Showcase							X						X	
Cyber-collaboration through an on-line learning community			X	X	X	X	X	X	X	X	X	X	X	X
ACTIVE GK12 FELLOWS	**8**			**9**			**9**			**9**			**9**	
NEW HS TEACHERS	**20**			**20**			**20**			**20**			**20**	

Table 5: Project Timeline