Integrating Professionalism throughout Engineering Curricula

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Abstract. *Design projects and communication technologies are planned vehicles to integrate professional skills development of engineering students during the 4-year curricula of chemical, civil, computer, electrical, and mechanical engineering programs of the Newark College of Engineering at NJIT. This initiative is consistent with current innovations for undergraduate engineering education at NJIT such as the Gateway Engineering Education Coalition and the Virtual Classroom™. A set of eight (8) core professional competencies has been developed and all educational courses and programs are to be evaluated based on these competencies. Over 30 core engineering courses and NJIT faculty members have been identified for participation in this initiative.*

Introduction

This paper describes a planned initiative at New Jersey Institute of Technology to integrate professionalism throughout the core of the principal engineering curricula. The initiative uses design projects and communication technology as vehicles to integrate professional skills development of engineering students during the 4-year curricula of chemical, civil, computer, electrical, and mechanical engineering programs.

The role of the engineer in their professional practice has changed tremendously in recent years. The days have passed when engineers were principally individual contributors focusing narrowly on technical problem solutions and designs [1]. In today's environment, besides being competent in the engineering sciences, engineers are expected to be well-rounded professional with abilities to function as a member of multitask multidisciplinary project teams [2]. In these team roles engineers must communicate effectively and demonstrate powers of persuasion based on their technical expertise and their broader professional knowledge and experiences. Even in cases of individual contributions, engineers are expected to analyze and interpret their solutions and designs, and as well assess the possible impacts of their technical results on the total business enterprise. With the advent of vastly evolving technologies engineering professional are expected to be comfortable with the use and application of modern technologies in their practice. Engineers are expected to be total professionals in the global workplace with knowledge of management, economics, ethics, and societal and contemporary issues. Finally, for engineers to be lifelong contributors to the profession they must be willing to continually acquire new knowledge. The "forces of globalization" have brought about these changes in the role of engineers in the profession. Today former so-called U.S. businesses and industries now operate around the globe and similarly today "foreign" companies have large U.S. markets and employ many U.S. citizens. As well current and new communication technologies bring global businesses, industries, and marketplaces in near instantaneous proximity. Businesses and industries realize that if they are to remain competitive these advances in communication technologies must be utilize to their fullest capacity in the design, production and marketing of their products and services. Hence, it is incumbent upon engineering programs to produce graduates that can apply their knowledge of mathematics, science and engineering in design, production and manufacturing, and equally function as a total professional in the workplace, and use and apply modern computer-based technologies in the conduct of their practice. Currently, U.S. universities and colleges are the most preeminent producers of engineers in the world. However, as with U.S. industry in the past, this preeminent position is not guaranteed forever. Then U.S. engineering schools must respond to produce graduate with excellent technical abilities, but also graduates must have broader attributes and skills that satisfy the expectations of the employer customers [1,3,4].

This initiative at NJIT Newark College of Engineering proposes three interdependent thrusts to implement and institute this systemic institute-wide reform of engineering curricula. The first thrust is to vertically integrate real industry-based design experiences and practices into core courses of the curricula. In recent years the engineering education community has come to accept that there should be more design in the curricula. There are many reasons for this shift in thinking, but first and probably foremost, industry has expressed concern that their current-day new hirers have little knowledge of the design process [5]. In a close second, educators, in seeking ways of

reducing the very high attrition rates of engineering students, have come to believe that more hands-on design and active learning experiences in the curricula will retain students' interest in engineering study [6]. The second thrust of this initiative focuses on integrating communications and multimedia technologies into the classroom to improve student learning and enhance the delivery of the engineering courses and programs. This thrust would be incorporating many concepts similar to distance education delivered via asynchronous learning network (ALN) formats, or the *Virtual Classroom*™ into on-campus face-to-face course instruction. Again, as businesses and industries globalize their operations, engineering graduates must be familiar with communicating, designing, producing and selling with their colleagues and customers in environments quite similar to computer-based asynchronous modes [7]. Purely for economic reasons, it will become commonplace for international business operations to communicate regularly using devices such as video conferencing and digital whiteboards. The third thrust, to integrate professional skills development in core courses and programs throughout four-year engineering curricula, is the focal point of this initiative. Industry leaders continually state that the technical skills of engineering graduates are in general excellent, but graduates are generally lacking in the "soft" skills such as oral and verbal communications. These "soft" skills will be referred to as the "professional" skills. NJIT has identified eight (8) core professional competencies or skills, in addition to technical competency, that engineering curricula should develop in graduates. These competencies are, Analytical Skills, Communication Skills, Creative Problem-Solving, Life-Long Learning, Project Management, Research Skills, Systems Thinking, Teamwork [8]. The first two thrusts of this initiative are used as vehicles to integrate these professional skills into NJIT engineering undergraduate curricula.

Background on NJIT

The New Jersey Institute of Technology (NJIT) is a public, urban technological-based research university with a comprehensive array of undergraduate, graduate and continuing professional education programs in engineering and engineering technology, computer science, architecture, applied sciences, mathematics, management, policy studies, and related disciplines. The academic programs at NJIT are housed in four major schools, College of Science and Liberal Arts (CSLA), New Jersey School of Architecture (SOA), Newark College of Engineering (NCE), and School of Management (SOM). The total enrollment at NJIT is nearly 8,000 students, where nearly 3,000 of these students are pursuing graduate level degrees. The NJIT, a technological-based university, has a student body that is rich in gender and ethnic/race diversity. Twenty-eight percent (28%) of all students enrolled are women, over 20% of the students are Hispanic, Black or Native Americans, 15% of the students are Asian/Pacific Americans, and 10 % of the students enrolled are non-citizens of the United States. In comparison to some U.S. national statistics the traditional under-represented minorities and women are well represented in all NJIT engineering programs. Having been founded in 1919, the Newark College of Engineering (NCE) is the largest academic school at NJIT. NCE enrolls 3700 (48%) of NJIT students, where in NCE 57% of the student population is undergraduates. Nearly 70% of the recipients of B.S. degrees each year at NJIT are from NCE programs. There is a total of approximately 160 full-time equivalent NCE faculty. The college has five major undergraduate engineering degree programs: Civil Engineering, Chemical Engineering, Computer Engineering, Electrical Engineering and Mechanical Engineering.

This initiative is consistent with the university's vision and with several past and current innovations for undergraduate engineering education at NJIT. For purposes of this initiative, principal among these education reforms activities at NJIT are the Gateway Engineering Education Coalition and the Virtual Classroom™. This initiative also exploits upon the infrastructure developed at NJIT to support a computer intensive educational environment.

The Gateway Engineering Education Coalition [9] is a partnership of seven schools collaborating to develop new undergraduate engineering curricula focusing on incorporating design in the early years, integrating the engineering and science subjects with the social sciences and humanities, and creating interdisciplinary courses. Gateway is funded by NSF and is currently operating in the second 5-year (1997-2002) award period. NJIT has been a successful contributor in this endeavor by introducing new model freshman fundamentals in engineering design (FED) courses. The course serves over 600 students each year. In the course students have hands-on design experiences in collaborative team environments. The design experiences are presented through modules developed by the NJIT faculty. The nearly 20 modules are representative of all engineering disciplines, and as well, there are also computer science, humanities, communications and management components. The modules simulate real design issues that may be encountered in industry and society by engineers. In the (FED) courses faculties of the Department of Humanities and Social Sciences (HSS) and engineering team-teach such that communication skills are integrated with engineering principles being presented. The faculty of the department of Computer Information Science teach programming and computer applications software at a "just-as-needed" level for

students to complete their design projects. The FED students present their design solution in written reports and oral presentations at the end of the semester using the communications and computer skills gained in the course. The FED course has been institutionalized at NJIT. Under the Gateway Coalition grant the Newark College of Engineering (NCE) also developed a set of eight (8) core professional competencies students are expected to achieve. All educational courses and programs are to be evaluated based on these competencies. These competencies are consistent with those of the ABET Criteria 2000 [10] and those published in other studies [4]. These competencies and their definitions are:

1. Analytical Skills – Ability to applies logic in solving problems and analyzing problems from different points of view; to translates academic theory into practical application using appropriate technical techniques, processes, and tools.
2. Communication Skills – Capability to articulate ideas in a clear and concise fashion and uses facts to reinforce points of view; to write materials flowing logically and grammatically correct; to plan and deliver oral presentations effectively; and to use technology and graphics to support ideas and decisions.
3. Creative Problem-Solving – Confidence to suggest new approaches and to challenge the way things are normally done; and to develop many potential solutions to problems while discouraging other from rushing ideas and decisions.
4. Life-Long Learning – Ability to learn independently and continuously seeks to acquire new knowledge; to exceed basic requirements of an assignment and brings in relevant outside experiences to provide advanced solutions at hand.
5. Project Management – Ability to set goals, prioritizes tasks and meets project milestones; to seek clarifications of task requirements and take corrective action based upon feedback from others; and to create action plans and timetables to complete assigned work.
6. Research Skills – Capability to use computer based and other resources effectively thus acquiring information from multiple sources and organizes and interprets data appropriately; and to design and conduct experiments to validate theories.
7. Systems Thinking – Capability to understand how events interrelate and demonstrates an ability to take new information and integrate it with past knowledge; to integrate and use knowledge from various courses, including engineering, physics, mathematics, and social sciences; and to solve technical problems.
8. Teamwork – Be a leader and as well a member contributing a fair share to the completion of the project. Ability to listen and cooperate in a group setting.

The Virtual Classroom™ is a teaching and learning environment where the connectivity between students and instructor and students and students is mediated by computer-based telecommunications systems. NJIT Distinguished Professors Starr Roxanne Hiltz and Murray Turoff of the Computer and Information Science (CIS) Department at NJIT introduced in the 1970s software for asynchronous group communication called Electronic Information Exchange System™ (EIES™). In the 1980s, with support from the Annenberg/Corporation for Public Broadcasting project, EIES™ was modified to create special features to support teaching and learning; this version was called The Virtual Classroom™. With support during the 1990s from the Alfred P. Sloan Foundation, The Virtual Classroom™ has principally been applied to support distance courses in computer science on the undergraduate level. Hence, it is possible for students from their home or office located off campus to attend lectures, take tests, receive feedback from instructors, participate in discussions, undertake team projects with classmates, and much more. Many universities have experimented and implemented ALNs in distance education and as well ALNs have been applied to near campus and on-campus education. [11-15]. Observations show that in a computer-meditated asynchronous learning environment the quality of education and student learning compare favorably to the face-to-face traditional classroom setting [16]. Observations also show that in a computer-mediated teaching and learning environment, there is an increased collaboration and interaction between students and students with their instructors, as compared to other classroom settings, which then results in an overall improvement in the educational experience of students. Because of these observations in distance learning settings, ALNs are being used in near campus education, for institutions with high commuter student populations to facilitate teaching and learning in on-campus face-to-face courses [17]. Several academic departments at NJIT are involved in developing courses and programs for distance education and incorporating the ALN format. For example, the CIS department, with financial support from the Sloan Foundation, has completed degrees for a B.A. in Information Systems (BAIS) and a B.S. in Computer Science (BSCS) delivered via an ALN format.

NJIT has developed an extensive computer network and academic computing system because of the different levels of expertise and wide-ranging needs for connectivity inherent in the diverse population of students, faculty and staff users within the university community. This system is designed to serve these populations in their classrooms, laboratories, offices, and residences, as well in the campus facilities such as learning centers and libraries. Additionally, the system

serves the needs for computing connectivity for students and faculty at off-Newark campus locations. All freshman students are provided with a personal computer (PC) and software via the NJIT PC Distribution Program. The PC Distribution Program has been in place for fourteen years. Currently freshman students receive a state-of-the-art PC with a Pentium MMX processor and CD-ROM. Students have use of their PCs while enrolled as undergraduates at NJIT.

The Implementation Plan

The three trusts of this initiative are, A. Integration of practical industry-based design projects throughout all four years of the curricula; B. Integration of computer-based technologies within the curricula to enhance course delivery and student learning; and C. Integration of professional skills development throughout the four years of the curricula. These thrusts are derived from proven innovations in engineering education reform previously implemented in smaller scale activities at NJIT. Implementation Plan is scheduled over a 4 to 5-year period. Discussed below are the operational plans for implementing and institutionalizing more design, technology and professionalism into the engineering education at NJIT.

A. Integration of practical industry-based design projects

Each year engineering departments will identify an engineering system or series of related design topical areas that would be a relevant focus of the undergraduate education of that entering class. The engineering system or series of related design topics will have the robustness

Table 1 - Civil Engineering Design Initiative

Year	Course No. and Title	Description of Design Problem	Design Course Description
1st	FED 101 Fundamentals in Engineering Design	Design module on appropriate topic area	
2nd	CE 210-Construction Engineering	Construction of a track to test the prototype car.	Sophomore Year Course: Design and Professionalism in Engineering, Course focusing on the design process and issues related to design projects of that year
	CE 200-Surveying	Layout of the test track on a piece of property	
3rd	CE 341-Soil Mechanics	Design of foundations for special roadways for electric cars	Junior Year Course: Design and Professionalism in Engineering, Course focusing on the design process and issues related to design projects of that year.
	CE 332-Structural Mechanics	Design of elevated dedicated roadway for the electric car	
	CE 350-Transportation	Design of roadways for electric vehicles	
	CE 320-Fluid Mechanics	Design of pipe network system to deliver natural gas to distribution stations	
4th	CE 494-CE Design I	Students select CE or inter-disciplinary design team and topic or project. Students prepare proposal for conduct of the design project and begin their design project.	CE 495: CE Design II (Capstone) Design Course- Continuation of the design project. Presentation of the final report.

sufficient to develop many design projects of various complexities suitable for students at all stages in their 4-year engineering education. The engineering design topics or system would evolve from industry sponsors in consultation with the faculty. Initially, the industry sponsors would be from members of the NCE industrial boards [5] or through several industry-based research centers at NJIT. The engineering system or topical design areas would be first introduced to students in the freshman FED courses through design modules developed and used in this course. As an illustration, civil engineering propose to initiate their design program with the topic, “to build a hybrid natural gas-electric car to reduce air pollution in the New Jersey area

in response to a Environmental Protection Agency mandate." The CE department proposes to embed design projects in selected courses throughout the curriculum. Added in the sophomore and junior years is a self-study practicum for students. This practicum will cover various subjects to assist the student teams in their design projects. As a consequence of increased design experiences in the curriculum the two-semester senior capstone sequence will be modified as discussed later in this paper. In Table 1 these CE courses are listed along with illustrative examples of design projects that could be undertaken by student teams in the courses.

The remaining engineering programs have identified an initial design topic area for implementation as well. Each of these engineering programs has defined curriculum courses that are to be modified to embed an extended or semester-long design project or a series of design experiments interactive within the course subjects. Students would work on the design projects in a team environment. In all cases student teams would be required to give an oral or written report of results. Each engineering program will develop a sophomore and junior-year disciplinary specific course to cover the design process and professionalism in engineering as well.

With design activities embedded into many core curricular courses of the majors, the first (fall) semester half of the senior year capstone course, which traditionally introduces students to the subjects, design process, report writing, and oral presentation techniques, can be modified. These subjects would have been covered in the sophomore and junior-year self-study design practicum. Now, in this first semester senior course students can select their design project and teams sooner and begin their projects. Also, since this initiative creates a coordinated college of engineering wide focus on design, student can more easily become a member of interdisciplinary design teams for their senior year capstone experience. In the second semester of the senior year, the design project work continues. With these modifications of the curricula, students will have extended time to work on a more comprehensive design project, which could include manufacturing and fabrication, in their senior year. Hence, design experiences can be increased in NJIT engineering curricula through this initiative without increases in credit load or time to graduation.

B. Integration of computer-based technologies

This thrust of the initiative focuses on planning and implementing the use of computer-based technologies to improve course delivery and student learning. Only one computer-based technique, the Asynchronous Learning Network (ALN), will be discussed. ALN is a computer-mediated communication system, consisting of a server and USENET-like discussion groups, where students post questions to the instructor and the class. The positive outcomes of ALN are to strengthen the students' computer skills, improve learning, participation, connectivity to real-world situations, and teamwork. From the NJIT perspective, the benefits of ALN will translate to better quality of graduates, reduction of attrition, and an active learning environment for all, including women and under-represented minorities. As noted earlier in this paper, each engineering curriculum will integrate an industry-based design project into designated course in the curriculum. ALNs will be used to support student communication and collaboration for these projects. They will also be used to facilitate out-of-class discussion on material introduced in the lecture class. On the premise that students learn better when they work in-groups, this initiative seeks to introduce more group design work into the curricula to improve student learning. NJIT being primarily a commuter school and one where most students hold a part-time or full-time job off campus, group work presents particularly difficult logistical problems. ALNs can help to overcome these problems by allowing students to communicate outside of class while working on their project. Each group will be assigned a unique ALN group for their own discussion that is not accessible to the rest of the class. They may ask questions and post designs and working documents for everyone in the group to access at times convenient for their personal schedules. One significant benefit of using ALNs, both for on-campus and commuter students, is that the previous postings are always available for review, thus serving as a readily available log of their discussions and past designs. In addition to supporting project work, ALNs will be used to support and improve the delivery of material in the lecture component of the class. There will be a whole-class group that can be accessed by all members of the class. Students may have on-line discussions of material presented in the class. Instructors can post additional examples for students to review. Students may provide signed or anonymous feedback to the instructor and the rest of the class to help identify topics that require more explanation. Instructors can post homework assignments and solutions to the discussion group. Below are illustrations of implementing ALNs in electrical engineering courses.

EE 231, EE 232 Circuits and Systems I&II are sophomore/junior-level introductory electrical engineering (EE) circuit design course taken by approximately 170 students each semester. This course will be redeveloped to facilitate an ALN mode of teaching and learning using the EIES™ systems for example. The course will continue to be offered with the traditional three hours per week of face-to-face instruction. The ALN component will be added to the

course to replace the recitation. As part of this effort, an on-line "chat room" will be implemented for students to discuss questions and seek assistance from each other on the course material or in other words, an on-line study group. All other engineering programs have identified courses in their curriculum in which computer-mediated and ALN modalities of course delivery would be implemented.

C. Integration of professional skills development

Employers continually provide positive comments on the quality of the science, mathematics, and engineering disciplinary education received by students at NJIT. However, they equally express that these same students could have better oral and written communication skills. This is not a deficiency limited to NJIT. On numerous occasions and at many forums employers have made similar comments of engineering education in general in the U.S. As well, employers say engineering graduates should have better leadership qualities and a greater understanding of societal and economic issues in the global workplace [1]. Additionally, employers say engineering graduates say graduates should have a strong commitment of ethical values [1], greater independence, self-confidence and maturity [18], a greater awareness of the total business enterprise [1], and better research and discovery skills for continual lifelong learning. This thrust of the initiative presents plans to integrate these attributes into engineering core courses such that these professional competencies and skills are developed within the context of the engineering curricula and the profession. The thrusts of design and technology are used as the vehicles to integrate more professional skills development into the engineering courses and the curricula. Figure 1 below illustrates that implementing both the design in the curricula and use of technology thrusts will impact all 8 core professional competencies, and the technical competency of engineering graduates at NJIT.

In the initiative there are several programs that will be implemented to achieve and sustain these proposed reforms in the engineering curricula at NJIT. These programs are, Engineering Writing and Professional Communication Centers, Design and Professionalism in Engineering Course, Student Portfolio Project, and Faculty Training Program. For brevity only the proposed year-long self-study *Design and Professionalism in Engineering Practicuum* will be discussed. The course material will begin by assembling hardcopy materials that the capstone design course teaching

Figure 1 - Integration of Design and Technology with Professional Core Competencies

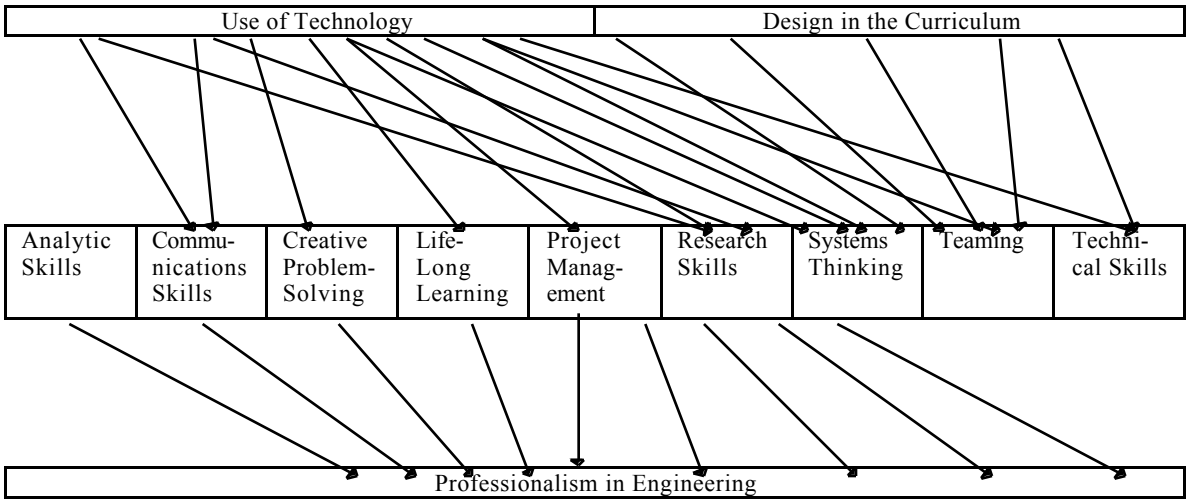

Table 2 - Curriculum Courses in the Initiative

Course	Title	D	C	Course	Title	D	C
Mec 235	Statics		1	ChE 221	Material Balance	1	1
Mec 236	Dynamics		2	ChE 232	ChE Thermodynamics I	1	1
EE 231	Circuits & Systems I	1	1	ChE 342	ChE Thermodynamics II	1	1
EE 232	Circuits & Systems II	1	1	ChE 363	Transport Operations I	2	2
EE 321	Signals & Noise	2	2	ChE 349	Kinetics&Design	2	2
EE 333	Circuits & Systems III	2	2	ChE 364	Transport Operations II	3	3

EE 413	Intro to EE Practice	3	3	ChE 367	Diffusional Systems	3	3
EE 415	EE Senior Project	3	3	ChE 471	Equilibrium Processes	3	3
CoE 328	Transmission Lines	2	2	ChE 472	Process&Plant Design	3	3
CoE 394	Digital Systems Lab	2	2	ME 304	Fluid Mechanics	1	1
CoE 485	CoE Design Lab	3	3	ME 316	Machnine Design	1	1
CoE 495	CoE Senior Project	3	3	ME 202	Elements of ME	1	1
CE 200	Surveying		1	ME 311	Thermodynamics I	2	2
CE 210	Construction Materials	1	1	ME 312	Thermodynamics II	2	2
CE 332	Structural Analysis	1	1	ME 403	ME Systems Design I	3	3
CE 320	Fluid Mechanics	2	2	ME 408	ME Systems Design II	3	3
CE 443	Foundation Design	2	2	ME 231	Kinematics	2	2
CE 494	CE Design I	3	3		Design Course	1	1
CE 495	CE Design II	3	3				

D-Design projects; **C**- Computer-mediation teaching and learning methodologies (ALN and/or IC)

faculty have assembled over the years on the design process (or stages of design) and other teaching materials on oral presentations, report writing, ethics in engineering profession and teaming. The materials on the stages of design would include: 1. Identification of the need, 2. Problem statement, 3. Design objective, goals and constraints, 4. Ideation – problem solving, and creativity, 5. Decision support design synthesis, 6. Detailed design – computer methods, optimization, 7. Prototyping, design for manufacturing, design communications, 8 Testing, marketing, refinement of solution. After the collection and assembling of these materials a hardcopy publication will be developed then an electronic publication for the Web will be done.

In Table 2 are listed the curricular core courses that are part of this systemic engineering education reform initiative. These courses will be modified to include design and/or the use of technology in the syllabuses. The column headed with an "C" indicated the course innovation will be in computer-mediation, and a column headed with a "D" means the curricular innovation with be design. The number 1, 2, or 3 indicates the year during the 3 to 4-year long initiative in which this course is scheduled to be modified. Over 30 NJIT faculty have been identified for participation in this initiative and to be involved in modifying the above courses.

Summary and Conclusion

The initiative proposes to make a systemic impact on the engineering curricula at NJIT. The focus is on improving the "soft" or professional skills development in the education of engineering students at NJIT. NJIT has developed 8 core skills or professional competencies students are expected to achieve. By integrating realistic design projects into the core course, teaching and learning will be in a more active environment and would have greater relevancy to the profession. The most basic psychology suggest that the process of learning would be best accomplished by "play the … (engineering) game" rather than a passive mode [19]. In this booming technological age, its use in education can not be ignored. As the future generations enter college much of their reading and learning will have taken place on a computer screen [20]. These students will be expecting that their teaching and learning will occur with the immediate availability of the rich resources of the Internet and World Wide Web. So by integrating communication technology and multimedia into the classroom NJIT would be in a position to serve these future populations. There will be a considerable number of senior faculty members participating in this project to ensure credibility. The courses involved are core to the curricula and will be offer regularly. This initiative at NJIT will be an exemplary model for systemic reform in engineering curricula.

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