# The Story of
# GATEWAY
# at Cooper Union

Progress in the process of creating a new engineer.
A summary of Cooper Union's participation in the
Gateway Engineering Education Coalition for the
years 1992-1999.

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## In a city of more than eight million people, Cooper Union stands for innovation and the individual voice:

- The school was founded in 1859 by Peter Cooper, a businessman, as one of the first colleges in the United States to offer full scholarships to all students. Cooper Union was an advocate for access to education long before public education became public policy.
- It was Peter Cooper's goal to provide both men and women of working-class families with an education equal to the best -- and thereby to develop talent that would otherwise have gone unnoticed.
- The first classes included the applied sciences, architectural drawing and art as well as training in photography, telegraphy, typewriting and shorthand. The latter served as the prototype for what is now known as continuing education.
- The school's Great Hall auditorium provided a national platform for a vital and varied menu of presentations -- educational lectures, political debate, social protest and the performing arts. Both the famous and the ordinary citizen found audiences eager to hear -- and to respond to -- what they had to say.

Over the years, Cooper Union continued to break new ground. Most recently, in 1987, it appointed as dean the first woman ever to serve as head of an engineering school. Five years later, it was only natural for such a school to embrace the proposal for educational reform at the core of the Gateway Engineering Education Coalition.

This report summarizes our enthusiastic participation in the Coalition during its first eight years, details our most outstanding achievements as Coalition partners, and outlines how we are positioned to carry the standard forward in the coming years.

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## Society Issues a Challenge as It Calls for a New Kind of Engineer

The physical body of our society has been created largely through the work of engineers. It is engineers who engage the properties of matter and the sources of energy in ways that are useful to the community and that help to promote its progress. It is engineers who develop the structures that protect and support us, the machines that work for us, the roads and waterways that ease our transportation.

Before the 1940's, engineers were technicians who created extraordinary structures such as the Brooklyn Bridge and the Hoover Dam. During the second World War, however, they had difficulty with projects such as the development of feedback controls on antiaircraft equipment, due to an insufficient background in science. Instead, physicists and mathematicians led the way.

Schools of engineering responded with an intense focus on mathematics and science to the exclusion of almost everything else. In the 1970's and 80's, however, industrial leaders began to ask for more. Engineers were now seen as having a vision that was much too narrow and technical, as being unable to function fully within the corporate and broader community. Lacking in human relations and communication skills, for example, they had difficulty in promoting their concepts, no matter how brilliant. The old model engineer was obsolete and the new model, inadequate; neither could provide the multidimensional skills required in a new economic age.

Today, the engineer must understand the context for his or her work -- not only the natural, physical environment but the political and social environments as well.  What will be the effect of each on the other as the work proceeds?  What are the forces of public opinion or law that will apply to what he or she is doing?  Who will approve the project, and what do they need to know or be persuaded of in order to support it?  With whom will the engineer need to collaborate, nationally or internationally, to develop the project successfully?

Today's engineer must be an enlightened and active participant in the community he serves as he plays a new and expanded role -- that of merging society's physical body with its intellectual and aesthetic sensibilities, its political and social considerations, into an integrated whole.

The challenge for the engineer in this new age is not to be a smarter scientist or more adept technician but a more fully realized individual.

The challenge to the schools that prepare this new professional is to achieve no less than a major paradigm shift in engineering education, one that redefines the culture of engineering.

## A Diversified Coalition of Schools Is Formed And Responds With the Gateway Revolution

Numerous studies by respected business and professional groups had identified the needs.

The new engineer must continue to possess a firm mastery of math and science as well as concepts of analysis and design.

In addition, he or she must also possess the following -- all new to the post-World War II engineering curriculum:

- Oral and written communication skills.
- Business acumen. An understanding of economics, marketing and organizational management, their relationship to one another and to engineering.
- Workplace leadership skills. The ability to work alone or in teams. Project management capabilities. Sensitivity to customer needs. A commitment to total quality management.
- A sense of professional ethics and legal responsibilities.
- An understanding of the intellectual breadth required to be both an engineering leader and a participant in the larger society. A grasp of the humanities, arts, politics, law and business beyond that which is scientifically or technically targeted.
- A sense of joy in learning and an appreciation of the need for lifelong learning.

Achieving all this would be a tall order. How could the scientific- and research-oriented curricula and the academic culture supporting them be changed to keep the best of the old while introducing the substantially new? How could a well-established scholastic tradition do a 180-degree turnaround from programs that are lecture-driven and teacher-centered to programs that are process-driven and student-centered?

As daunting a task as that might have seemed, it could be done, and it would. Encouraged and supported by the National Science Foundation (NSF) and the Accreditation Board for Engineering and Technology (ABET), ten schools of engineering formed the Gateway Engineering Education Coalition -- one of eight such coalitions nationwide -- to create a revolution.

The Coalition partners represented a wide diversity of institutional backgrounds. They were public and private, large and small, old and new. They were located in areas with large numbers of underrepresented minorities and a strong industrial presence, both factors essential to the project. Many were research-oriented. Some had connections with liberal arts programs. Some had already engaged in significant curriculum restructuring.

This rich mix assured that each Coalition partner would gain from the experience and special talents of the others, creating a fertile milieu for the development and testing of new programs.

# What the Coalition Faced: The State of Engineering Education In the Early 1990's

In 1991, the academic programs of the schools of engineering were highly traditional in content, structure and order. Most institutions provided a sequential or layered curriculum focused almost exclusively on science and math for at least two years before involving students in the subject of greatest interest to them -- engineering.

Design -- described here as the development of something that adds value to the economy -- was left as an activity for the third, or senior, year. Thus, for most of their educational program, students were engaged in focused, in-depth analysis rather than synthesis and creation.

With a few exceptions, little attention was paid to so-called "soft" subjects such as communication skills.

There was generally little help given in predicting the real world in which the student would ultimately practice or in anticipating and learning to manage career development issues.

Individual courses were rarely inter-related or grouped conceptually into a broader programmatic context. Except on an individual basis, there was little or no exchange or cross-fertilization between departments or colleges; to the contrary, these entities operated more like protectorates. Most curriculum development was confined to the updating of a special course, and student involvement was limited to making a few course selections.

The faculty role was seen as that of lecturer rather than coach or mentor, with little consideration given to the development of individual human potential.  Engineering faculty were rarely involved in the lower division aspects of their students' educational enterprise, even to consider fundamentals such as how students learn or how faculty could find new ways of teaching.  They were generally focused on the upper division courses in their disciplinary specialty and on disciplinary content rather than educational process.

In turn, the idea of faculty development was linked with new disciplinary research rather than the development of undergraduate educational initiatives.

Some analysts have likened the undergraduate program of the past to a hurdles race: students were presented with a set of obstacles to overcome at predetermined intervals until they reached the finish line. Evaluation meant periodic inspection of the student's mastery of exacting, detailed knowledge rather than analysis of the student's ability to apply principles to open-ended inquiry.

Unfortunately, this limited -- and limiting -- approach to the development of the professional engineer was not engaging.  It was making broad-based recruitment difficult and drop-out rates high, something the Coalition was pledging to reverse.

## Opening the Gates
## To the Future

The Coalition's goal is to open new gateways for learning -- and thereby gateways to the future -- through serious educational reform, a dramatic restructuring of the engineering education process.  This is a revolution to create systemic change, not a series of minor evolutionary adjustments, and it affects everything: content, structure and culture.

As a result of the Coalition project, undergraduate engineering education is changing its focus from course coverage to the development of the individual, from preparing the student for narrow technical training to preparing him or her to be a well-rounded professional.

To accomplish this mission, the Coalition is addressing a broad spectrum of issues:

- *The learning/teaching process.*  Examining how students learn and how faculty can find and adjust to utilizing new methods of teaching.
- *What is taught.*  Modifying the existing engineering curricula. Revising content and structure to meet new needs.
- *How it is taught.*  Changing and enhancing the instructional delivery system.  Developing new methods for making subject matter interesting and compelling, including the use of technology in advancing the educational process.
- *Institutionalization.*  Creating a catalytic effect for realistic implementation.  Assuring that new programs and methodologies that are successfully developed by the Coalition are fully assimilated by Coalition partners and promoted broadly to other schools of engineering.

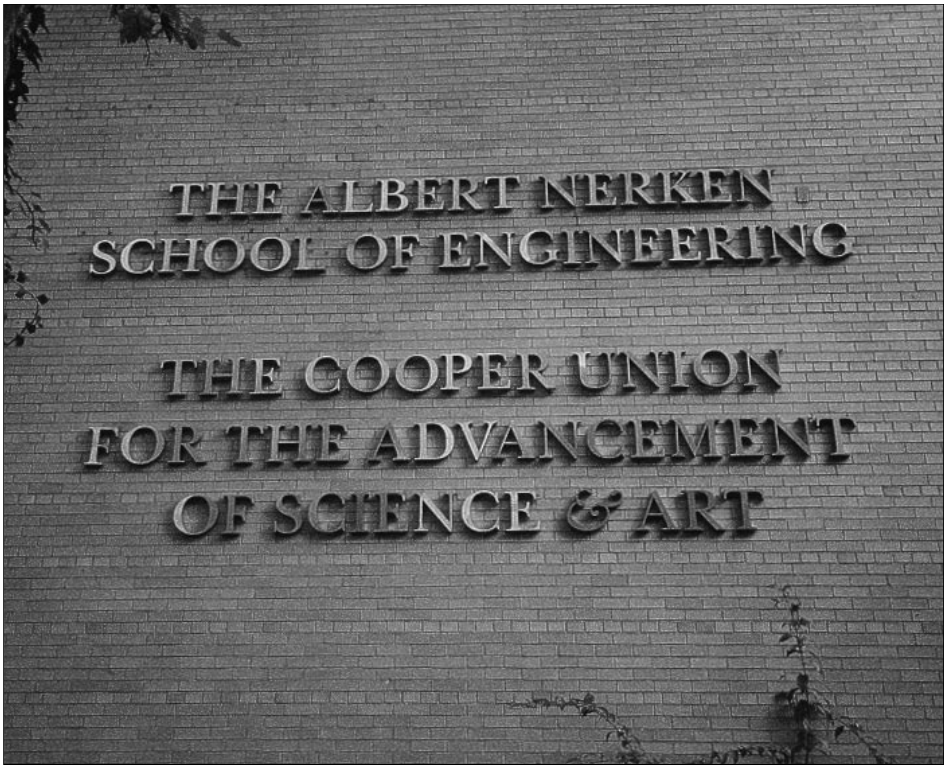
- *Keeping the pipeline full.* Developing effective methods of broad-based student recruitment and retention -- particularly among underrepresented populations -- to assure a steady supply of the best possible candidates for education and practice.

The Coalition initially created a framework for achieving its goal by identifying specific tasks in four areas of concern: Curriculum innovation and development, new educational technologies and methodologies, assessment and continuous quality improvement and human potential development. Coalition partners then accepted individual and collective responsibility for these tasks.

In general, the focus of the first five years has been on pilot studies to determine what kinds of engineering education experience reform should produce and on curriculum development. The final five years were to focus on implementation and institutionalization.

Individual institutions offered leadership in their areas of strength. In some cases, the partners enhanced and/or exchanged already existing programs that met the project guidelines. In the main, however, projects for change have been developed and implemented at one or several institutions.

Those found to be most successful initially have been and are being tested further at other schools. The best of these are currently in the process of being institutionalized at Coalition institutions and also promoted to other schools of engineering nationwide. All schools of engineering will be required to adopt similar educational reforms by the end of the year 2001. In that year, all accreditation reviews will be based on the new ABET 2000 criteria, which specify the competencies required for the new engineer.



# Cooper Union Shares the Vision And Contributes a Major Strength

## An Introduction to Cooper Union

The Cooper Union for the Advancement of Science and Art, established in 1859, is among the nation's oldest and most distinguished institutions of higher learning

The college occupies a special place in the history of American education. It is the only private, full-tuition scholarship college in the United States dedicated exclusively to preparing students for the professions of architecture, art and engineering.

Our history has prepared us well to be a Coalition partner.

More than 50 years ago, Cooper Union pioneered the development of project courses and of student teamwork. Today, the latter is one of the strengths of the curriculum and one of the reasons for student success in winning design competitions.

More than 25 years ago, the school experimented with the concept of competence-based education in engineering. The idea was ahead of its time, however, and the experiment was discontinued with a decline in funding. Despite this discouraging turn of events, the school retained a strong emphasis on the development of communication skills and problem-solving methodologies as well as the introduction of open-ended design problems at the freshman level. With the development of the Cooper Union Research Foundation (CURF), these skills were put to good use in real-world projects for industrial and consulting firms, government agencies and hospitals.

Building on a long institutional history of diversity, Cooper Union became the first college in the United States to prohibit discrimination on the basis of race, sex, religion and ethnic or national origin, which its engineering students reflect. Approximately 30% of a recent first-year class were women (nearly twice the national average); 46% were minorities (18% African-American, Latino-American or Native American and 28% Asian-American); and 47% were citizens who were not native-born.

Approximately one-half of the engineering students are from New York City, with one-third from the rest of the state and from New Jersey. The remaining percentage come from ten other states across the country.

Cooper Union believes that the value of an education is fully realized only in the leadership contributions of its graduates to the common good. With that as a foundation, the engineering school has been an enthusiastic partner in the Gateway Coalition since the Coalition's creation in 1992.

As a result of this collaboration, we have made great progress in changing our own academic content, structure and culture. We have also taken great pride in being able to share our individual strengths with others.

## Cooper Union as a Center For Engineering Design

The subject of design, which has assumed a position of central importance in current educational reform, is the academic area in which Cooper Union has made its most significant Gateway contribution.

Overall, our school has developed and/or collaborated on some 37 Gateway-related projects during the past seven years, some funded by the National Science Foundation and others partially or totally funded by Cooper Union. Of these, 13 were in the area of design -- projects that have both enhanced this school's signature strength and enabled us to share it.

In the last decade or so -- but particularly since the advent of Gateway at Cooper Union -- design has been in the forefront of curriculum reform here from the freshman level up. A recent article in the *Journal of Engineering Education* on freshman design shows Cooper freshmen to be exposed to at least four different methods, more than any other school.  The range extends from the redesign of local city projects to case studies to reverse engineering to creating something new and useful.

By the time they are seniors, Cooper Union students have been introduced to other methods as well, such as participation in various competitions or in small projects in collaboration with industry or non-profit organizations.

The school provides opportunities to develop, test and expand design concepts in contexts that are rarely offered elsewhere:

- Among the most daring of these have been our interdisciplinary project courses, including students and faculty from art, architecture and the humanities.  An example of this approach is found in **MYMUP**, Gateway's Multi-Year, Multi-University Project, now institutionalized as **Design, Illusion and Reality -- EID 111**, described on page 33.
- The Gateway **Concurrent Engineering** project, described on page 26, makes full use of Internet facilities, videoconferencing and face-to-face meetings among student teams at five Gateway schools.
- **GlobeTech,** another Gateway initiative, described on page 30, puts students at the cutting edge of international competition.  This project allows students to participate in international negotiation and project development simulations with student groups from schools spanning the world, including France, Hungary, Japan, Romania and Russia.

Cooper Union is currently revising its fundamental courses in engineering mechanics and fluid mechanics to bring analysis and synthesis more into balance as fundamental elements of the design loop, thus complementing theory with practice.

These various initiatives illustrate the comprehensive program in design education that our participation in the Gateway Engineering Education Coalition has made possible.

## Building the Cooper Union Comprehensive Program in Design Education

The pressure for educational reform in engineering began very quietly in the 1970's. Some educators believed that the function of engineering schools was to provide theoretical education and that industry should provide on-the-job training, with design as part of that training. Others believed that engineering education should form an integrated experience for preparing young professionals for full participation early in their careers.

To the first group, design was seen as unworthy of academic attention -- too empirical, diffuse and ill-defined -- and which, in any case, required a thorough analytical background. To the others, it appeared, in spite of its apparent lack of scientific basis, as one of the essential elements to which most of the competencies required for professional practice should be related. They also recognized that design as a process could be carried out at various levels of sophistication. It was in this spirit that, with support from the Mellon Foundation and the NSF, the nation's first competence-based program in engineering education was developed at Cooper Union.

Somewhat too radical for its day, that first program was withdrawn under the pressures of entrenched habits and fear of the different. It survived, however, in the freshman experience and remained as an inspiration that, in one form or another, has now found its way into the mainstream.

The rapid development of computer aided engineering in the 1980’s and 90’s engendered a concomitant interest in research on the design process. It also radically changed the practice of design, bringing it academic respectability.

It was in this general climate that ABET issued new criteria for engineering education outcomes and the work of the Gateway Coalition began at Cooper Union.

The Gateway program stimulated the development of the Cooper Union Comprehensive Program in Design Education -- built step by step on a foundation of existing expertise, in addition to the more classical design work that is part of the regular curriculum. All courses, workshops and projects are interdisciplinary in nature.

**Purposes**

The purposes of the comprehensive design program are to:

- Make design the central vehicle in engineering education in order to re-establish the historical balance of theory and practice.
- Blend design activities, the purpose of engineering, with analytical work, the indispensable feedback that checks and justifies the design.
- Use the design process as a paradigm for reasoned action and for the educational process itself so that students and teachers focus on “acting with knowledge” rather than simply “having access to knowledge.”

- Bring undergraduate design education to a high level of excellence.

### Philosophy

The development of this program has been based on a comprehensive and humanistic view of design. Reduced to its essentials, design is *the rearrangement of the elements of the environment for a purpose*. Given the fact that “environment” spans the gamut from the physical to the spiritual, design can be viewed as encompassing all thought-out human actions. Engineering design naturally has as its immediate focus a more restricted bandwidth but resonates in all spheres -- such as the biosphere and the spheres of society, business and technology.

Design is an integrative activity that not only balances theory and practice but also introduces ethics, communication, interpersonal skills and group dynamics. New developments in computer visualization, rapid prototyping and the integration of analytical softwares with computer-aided design now make possible the development of intuition, based not on the traditional mathematical linear models but on non-linear realistic models.

However, the ready availability and the sophistication of these computer models have their drawbacks. We agree with Sherry Turkle, a physicist at MIT, who says:

> *My students know more and more about computer reality, but less and less about the real world. And they no longer even really know about computer reality, because the simulations have become so complex that people don’t build them anymore. They just buy them and can’t get beneath the surface. If the assumptions behind some simulations were flawed, my students wouldn’t even know where or how to look for the problem.*[1]

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[1] Quoted by Robert Borgmann in *Holding On To Reality – The Nature of Information at the Turn of the Millennium,* Chicago University Press, 1999, p. 176.

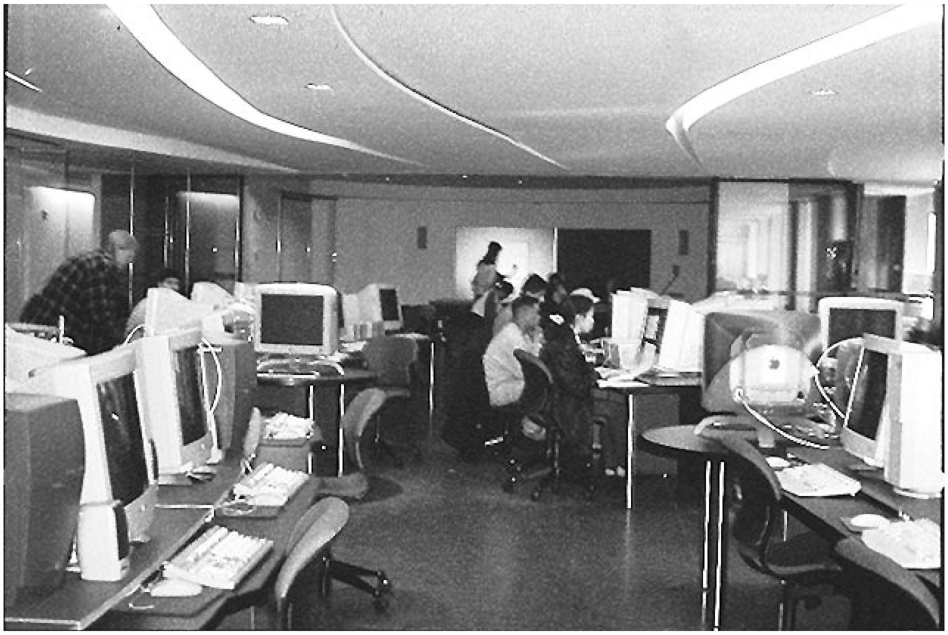
Unless the assumptions behind these models are tested experimentally in an actual physical situation, users are open to unforeseen and unforeseeable error.

We at Cooper Union have come to recognize the need to anchor students in the physical reality through their senses by means of prototyping, creating a physical model which demonstrates that the product is feasible and will work. Students are also engaged in actual experiments, material handling and other design exercises that lead them to see and touch directly and to discover for themselves what the equations and the models mean. As James Nasmyth, inventor of the steam hammer, said in his autobiography:

> *The truth is, that the eyes and fingers -- the bare fingers -- are the two principal inlets to sound practical instruction....No book knowledge can avail for that purpose....*

In the design projects described on pages 26-44, we show how, through rapid prototyping and simulation, the designer who conceives the product may also have his hand on the finished item.

We also show that, in the larger context of an interdisciplinary project such as **MYMUP**, students are led to see how designs generated in a certain milieu (intellectual, religious, affective, economic) come about; how they are shaped and conditioned by the values and myths of the peoples who conceived and realized them. The goal is to see not only how constraints (historical, geographical, social, technological) favored certain options rather than others, but also how some designs can transcend their origins and function in conditions that were never thought of by their designers.



This 3,000-square-foot, state-of-the-art design center will produce a new generation of engineers, able to work at the highest level of competence in design technologies.

## The Louis and Jeanette Brooks Engineering Design Center

Cooper Union has created new possibilities in the area of design education with the 1998 inauguration of the Brooks Engineering Design Center, a key component of the Cooper Union Comprehensive Program in Design Education.

The purpose of this center is to emphasize the centrality of design in engineering by providing a physical focus for that activity. This center is an industrial-strength facility making available the tools, information and services that students and faculty engaged in design projects or design research require at the point of need. Interdisciplinary in character, the center was conceived to create a synergy of powerful computers, good software and people: students, faculty, engineers from industry, business people, artists, architects and even poets.

In combination with the school's Forrest Wade Rapid Prototyping Laboratory, the Andrew Labowsky Sr. Materials Engineering Laboratory and the Acoustics Research Center, the design center emphasizes hands-on, real-life experience through the design and building of real products for real customers in conditions similar to those found in the best industrial practice. In combination with the Multimedia Presentation Room/Theater and the Gallery, it offers an opportunity to explore new dimensions of design.

This state-of-the-art facility has a dual mission: pedagogical and applications.

**The design center's pedagogical mission is to:**

- Produce a new generation of engineers trained in the latest design methodologies and able to work at the highest level of competence in technologies reflecting the needs of industry.
- Disseminate design methodologies and practice in the engineering curriculum through course development, workshops, symposia and projects.
- Engage students from their first year on in meaningful actual projects.
- Emphasize design as a social process involving communication, negotiation and collaboration as well as competition.
- Educate students to the usages of the "dialects" of the language of design, from textual statements to graphic representations to analytical models and their integration in the context of practice.

- Provide opportunities to conduct pedagogical research in the design process.
- Provide facilities for experimenting with new learning and teaching methodologies in all fields where a design approach can be applied, from the humanities and social sciences to science, engineering and art.
- Show design as “purposeful action,” not limited to producing machines, bridges, consumer goods, buildings and organizations, but equally applicable to rhetoric, poetry, the fine arts and the performing arts as well as the sciences.
- Foster the process of synthesis and conceptualization by bringing together for courses, projects and seminars scholars from disciplines within engineering as well as from outside disciplines such as art, architecture, social sciences, poetry, rhetoric, theater, computer science, mathematics, physics, chemistry, biology, film and video, emphasizing heuristic and metaphoric thinking.
- Provide pedagogical tools to bring about the seamless integration of conceptualization, analysis, communication, teamwork and production techniques -- as applicable to the theater as to engineering -- to introduce students to the idea of engineering design as a performing art.

**The applications mission is to:**

- Keep informed and current about design research worldwide.
- Validate, demonstrate and disseminate cross-disciplinary design methods and tools to academic and industrial partners by offering on-site and/or on-line workshops, symposia, lectures, demonstrations or exhibitions.
- Foster, in projects of common interest, the collaboration of disciplines participating in the design for manufacturing process (manufacturing, materials, systems, robotics) and the integration of new technologies, such as smart materials, in collaboration with industry or government agencies.

**Specific features of the Design Center include:**

- The design studio, where four clusters of seven workstations are connected to printers and a plotter. It is also visually integrated and networked with the Forrest Wade Rapid Prototyping Laboratory across the Gallery.
- Four design carrels, each equipped with table, chairs, a video-conferencing set, a monitor, and power and information terminals for laptops, can accommodate design groups of up to five or six people for design reviews or conferences. These carrels, acoustically isolated from the design studio, can be accessed from the studio or directly from the gallery. They also communicate with one another.
- The Mutimedia Presentation Room/Theater is an auditorium/lecture room able to accommodate 40 people comfortably. Fully equipped with cameras for videotaping presentations and audiovisual and computer facilities, it features high-resolution rear projection so that an adequate level of lighting may be maintained for the audience. Outlets for laptop computers are available in the center of the room under a floor tile. Walls can be used for projection from roll-in computer projectors or slide projectors, and a blue screen for chroma keying video can be unrolled from the ceiling.
- The Gallery can accommodate flat displays and has shelves and cases for three-dimensional objects. Glass walls allow for visibility of design activities. Also included are computer monitors and projectors, and projectors in the Gallery to showcase lab activities or exhibits. The Gallery includes benches for informal gathering of students, faculty and visitors.
- The Forrest Wade Rapid Prototyping Laboratory, visible across the Gallery, contains an industrial CNC Bridgeport Milling machine and a Unival Puma-762 Robot. It also features an Actua 2100 rapid prototyping machine that can directly produce wax or resin prototypes to be used either as

models for investment castings or for shape analysis. In addition, a Morgan-Press GT-100 injection molding machine, a Light Machines SpectraLight turning center, and a desktop Dyna 2200 milling machine allow for prototyping products designed in the Design Center.

## The Gateway Design Projects

Participation in the work of the Gateway Coalition has allowed Cooper Union to amplify, strengthen and diversify the design component of our curriculum and to create the Cooper Union Comprehensive Program in Design Education.

**Two projects, in particular, have achieved outstanding success in meeting Gateway criteria.** These projects demonstrate innovation in curriculum design and uses of technology to create a virtual teamwork experience for students, collaboration among faculty, and the sharing of resources among institutional participants:

**Concurrent Engineering and Manufacturing -- CID-U-04-OS**. A Gateway project developed by Ohio State, Cooper Union, Drexel, New Jersey Institute of Technology and the University of Pennsylvania.

The overall aim of this project, which was inaugurated in 1992, is to teach design methodology together with teamwork and human relations skills in both real and cybernetic environments. The team solves a concurrent engineering problem in a context of computer-aided engineering and manufacturing, replicating contemporary high technology industrial practice. Concurrent engineering involves the integration of design, manufacturing and marketing issues in the making of a product from conceptualization to finished prototype.

The project has two major objectives:

- Conduct a concurrent engineering project that involves teams of students at a number of schools.
- Develop a suite of course modules around which a concurrent engineering course can be built, combining engineering design, manufacturing and computer-aided analysis and applicable to various engineering disciplines. The modules include tutorials based on Authorware or other multimedia applications that support the concepts presented in more traditional ways.

Maintaining constant communication through Internet-based videoconferencing and other means, Cooper Union seniors collaborate with teams from four other schools in the design and manufacture of a product.

To achieve the first objective, the project creates a virtual campus in which senior-student teams from a number of universities share their expertise and resources in the design of a common model; one recent example was a wheelchair-mounted robotic manipulator to assist children with disabilities. The project problem is assigned and the students do the rest, learning the importance of interaction and cooperation to overcome communication and technical problems in developing the design.

The project is divided into two phases:

**Phase I.** Each team produces a conceptual design following a discussion of the scope and goals of the project, a report of market research and a set of common design criteria introduced at an initial meeting of all teams. The designs are critiqued by faculty and students and one is chosen at a second meeting.

**Phase II.** Each team takes responsibility for further analysis and manufacture of one part of the assigned device, employing, for instance, stereolithographic prototyping, in which a computer generates a wax model of the design that can then be cast in metal. At the end of the project all pieces must fit together.

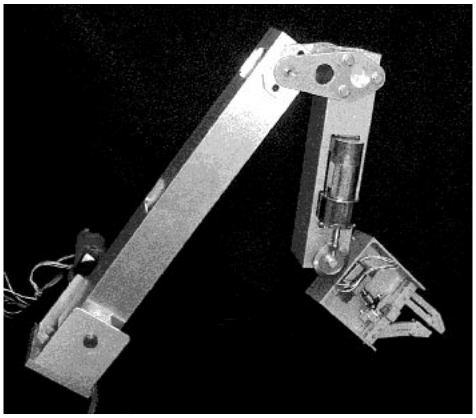
To maintain constant communication, the teams use a Mac-based software package for Internet-based videoconferencing; e-mail and fax for data and daily message transaction; and telephone conference calling for weekly group discussion.

Communication is highly organized. Individual team members meet assigned deadlines and report back to their team. A decision by one team is forwarded to the other teams for consultation and discussion. A designated liaison at each school sends and receives messages from the other teams and disseminates the information among his own teammates. Individual members keep written logs and the teams submit weekly progress reports to their advisors.

The teams are also participating in the development of 17 teaching modules. Each module consists of a manual, lecture viewgraphs and notes for the instructor; reading material and homework assignments for the students; and multimedia demonstration material that can be shown to the class to reinforce concepts.

Graduates of this project report extremely positive responses from job interviewers, who are impressed with the technical and communication expertise the graduates have gained.  The project has been institutionalized in project courses **ME 163, ME 164, ME 363 and ME 364.**

A recent Concurrent Engineering assignment produced a wheelchair-mounted robotic manipulator to assist children with disabilities, to be attached in front of the right arm rest.



One of several designs considered during project development.

**GlobeTech/Global Perspectives in Technology Management -- EID 372.**  This simulation, though not strictly speaking a design course, is included here because its main purpose is to develop abilities that are crucial for designers and entrepreneurs.

By working on clearly defined projects in multi-university international teams via the Internet, the GlobeTech simulation aims to:

- Enhance students’ global technology and management skills.
- Increase their social, political, cultural and economic awareness of the environments in the countries or world areas discussed.
- Increase their awareness of sustainable development and environmental issues by choosing projects related to these subjects.

- Create a stimulating work and study environment based on collaboration and competition between students from various domestic and foreign teams. Participants have come from countries as diversified as France, Japan, Hungary, Romania and Russia as well as the United Sates.
- Improve students' communication, teamwork, leadership and negotiating skills through proposal writing, negotiating and finalization of contract awards.
- Improve their familiarity with the use of the Internet, the information superhighway and other modern means of communication, to do research and communicate effectively long-distance.

To develop the above competencies, the GlobeTech project has been structured to be completed in an eight-week interval, starting each year in the middle of October and finishing in the middle of December. The major activities are as follows:

- Student teams develop requests for proposals (RFP's) and proposals for international joint venture projects based on given scenarios. The work involves:
  - Researching political and technological conditions in one or several countries.
  - Getting in touch with various equipment and engineering services vendors to obtain price and technology information.
  - Finalizing the processes and equipment to be used as well as project costs.
  - Writing complete, professional-level RFP's and proposals.
- The RFP's and proposals are thoroughly discussed and negotiated via the Internet and teleconferences by the various participating teams, and contracts are awarded to the best proposals overall.

- Students and faculty have the opportunity to participate, via the Internet, in the project feedback process, to discuss the positive and negative aspects of each team's participation.
- Recent projects have involved measuring and controlling air pollution at a Russian power plant; measuring air pollution on the German autobahn and proposing remedial solutions; design and fabrication of 100 fuel-cell-powered taxis annually for the Los Angeles Fuel Cell Corporation; consulting, design, testing and final assembly in South Africa of 100 mobile health vans equipped with photovoltaic electric generation systems for use in rural areas.

The GlobeTech project aims to prepare all participating students for a real world of multiple teams, located in various parts of the world, working together, focused on resolving common issues and implementing projects.

A GlobeTech team competes and collaborates with students in other countries as they research, write proposals, negotiate and finalize contracts for an international project.

By its nature, the GlobeTech concept is extremely flexible and can be used effectively to enhance students' practical knowledge in many areas. One of our main goals is to develop the students' managerial skills, bringing them to the same level of excellence as their technical skills. As the global marketplace becomes increasingly competitive in quality and price, projects such as this one will position U.S. engineers for leadership in project management.

**The course Global Perspectives in Technology Management -- EID 371,** which uses GlobeTech as its project component, has now been made available on the Web so that students participating in the simulation anywhere can have access to the course material.

## Additional Gateway projects of the Cooper Union Comprehensive Program in Design Education:

**Engineering Design and Problem Solving -- EID 101.** A course taken by all engineering freshmen that introduces them to graphics, computer graphics and the process of design. Design is presented as a process applicable to a broad range of activities, from the design of a technical solution for a vaguely formulated situation to the design of a written report or the design of an oral presentation for a particular audience. The approach is experiential; students learn the process by going through it. Projects chosen vary from year to year, though the theme remains constant: "Engineering Design in the Urban Environment."

The projects are general enough to be approached with the sort of knowledge a freshman may be expected to have, and specific enough to help them focus on a particular topic. Past topics have included "Gridlock in Manhattan," "Solid Waste Disposal in the City," "Redesign of a Subway Station," and "Redesign of a Pier on the Hudson River." The idea is less to come up with *the* solution -- or even a *particular* solution or group of solutions -- but rather to let students grapple with the many dimensions of technical problems.

Coming as close as it can to professional practice at this level, the course confronts students with engineering in the social, political and ecological context of the city, and therefore with concerns of professionalism, ethics and social awareness. They work directly with city agency engineers, architects and other experts. Throughout, emphasis is put on initiative; group work; interpersonal skills; communication in graphic, written and oral forms; and a realistic approach to problem solving. Each section of the course is taught by an engineering instructor assisted by an oral communication coach, writing tutor and graphic design instructor, with a liaison engineer from a city agency coordinating their work externally. Extensive use is made of videotaping in presentations.

A Web site contains information made available for the course and each student group maintains a sub-Web site to archive its work and to centralize communication between members.

**Principles of Design -- EID 103.** A new elective for freshmen combines reverse engineering with the creation of a simple device. In reverse engineering an object -- such as a floppy disk drive, a toy robotic arm or computer mouse -- is dissected and the components as well as the assembly are analyzed, sketched and discussed.

For the first five weeks of the project, student teams discuss the rationale for selected materials, components operations, dimensions, manufacturing, repair replacement, modification, patents, economics of production, marketing and recycling. They keep a journal, report their findings orally and in writing, and prepare a short video demonstration. Over the next 10 weeks, they design a simple product, such as a dish rack or bicycle rack, making use of what they have learned. The product must be embodied in a prototype of 10 pieces or less and the presentation must include a patent search and a marketing plan.

**Design, Illusion and Reality -- EID 111.** An elective course given to students of engineering, art and architecture, which was strengthened and amplified through MYMUP, Gateway’s Multi-Year, Multi-University Project. The participation of architecture students and faculty from Florida International University as well as humanities students and faculty from Polytechnic University in common projects has enlarged the concept of design to which students are exposed. Group projects such as “The Intersection of the Future” emphasize the interplay among ideas, concepts and values on one hand and the appearance of the design on the other. The projects aim at being vivid demonstrations of how design brings illusion and reality together; how illusion, however conceived, shapes reality, however experienced; and how that reality in turn contributes to reshaping the illusion in a constant interplay -- design becoming the stimulator, the moderator, the revealer, the resolver, the means to an end.

**Redesigning in Practice.** The goal of this project is to develop, in collaboration with industry, case studies involving interdisciplinary groups of students working together on product redesign. Initiated as a Gateway project in the spring of 1999, "Redesigning in Practice" was so successful that it was institutionalized as **Product Design -- ME 425** after its first term.

Projects are solicited from industry during the fall term. The products to be redesigned have included biomedical instruments, cell phones and industrial scanners. In the case of the cell phone, there was a problem with heat in operation, which reduced the phone's performance and eventually made it uncomfortable to handle. The biomedical instrument presented problems with aseptic sealing. The scanner's performance was considerably reduced by environmental noise.

Students work in groups and communicate with the client through a company liaison engineer. They meet in person; visit the plant; keep in touch via e-mail, telephone, and/or videoconferencing conferencing; and develop a Web site. Under the guidance of the instructor, students are encouraged to begin prototyping from the start. It is not that the entire design needs to be prototyped at once but, rather, elements of it -- the innovative parts using breadboard, hardware, simulation and other methods. This hands-on approach should continue throughout the project.

Prototyping, testing and working with physical models is an effective way of enhancing the engineering culture of students and heightening their interest and involvement. Prototyping is recognized in industry as an essential element in reducing the design time and time-to-market of a product and may be one of the most valuable core competencies a student can develop.

The pace of this course is intense, and parallels industrial practice. Students hold design reviews with the client, make a final videotaped presentation to the client and submit a final written report, together with a prototype, to the instructor.

**Assessing Communication Modes in Students' Engineering Design Projects.** This project is an educational research faculty project. The goal is to develop a model or protocol to assess the effectiveness of the various modes of communication used by students in the elaboration of a group design project.

In the course of an engineering design project a group of students, under the guidance of a faculty member, develops a prototype for a client. In order to maximize the academic profit that students derive from this work, we propose to identify the sources of information students rely on (previous courses, hearsay from friends and acquaintances that leads to books, people, Web sites and other sources), identify the recipients of the information, the types of information obtained, retained or transformed, the decisions and actions taken, the agents deciding and/or taking action, the means of action used for implementation and the constraints bearing on each step.

Questionnaires are used to facilitate tracing sources and information flow. A second, more objective, method makes use of a Web-supported information system including Web page, notebooks, e-mail, personal notes and minutes of meetings. Communication is automatically archived and organized by a HyperMail utility on the Web to function as a cumulative team and curriculum memory.

Concerning the means of communication used, questions of interest include: What means of communication are most commonly employed by the students, their advisors, and clients (formal meetings, informal meetings, written memos, e-mail, chance encounters in the halls, going to libraries, surfing the Web, frequenting exhibitions)? What is each one's "effectiveness" (the number of good ideas or useful tips in the development of the project)? Which contributed most? Which were crucial? Which were useless and clogged up the pipes?

A project in which five students develop a robot for theatrical performances has provided a fertile field for this investigation. It involves the engineering fields of robotics as well as electrical, mechanical and controls engineering, from initial concepts to physical implementation. It also involves theatrical considerations such as performance quality, stage design, coordination with live actors and remote operators, and impact on viewers. Many worlds co-existing, sometimes touching and even intersecting; sometimes remote from one another, but in need of connecting. Through whom? Through what? How?

**Environmental Design/Manufacturing Management.** This project is in development. The goal is to create a senior design project course (case studies/modules) to train engineering students in designing products, processes and systems while balancing industrial manufacturing activities with environmental stewardship. The idea is to establish for the students an intellectual framework through which they can become familiar with concepts of “green design” and sustainability in an economic and regulatory context.

The idea is not new, and we have talked about this in various ways in the past. More than two decades ago, Barry Commoner in “The Closing Circle” advocated a redesign of technologies to alleviate the environmental load created by then-new developments -- such as the substitution of aluminum for wood in construction and of plastics for glass in containers -- which greatly increased energy and raw material utilization and stressed the environment. With the continuous deterioration of the environment due to this more intense mode of production and the extension of industrialization (particularly in developing countries), the time is now more than ripe for action.

One can think of many areas of manufacturing, processing and construction in which students could work together on projects involving a fundamental re-thinking of the way activities are carried out so as to de-stress or repair the environment. Note that in this area, in particular, changes in technical design often depend on changes in the regulatory and legal fields, so the solution envisioned should be very attuned to these fields.

The NSF-supported graduate programs being developed at Clarkson University could serve as a philosophical template for this project. The project would consist of the development of senior- and advanced-level design projects (case studies/modules/labs) which could be used in courses calling for the participation of students from ChE, CE and ME working together on a design problem, preferably with industry participation. In the future, this effort might lead to developing an option at the master's level.

**Tools and Techniques of Design Workshop.** Introduced in the fall of 1999.

It is well documented that the initial design phase is critical to the development of any design project. The earlier a decision is taken, the more expensive it is to try to correct its consequences further down the line. With present pressures to decrease time-to-market for products as well as the design-cycle time itself, it is essential to let this initial phase be fluid and to experiment with as many alternatives as possible in the shortest time possible before firming up the design. This approach enables designers to do fast computer modeling and to build mockups, physical models and prototypes to rapidly test alternatives before they settle on the most promising ones. In the present state of our technologies, this requires a familiarity with certain tools and techniques of design.

Among these tools and techniques are a set of rather complex computer packages such as Pro-Engineer, SolidWorks, Adam, Catia, Algor and others, as well as the workshop practices necessary to build mockups, models and prototypes.

Although students are expected to be able to pick up these skills on their own, curriculum pressures and other factors render the task unrealistic in most cases. Students spend either an inordinate amount of time mastering these techniques -- and they are not passed along systematically -- or they learn the bare minimum compatible with their particular project. In any case, they do not enjoy the freedom they need to experiment with alternatives. A mismatch exists between the potential available to the students in the Design Center and the benefit they can reap out of it. The result is that the quality of their education and the quality of their projects suffer.

A workshop to provide students with a systematic understanding and mastery will run for 6 to 10 three-hour sessions in the fall term each year. It will carry no academic credit but will require a firm commitment on the part of the student and the permission of the instructor.

The program was initiated in the fall of 1999 with a workshop on FreeForm, a 3-D digital tool that emulates physical sculpting but offers additional techniques not possible in real clay -- for conceptual modeling design and animation.

**The Engineering of Nature; Constructals.** This project is a work in progress, to be implemented in the spring of 2000. More than 30 students are currently registered for this course.

There is much that engineers, architects and artists can learn through a study of nature. It is evident that organisms in nature (animals, trees, even rivers) have a spatial and temporal organization and that these organizations serve functions, however defined and from whatever viewpoint. Any such naturally organized systems, living and not living -- any particular arrangement of elements in space and time *that serves a function* -- constitutes a “design.” Indeed, as science probes deeper into the molecular constituents of life, whole arrays of molecular engines, similar from organism to organism, are seen. At the macroscopic level, there are obvious similarities between networks visible in tree branches, roots, leaves, lungs, vascularized tissues, dendrites in rapid solidification, axonal arbors, river basins, deltas, lightnings, streets and other paths of telecommunication. Even in temporal organizations, similarities in the finely tuned frequencies of respiration, circulation, and pulsating and meandering flows are apparent.

Understanding how nature is engineered can help to determine how a shape occurs and how a structure develops. It can also stimulate the imagination of would-be designers and teach them observation, extrapolation, adaptation, flexibility, simplicity, ingenuity, humility and other qualities that make for a good designer.

A world of naturally developed forms opens up. The lines between engineering, architecture, science and sculpture fade without these activities losing their integrity.  New construction methods simulating natural processes may be suggested.  Structures may be “grown” rather than “constructed.”

The course will have three modules: descriptive, theoretical and a project.  Participation in a project will be required of all students, while the descriptive or theoretical modules will be at the student’s choice. Modules for in-depth study will be available in written and video forms. However, surveys and lectures about the material in the descriptive and theoretical modules will be of a level accessible to all students and will be required of all students, so that a common language and a basic understanding can be established in all participants.

Principles of design can be abstracted and applied to various projects through a survey and description with direct lab observation and experimentation.  A firm theoretical background can be established through study and research in the modeling of these systems as presented in Adrian Bejan’s book “Advanced Engineering Thermodynamics” and his numerous articles.  On that basis, projects can be developed for designing optimal “natural structures.”

**Fluid Mechanics and Engineering Mechanics in Design: The Pilot Interdisciplinary Studio/Classrooms.**  This project is in development. Proposals to foundations have been prepared for funding the equipment acquisition and space renovation required for implementation of the curricular changes being described here.

The idea for this pilot interdisciplinary studio/classroom came out of discussions by a group of faculty from ChE, CE and ME regarding the revamping of our **Fluid Mechanics -- ESC 140** course in the context of design education.

Part of the faculty concern was to bring analysis and synthesis more into balance with each other as fundamental elements of the design loop. The idea is that theory does not appear as an entity born full-blown out of the blue. Rather it develops out of experiments and observations in the laboratory and in the field, which are fed back, through analysis, in the design process.

Although full-scale fluid mechanics experiments can be (and indeed are) carried out in our three departments in more advanced courses, there is presently no lab in the basic course ESC 140. The scale of the equipment, the physical set-up of the labs and their dispersion in the building make it impractical to use them for hands-on experiments or even demonstrations in an introductory course.

The curriculum development work now under way will:

- Modularize the common core in those courses and present it in a design context. Through examples, students will learn how analysis is used in the design process as feedback to modify and optimize the work of synthesis interactively as the design proceeds; how, in fact, analysis is a most powerful design tool rather than being opposed to design, as is often thought.
- Experiment with the design of methodologies best adapted to teach this material most effectively. This will be done in a setting that allows for the use of audiovisual and computer presentation as well as hands-on desktop experiments that can be performed during class time or assigned as homework, and experiments to be performed outside class time by students under the supervision of a teaching assistant.

- Make this material exportable to other schools, so the material is easily accessible not only to Cooper Union students but to students worldwide.

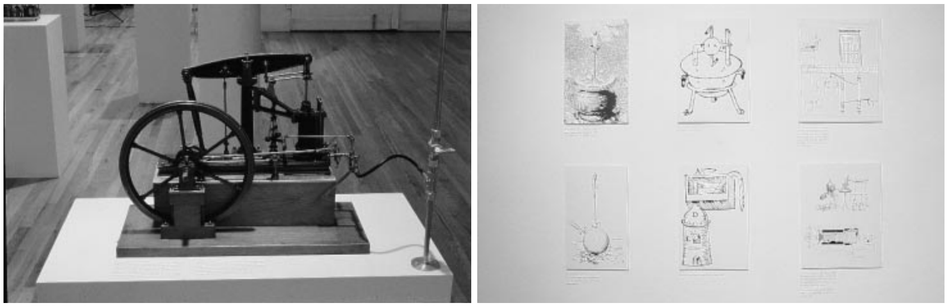
The same applies to **Engineering Mechanics -- ESC 100,** taken by CE, Me and EE students. The adjacency of the Brooks Engineering Design Center equipped with software packages related to fluid mechanics, engineering mechanics and design topics will contribute to the integration of the course into the design sequence.

**Engineering Design in Context.** To show students the importance of the interrelationship of physics, mathematics, engineering science, materials, experiment design, synthesis and analysis. To illustrate, we prepared a text and CD-ROM on “Leonardo da Vinci and His Flying Machine.” In it, we show that, despite all his genius -- before Galileo and Newton, before modern physics, material science or fluid mechanics, before concepts such as mass, force, work, power, lift and thrust -- Leonardo could not have succeeded. It is an interesting, and amusing, yet sobering, lesson.

In order to reach a wider audience, we included this CD-ROM in exhibitions of flying machine models constructed from Leonardo’s notes and sketches and built by students at New York City Technical College, under the direction of Professor John Razukas. The exhibit took place at the library of the college and at the gallery of the Brooklyn Union Gas Company at Metrotech in Brooklyn, New York, the latter featured in the local media.

We have also developed other, most extensive exhibits. For instance, in conjunction with the gift of a collection of steam engine models received from a Cooper alumnus, we recently organized an exhibition of these models at the Electrokinetics Gallery on Lafayette Street in New York City, under the auspices of the American Society of Mechanical Engineers (ASME) and the Science and Technology Mission of the French Embassy in Washington, DC.

The Cooper Union exhibition “On the Motive Power of Fire” explored the development of early steam engines in their historical, technological and social contexts.



The exhibit featured working models of early steam engines, now housed in the Gallery of the Design Center.

The exhibit originated in the course “Design, Illusion and Reality,” discussed on page 33. This is a project course, bringing together students and faculty from engineering, humanities, science, art and architecture. The project topic changes from year to year, but the format remains essentially the same and features an exhibit and an external critique at the end of the course. Professional engineers, artists, art critics, humanists and others who have not participated in the project itself are invited to critique the students’ work. The exhibits with real potential are then professionally developed and presented to the public. This is the second time that such a public exhibition has taken place in this course.

The aim of the course in this instance was to document a case study of the early steam engine and its impacts on the economic, cultural, and intellectual life of the period.

The focus of the exhibit was a celebration of the 300th anniversary of the conception of the first industrial steam engine by Thomas Newcomen in 1698, and of the 200th anniversary of the birth of Sadi Carnot in 1796, the founder of thermodynamics and author of the famous treatise “On the Motive Power of Fire,” which gave the exhibition its title.

The exhibit illustrated how, from first concepts and many experiments, trials, failures and serendipity, a working engine eventually emerged; how it was later refined and developed by James Watt; and how it was finally abstracted by Carnot, who in so doing opened the gate not only to better design for heat engines, but revolutionized science and philosophy and completely changed our view of the world.

On the occasion of the exhibit, we prepared a fully illustrated *catalogue raisonné*, which unfortunately could not be ready for the exhibit itself, but will be published in the near future. The text and the illustrations blend the history of engineering design in its technological as well as cultural and social contexts -- the relationships between design, science, art, philosophy and the state of technological development. The abundance of illustrations, the details of the captions, the specificity of the footnotes and the broad sweep of the text should make it appealing to a wide and varied audience.

The book has the potential to interest many, and will give visibility to the work of the Coalition in marrying design, engineering science, the humanities and the arts. It will show engineering students and engineers the humanistic and philosophical implications of their work, to which they rarely pay attention. It will also show non-engineers not only the contribution that engineers have made to material and economic conditions, but also how, through the means of a most grubby contraption such as the early steam engine, a few engineering men of genius and a multitude of anonymous mechanics revolutionized the world and our view of it, from art to philosophy to science.

Development of the CD-ROM is now close to being finished. This highly interactive CD-ROM will let the viewer:

- See alchemists at work and 19th century entrepreneurs in action.
- Explore the quaint representations of Newcomen’s engines.
- Learn how the genius of Carnot applied scientific principles to explain the operations of all heat engines and to open the field to a whole new way of looking at the world.
- Enter an animated environment where one can see and operate working models of early steam engines, from James Watt’s machines to Victorian-era locomotives.
- Explore some design features of the model engines.

Models are described in detail, including the principles of how they work. We believe it will be a product that will reflect favorably on the Gateway Coalition’s work and its concerns in integrating engineering with the humanities.

> The foregoing examples of interdisciplinary design activities at Cooper Union, undertaken under the aegis of the Gateway Engineering Education Coalition, show the diversity, richness and depth of our effort. Many of these projects are at the forefront of development in design education in the United States.

### An Additional Gateway Project of Special Note:

**Virtual Soil Mechanics Laboratory -- ETM-11-CU2.** This virtual soil mechanics lab is a sophisticated, online, interactive Web-based software package that gives a virtual tour of Cooper Union’s real-world soil mechanics lab and demonstrates the fundamental experiments that all undergraduate Civil Engineering students must understand. Its purpose is not to substitute for the real lab but to complement it.

Developed and continuously updated by a team of faculty, undergraduate and graduate students, the program incorporates video and audio explanations, photos, 3-D designs and other illustrations, cues and prompts to assist the student in understanding the material. It currently includes demonstrations of 11 experiments along with data files on the soils being analyzed.

The experiments include the following:

1. Soil sample preparation. Takes the soil and breaks it down into various gradations for use in experiments 2-5.
2. Specific gravity determination. Obtains the specific gravity of the sample.
3. Grain size distribution analysis. Grades the soil's grain size distribution using mechanical sieves, hydrometers and sedimentation techniques.
4. Liquid and plastic limits of soil. Determines consistency limits to ascertain the presence or absence of clay in the sample.
5. Compaction. Determines the relationship between moisture content and density in the sample.
6. Constant head permeability test.
7. Variable head permeability test. These two tests determine the permeability of the soil; that is, how fast water would be able to flow through it. Test #6 is used for granular soils and test #7 for fine-grain soils such as clay or soot.
8. Consolidation. Performed on clay soil to estimate how much a structure built on this soil will settle due to loads.
9. Direct shear test of cohesionless soil.
10. Unconfined compression test.
11. Triaxial compression test of cohesionless soil. Tests #9-11 determine the strength properties of the soil.

The first five experiments form the basis for a class project in which teams of three or four students analyze soil samples as subgrade, or the foundation for a flexible pavement, which they then design. The students submit a written technical report and make an oral presentation of their findings and design, the latter of which is critiqued by a senior engineering consultant from industry.

The second six experiments do not require a written report. Instead, students hand in completed data sheets, sample calculations and pertinent graphs to demonstrate their understanding of how to process the data.

This virtual lab enriches the students' learning experience by making more information available in more interesting form, when and where the student needs it. Students can view the experiments and do the calculations from any computer with access to the Internet, making the material easily accessible not only to Cooper Union students but to students worldwide.

The lab facilitates work with a saving function that makes it unnecessary to re-enter data and an exporting function that precludes having to copy anything down; data can be transported directly from the site to a plotting program.

The virtual soil mechanics lab is regularly updated based on input from users. An extensive assessment process surveys students to determine the degree to which they feel the team has developed *specific knowledge, skill and ability* during the first five experiments.

Each student also evaluates *how effective the lab has been for accomplishing the goals of the course.* They rate the lab for five characteristics or features applied to each experiment: understanding the objective of the experiment and how to carry it out; ease of choosing and using apparatus and making and applying calculations; and usefulness of resources. The students are also asked to make specific suggestions for improvements they would like to see.

A survey taken in the spring of 1999 shows that 77% of the students rated the usefulness of the lab a four or five overall on a scale of one to five.  Scores lower than four for any feature of any experiment were targeted for further evaluation and appropriate adaptation.

## The Assessment Program

### Establishing the Process

The purpose of the assessment program is to assure that the educational process is fulfilling its promise to students -- to engage them in a stimulating, experiential learning process that prepares them fully to take their place in the job market and develop successful professional careers. The focus of the assessment program is on the student learning and on how the program can help the student to learn more effectively. Although assessment may be focused on classroom activities, it can be implemented at different levels (course, department, school wide), and it reaches a full potential when is fully institutionalized around a set of clearly defined institutional, program, and course objectives and outcomes. When assessment serves the goal of institutional strategic planning, it becomes an effective Continuous Quality Improvement strategy that contributes to the achievement of the institutional vision and mission.

Gateway support and expertise have been critical in the development and institutionalization of an increasingly comprehensive Assessment Program at the Cooper Union School of Engineering. Cooper pioneered some 25 years ago the implementation of assessment into engineering education, but the program was ahead of its time then, and did not prosper. Just before Gateway started in 1992, a few assessment practices were in place at Cooper, mainly procedures conducted at the institutional level with little effect within the classroom. Gateway's vision and implementation strategies established the initial impetus and provided continued support for a process that at Cooper developed gradually in several steps:

- Assessment of Gateway projects.
- Assessment of courses.
- Extension of assessment to other courses and programs outside of Gateway.
- Preparation of departmental assessment plans.
- Preparation of schoolwide assessment plans.

The program was introduced by the local evaluator on a one-to-one basis and started with a few Gateway projects (Figure 1, page 50). The evaluator spent time with each faculty member explaining the value of the assessment program, illustrating how it would work, describing his role as special resource and facilitator, and gaining trust. Without faculty involvement no assessment process can develop successfully. The program development strategy was to present assessment as useful for the pedagogical work of engineering faculty and to extend it to courses and programs whenever possible. In order to do that, an effort was made to customize a set of the ABET criteria with the interests and needs of specific courses and projects. Faculty could this way see assessment as a tool of their own, rather than a strategy to monitor their work, and began to participate.

Engaging faculty in assessment often required continued explanation of the process at each of the implementation levels (planning, data gathering, feedback). The institutional commitment to the process by the Dean of Engineering and the Gateway Institutional Activities Leader were critical for advancing our goals. Also important was the collaboration of the department chairmen who, in different degrees, contributed to the acceptance and development of assessment procedures by faculty within their own departments. The Civil and Mechanical Engineering departments started early. The Electrical and Chemical Engineering departments followed.

Since the assessment program developed simultaneously at different levels (institutional, program and classroom), the results created a multiplier effect that gave impetus to the whole process. Assessments being done within the classroom had an effect on the ongoing departmental assessment plans, and the lessons learned in implementing these plans were used for developing schoolwide assessments.

Today, the assessment program develops vigorously toward institutionalization. The feedback process (Figure 2, page 51) is designed to involve in various degrees all parties in the Cooper community (administration, faculty, staff, students, alumni and employers) and

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The Cooper Union for the Advancement of Science and Art

# The Process of Assessment of Courses

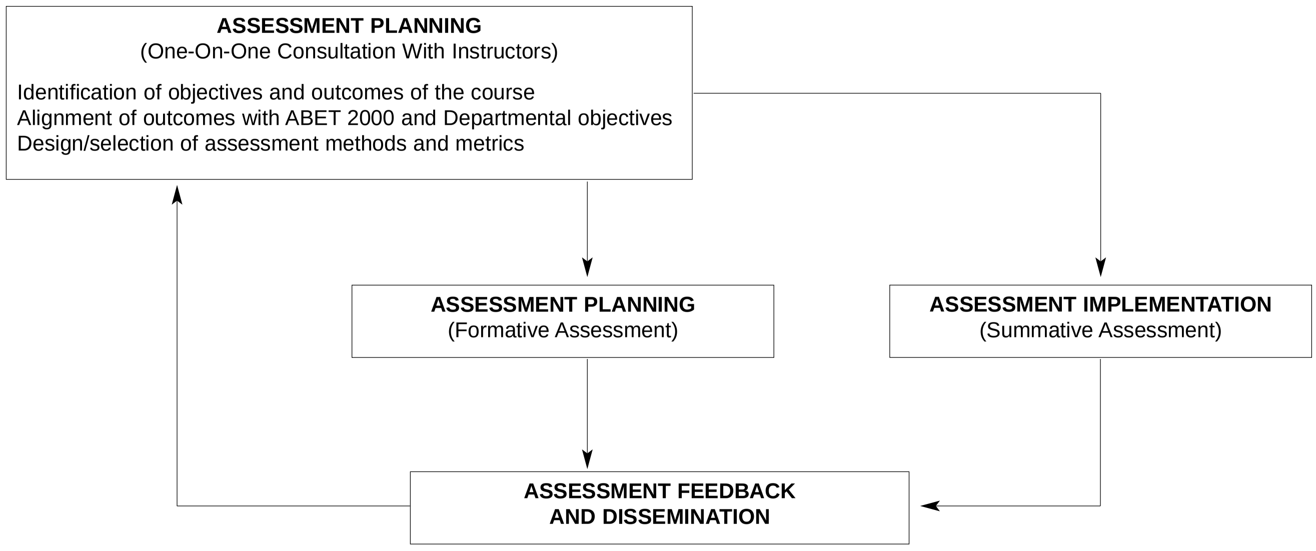

Figure 1

The Albert Nerken School of Engineering
The Cooper Union for the Advancement of Science and Art

# Assessment and Feedback Process

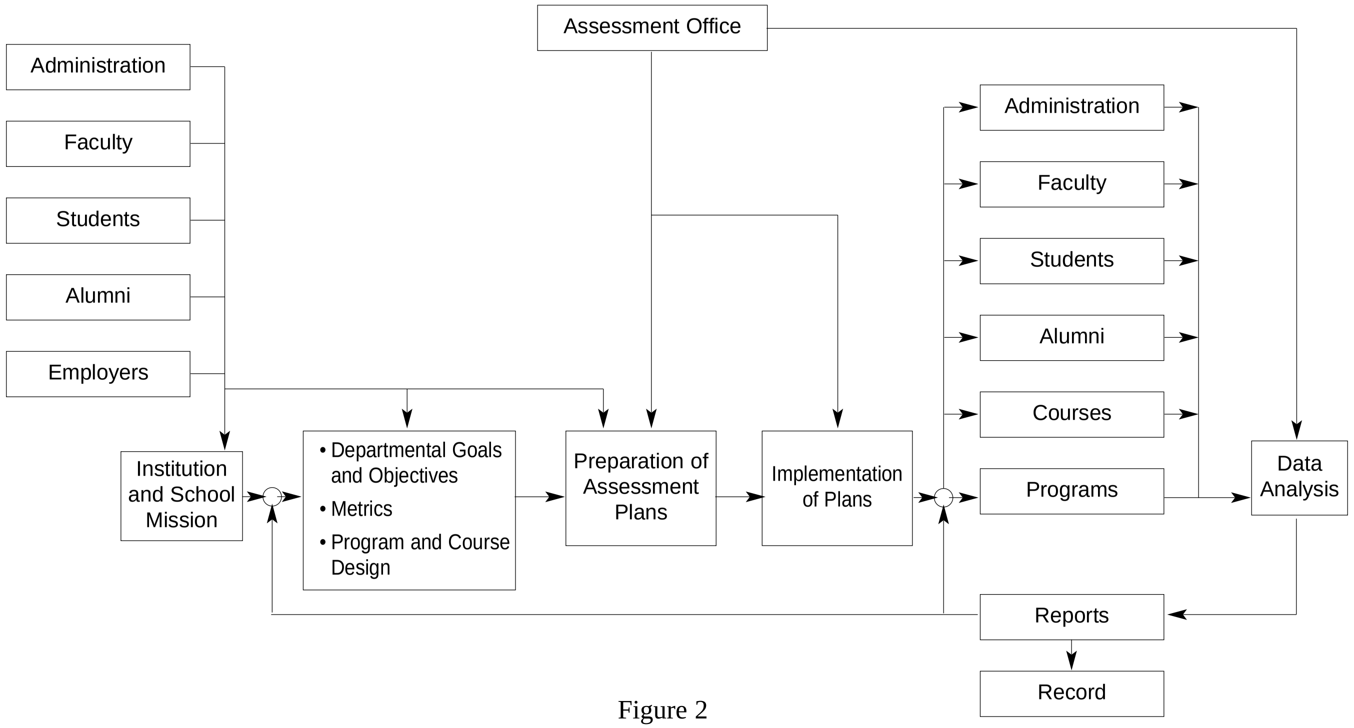

Figure 2

to utilize the information generated for continuous improvement of the educational program. To this end, we routinely conduct a number of schoolwide assessments. The content, scope and results of assessment at Cooper can be seen in Table 1, page 53.

## Lessons Learned

**1. Assessment can be a powerful and effective communication tool.** The development of the assessment process has triggered a discourse between faculty and students at Cooper Union over a fundamental, common concern: the teaching and learning process. The spread of assessment procedures throughout the school has also helped to focus attention on the benefits of the following:

- *A competency-based, learner-centered education,* which is making students more aware of, and more responsible for, their own education, and is also contributing to notable changes in faculty’s teaching habits,
- *Knowledge management for institutional development purposes,* which is useful for designing and revising schoolwide strategies in times of rapid transformation of the educational enterprise.

**2. In a small school like Cooper Union, the implementation of assessment on an individual basis through one-on-one, in-depth interaction with faculty, has proven to be an effective approach to changing the mindset.** Indeed it has been critical in order to build faculty trust and support for the process. The evaluator strategy was twofold: first, to have faculty try assessment as an intellectual exercise rather than a duty imposed from above; second, to relentlessly disseminate the successful examples of assessment conducted in the school. Although there is still work to do in terms of embedding assessment in the classroom and making it effective as a learning-driver strategy, the results are very encouraging.

## Table 1. Institutionalization of Assessment at Cooper Union
### Schoolwide Assessments

| PROGRAM | PURPOSE | STARTED/ PERIODICITY | RESULTS | DISSEMINATION |
|---|---|---|---|---|
| **Department Assessment Plans** | Establishment of measurements of achievement of objectives and outcomes. | 1998/<br>To be revised upon results. | All four engineering departments have drafted and discussed their assessment plans. | Department Chairmen, Faculty, Dean's Office |
| **Course Assessment Plans** | Student self- and peer assessment on development of specified learning outcomes. | 1997/<br>Semestral | About 25% of all courses are routinely assessed and evaluated. About 300 students have participated in the process. About 2/3 of students have developed competencies "to a great extent" and "to a very great extent." | Instructors, Students, Department Chairmen |
| **Alumni Survey** | To gather feedback from cohorts of engineering alumni on their further education, employment status and their perception of Cooper education. | 1996 (Revised 1999)/<br>Yearly | Survey sent out via E-mail to about 1800 alumni; redesigned for ABET purposes. Analysis of results in early spring 2000. | Dean's Office, Department Chairmen, Administration, Faculty, Student Representatives |
| **Exit Survey** | To gather feedback from graduating senior students on the quality of Cooper education. | 1996 (Revised 1999)/<br>Yearly | An electronic survey was pre-tested in the fall of 1999. Full implementation in early spring 2000. Analysis of results will include information from the Dean of Students Office. | Department Chairmen, Dean's Office, Administration, Faculty, Student Representatives |
| **Entry Survey** | Establishment of baseline on competency development for individual longitudinal tracking. | 1996 (Revise 2000)/<br>Yearly | Information on career plans is currently being gathered by the Dean's Office staff. | Department Chairmen, Dean's Office, Administration, Faculty, Student Representatives |

*Continued on next page*

## Table 1. Institutionalization of Assessment at Cooper Union
## Schoolwide Assessments

| PROGRAM | PURPOSE | STARTED/ PERIODICITY | RESULTS | DISSEMINATION |
|---|---|---|---|---|
| **Recruiters Survey** | To gather feedback from recruiters on the performance of students during job interviews. | 1997/ Yearly | Administered through Dean’s Office. | Dean’s Office, Career Services |
| **Employers Survey** | To gather feedback from employers on the job performance of Cooper graduates. | 1998/ Yearly | Administered through Career Services. Survey was modified in 1998 for ABET purposes. | Department Chairmen, Dean’s Office, Administration, Faculty, Student Representatives |
| **Summer Internships** | To gather feedback from supervisors of Cooper interns. | 1996/ Yearly | Administered through Career Services. Survey was modified in 1998 for ABET purposes. | |
| **Study Abroad Program** | To gather feedback from supervisors on performance of Cooper students abroad, and from students on the quality of the program. | 1998/ Yearly | Administered through E-mail. Very high rate of response. Analysis of results will add to individual reports by students. | Dean’s Office, Departments, Student Representatives |
| **Longitudinal Tracking** | Cohort data on retention, graduation and drop out rates, by department, gender and ethnicity. | 1998/ Yearly | Cohort data allowed accurate knowledge of program development and enabled institutional action. Conducted by Office of Admissions and Dean’s Office. | Dean’s Office, Department Chairmen |

The evolution between Gateway Year 1 (1992) and Gateway Year 8 (1999) is very positive, as seen in Figure 3, below. Most students (about 80% in each cohort) are exposed to self- and peer-assessment practices. An outstanding number of full-time faculty -- about 70% -- now use some kind of classroom technique other than the traditional grading of written exercises to assess student learning. About 50% of the courses have explicitly stated objectives, expected outcomes and strategies to achieve them as well as assessment methods to monitor performance. About 25% of the courses have been assessed and evaluated.

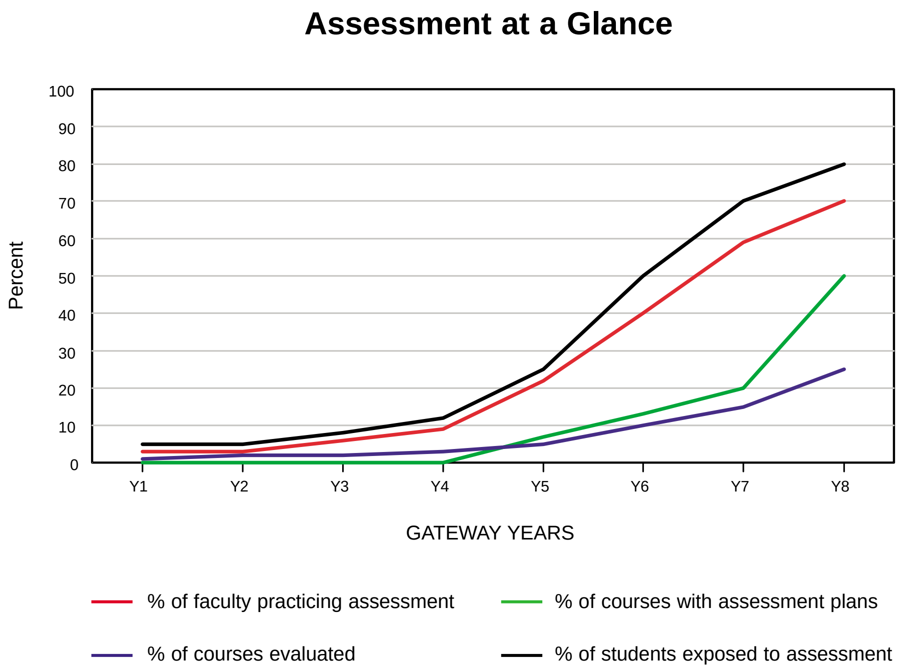

Figure 3

Moreover, most instructors are using the assessment results to change the format and content of their courses. Some instructors have experimented with experiential approaches to teaching and learning, away from the traditional lecture format (e.g., ESC 130 and ESC 140);

some others have become interested in knowing more about their students' learning habits and styles (e.g., CE 141); still others have become interested in assessment itself as a way to measure the impact of their new pedagogical techniques. In summary, many changes in the classroom are under way and are visible. We expect to continue doing assessment beyond the experimentation stage, and to assess additional courses.

**3. When treated as *emerging professionals* -- that is, when given the means to learn and develop competencies and abilities critical for their professional careers -- Cooper students behave very professionally;** their participation in the educational process becomes more active, their confidence in their own skills and abilities increases and their learning is more successful. Most Cooper students exposed to a competency-based approach to education in selected courses show very positive results, as measured by degree of competency development shown in Table 2. Almost two-thirds of the students participating in these assessments have developed the competencies "to a great extent" or "to a very great extent," and less than one-quarter of the students manifest the competencies "to a limited extent" or "not at all."

**Table 2. Student Self-Assessment at Cooper Union**

| **Student Perception of Competency Development*** | **Percent of Students Who Developed the Competency** | | | | |
|---|---|---|---|---|---|
| **COMPETENCIES (ABET criteria as customized by Cooper Union)** | **Not At All** | **To a Limited Extent** | **To a Moderate Extent** | **To a Great Extent** | **To a Very Great Extent** |
| Ability to use technology | 0 | 8 | 8 | 63 | 21 |
| Analytical skills | 0 | 14 | 7 | 59 | 20 |
| Research skills | 2 | 6 | 30 | 48 | 14 |
| Understanding of the design/ experimentation process | 4 | 10 | 22 | 45 | 19 |
| Communication skills | 8 | 14 | 20 | 42 | 16 |
| Teamwork | 10 | 20 | 13 | 36 | 21 |
| Creative problem solving | 0 | 15 | 26 | 35 | 14 |
| Lifelong learning | 13 | 17 | 13 | 34 | 13 |
| Global awareness | 12 | 25 | 18 | 33 | 12 |
| Project management/leadership | 6 | 20 | 26 | 32 | 17 |
| Humanistic values | 20 | 21 | 24 | 20 | 15 |
| **AVERAGE** | **7.2** | **15.3** | **18.6** | **41.3** | **17.7** |

* *Average of 15 engineering courses assessed between 1997 and 1999. N=486. 300 students impacted.*

Gateway leadership in curriculum innovation deserves credit here, and is most felt in the ability of students to use technology, their research skills and their overall understanding of engineering design and experimentation.

Cooper engineering students have always excelled in developing strong analytical foundations, and this is visible in the results shown in Table 2. However, these results also indicate that a new type of engineer is in the making at Cooper:  an engineer who communicates better with peers, instructors and professional engineers; who is sensitive to the importance of teamwork and is more exposed to it; who understands the importance of individual research and life-long learning; and who is aware that engineering is a design activity of open-ended, interdisciplinary solutions.

**4. The assessment process contributes to changes in teaching styles,** particularly when assessment serves the purpose of enhancing communication between instructors and students. At Cooper, more faculty are adopting new approaches to teaching (Figure 4) because of Gateway's stress on curriculum innovation and because, through assessment, faculty now know more about the students' learning habits and styles. This is a consequence of various self and peer assessments introduced in the classroom and of an overall emphasis on a learner-centered, individualized education promoted at Cooper Union under Gateway auspices.

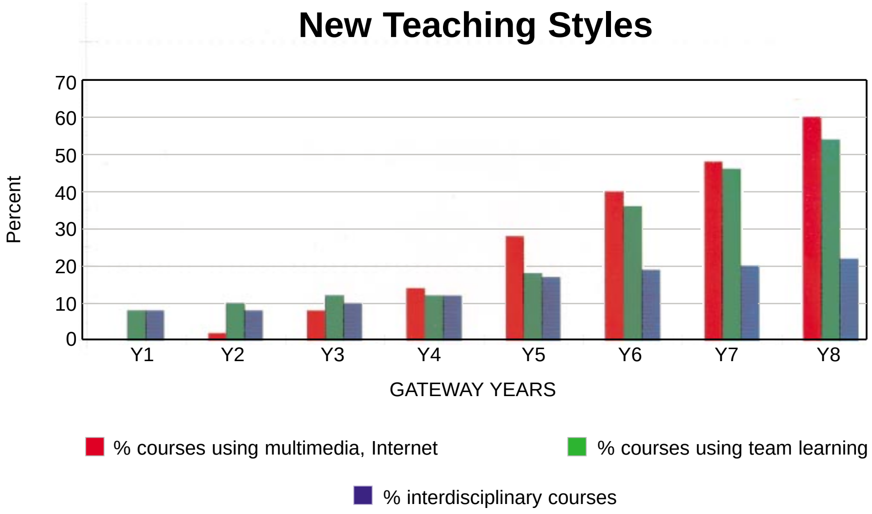

Figure 4

**5. Implementation of longitudinal tracking and dissemination of cohort data analysis and results represent a sea change in the practices of institutional data gathering,** and have revealed important information about the educational process at Cooper Union. A more accurate appraisal of data on retention, graduation and drop-out rates resulting from such longitudinal analyses has contributed to institutional actions that, in turn, have begun to yield visible results in each of the main indicators (Figure 5). Compared with eight years ago, more engineering students are returning for the second year, more graduate in four years (fewer taking five years to graduate), and fewer drop out. The upward trends in retention and graduation rates as well as the downward trend in drop-out rates for cohorts between 1986 and 1995 reveal the synergistic influence of Gateway at Cooper Union.

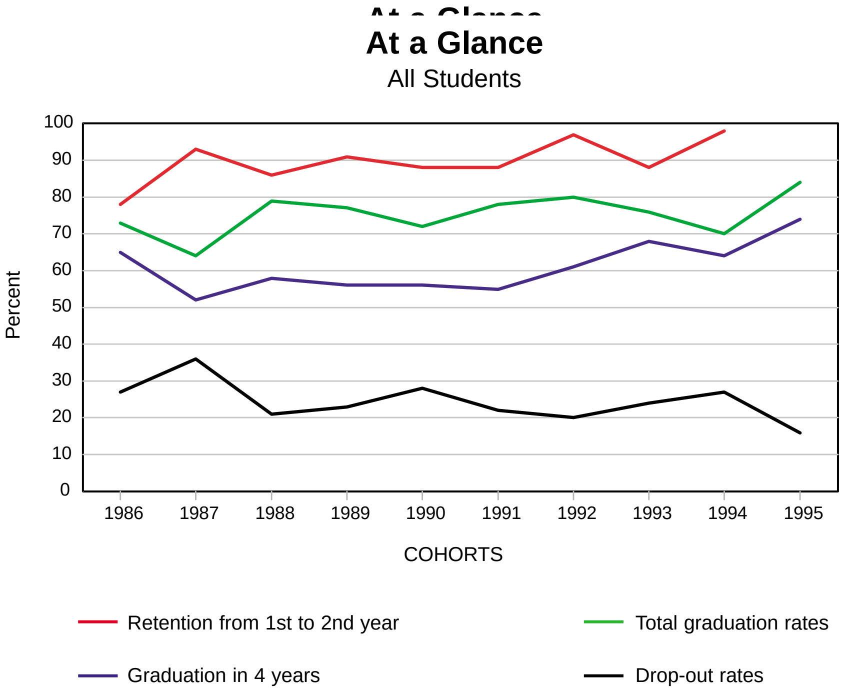

Figure 5

Data for female engineering students (Figure 6), who represent about one-third of the school's population, are especially significant because their retention, graduation and drop-out rates resemble those of the overall Cooper Union student population and show similar trends. This is highly unusual, because the performance of female students nationally has not been as good as that of male students. The figures become even more impressive if we take into account that Cooper's traditional performance has been and is well above the national standards for engineering schools.

*A complete review of longitudinal tracking results is included in the appendix, pages 23-31.*

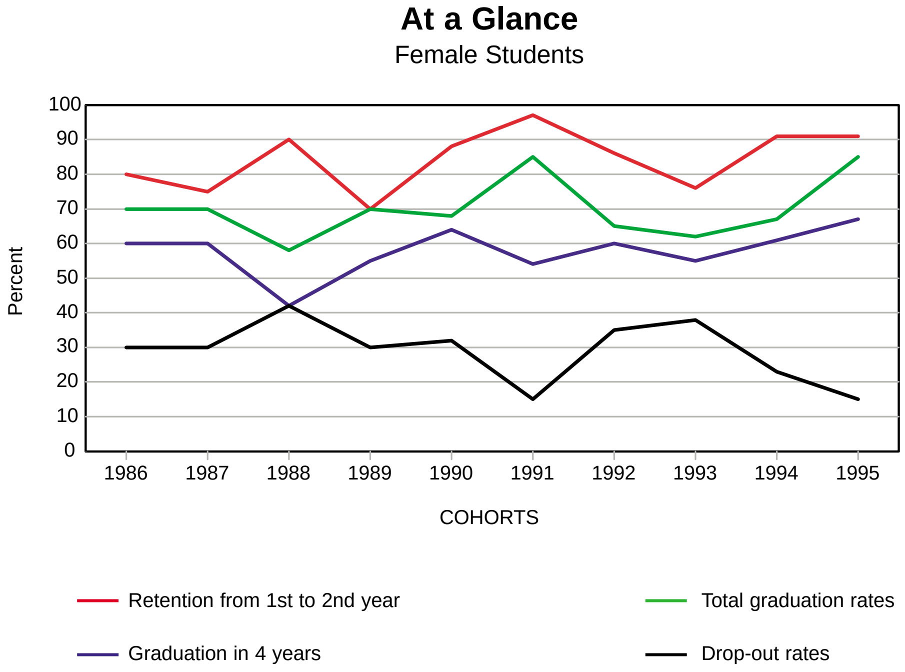

Figure 6

## Looking Ahead: Assessment by Design

Gateway leadership and support have contributed to the development of a vigorous assessment program at Cooper Union. Gateway support will also be critical in the years to come for some specific areas that deserve attention. The small size of the school, and the possibility of a better integration of the Engineering program with the Art and Architecture programs, make assessment suitable for expansion into exciting areas of notable interest for engineering education. The rationale is **to develop a program of assessment *by design*** that does the following:

- Stresses the gathering and analysis of qualitative data
- Drives the learning within the classroom
- Is highly flexible and customizable to individual backgrounds, profiles and career projects
- Allows data aggregation for institutional purposes
- Promotes the unification of work, learning and innovation at Cooper
- Promotes the concept and the practice of learning networks

Our plan includes the following tracks:

- *Knowledge-building environments*. We plan to continue using the assessment results for designing formative assessment plans for courses and programs. The rationale is to have assessment fully integrated into the learning process and for each student to practice self-assessment routinely. We plan to design Web-based “knowledge-building environments” (KBE’s) where data and information produced individually throughout the various courses and projects can be easily stored, retrieved, turned into knowledge (through collective discussion), and then used for in-time improvement of performance.

  Particular emphasis will be placed on tracking process knowledge -- that is, the origins, flows and destinations of ideas considered during the development of the projects at hand. When turned into a design activity, innovative work by engineering students generates vast amounts of data and information that is worthwhile to preserve in a systematic way. Students will gain a thorough understanding of their own learning process and simultaneously will enhance their academic performance. The information stored will be accessible to instructors, peers, and industry mentors for ongoing monitoring. In addition, the students' *work-in-process* will be available for future employers.

- *Educational research.* Storing and using information through KBE's may also serve the purpose of educational research in engineering education. This is an emerging, exciting field pioneered years ago by social research practitioners in industry settings such as PARC Xerox in Palo Alto, California. It is exemplified today by the spread of "knowledge labs" in major companies' R&D divisions (IBM, Bell Labs) and of "learning labs" in the country's major engineering schools, such as Stanford and MIT.

  Learning to learn by observing how learners learn is a major project to which the assessment expertise and resources accumulated during the Gateway years can contribute a good deal. In fact, one of the projects funded by Gateway at Cooper, "Assessing Communication Modes in Students' Engineering Projects," was developed along these lines (see page 35). We learned that face-to-face interaction via informal meetings combined with the proliferation of "weak ties" in the students' learning network promotes innovative research and design in collaborative projects.

  We presented the results of our research at a recent international conference on collaborative learning at Stanford University. With a plan for building a learning lab at Cooper currently developing, the objective of expanding assessment into educational research will become a reality.

- *Individualization of assessment.* The development of the assessment tracks specified above will contribute to an individualization of assessment at Cooper. By having individual students develop their own knowledge-building strategies, and by learning about the learning process by observing students at work, we can contribute to an educational program which is fully sensitive to the individual needs and learning styles of each student. The ultimate goal is to help students to be *entrepreneurs of their own education.*

Under Gateway auspices, we have already started two projects that contribute to that endeavor.

  - The first is longitudinal tracking, which could naturally develop into *individual* longitudinal tracking of each student's performance throughout the program. The traditional student records, which merely reflect course grades and GPA's could be redesigned into a portfolio summary for each engineering student.
  - The second project is the measurement of each freshmen student's learning styles, as indicated in the results of standardized tests such as the MBTI, a very useful pedagogical tool for instructors who want to keep in touch with their students' learning processes.
  - This individualization of assessment approach may also be used for tracking the cohorts of students beyond graduation.

- *Collaborative learning*. Teamwork (including virtual teamwork) is currently practiced at Cooper in various courses, projects and labs. Students seem to develop an awareness of the importance of collaboration by working in teams, but the current practices could be more systematically examined. Our collaborative learning proposal projects the development of a more comprehensive view of teamwork and collaborative learning at the school to accomplish the following:
  - Know exactly how teamwork is practiced and what stu-

dents learn from it.

- Assess the different practices and the various types of teams and recommend the best ones.
- Learn about the various roles that each student takes during the projects at hand and their various learning styles.
- Establish different competency levels for students in each year.
- Assure that Cooper students graduate as effective team engineers, according to a set of specific criteria that should be defined for the school overall.

Special attention will be given to the development and assessment of asynchronous learning networks, in which Cooper students have an opportunity to develop virtual teams with students from other schools (as they already do in the GlobeTech, MYMUP and Concurrent Engineering projects), with industry professionals (as in Engineering Design and Problem Solving and in Product Design), and in general with parties outside the school. The rationale of assessment of learning networks is to embed formative assessment techniques (particularly those that foster interpersonal communication) in the development of the projects from the outset, so that assessment drives the learning process.

# The Gateway Legacy

## Impact at Cooper Union

Participation in the Gateway program has had a significant impact on the content, structure and culture in our school of engineering.

- The pilot projects we conducted were invaluable in opening up, for both faculty and students, the concepts of virtual lab, (e.g., Virtual Soil Mechanics Laboratory, page 44), virtual and distance collaborative learning (e.g., Concurrent Engineering and Manufacturing, page 26), sharing of resources and new approaches to teaching and learning (e.g., GlobeTech/ Global Prespectives in Technology Management, page 29).
- Students are expressing tremendous excitement about what they are learning. Retention and graduation rates, as shown in Figure 5 on page 58, have increased.
- Faculty are being energized by new methods of teaching and learning and are incorporating student comments into new or changing formats. The use of new teaching styles has increased significantly, since 1992, as shown in Figure 4 on page 57.
- We have been extremely successful in “bringing engineering up front.” This has been done by first revising an introductory engineering design course for freshmen (EID 101) to develop the concept of pedagogical teams, bringing together with the engineering instructor specialists in oral communication (theater professional), writing communication (tutor from the Writing Center), visual presentation (graphic artist in residence) and information technologies (librarian).

This team proceeds by “intervention” at certain points in the course -- for example, coaching students before an oral presentation, critiquing a visual display or giving advice on preparing or editing a video. The tutors assess the students in terms of specific proficiencies and document the assessment. Tutors come to the classroom or lab to coach and critique the work as it is being developed rather than relying on the students going to the coaches.

- The second step taken in “bring engineering up front” has been the development of a new freshman/sophomore design course Principles of Design -- EID 103, which uses reverse engineering to find principles of design and apply these principles to product development.
- We have also been extremely successful in establishing our assessment program, which has the full support of the school’s leadership and is now fully institutionalized. This process has opened up a new way of looking at the educational forum that will continuously improve the students’ learning experiences. Faculty are now more interested in and involved in how students learn, which, in turn, is substantially impacting how faculty teach. (See “The Assessment Program beginning on page 48.)

## Implications for Engineering Education

The Gateway Coalition has created a critical mass of thought and action that are key to meeting the ABET criteria and achieving educational reform.

- The Coalition has raised awareness and provided models. Non-Coalition schools will be able to meet the 2001 ABET accreditation criteria by adopting Gateway programs and materials and by emulating Gateway processes.

- The Gateway program has had a tremendous impact on faculties. In an era of vast technological advances, the professor and text are no longer the only channels of information. Faculty must not only understand the new technologies, they must also utilize them fully in their new roles as facilitators of learning rather than purveyors of information. Gateway has shown them how.
- Gateway has created changes in culture and climate that have made possible new programs such as LEAP and CONNECT.

  LEAP is a certificate program involving a series of workshops and other participatory experiences specially developed to enhance leadership potential. Each session is two to three hours long and involves interactive or learner-oriented techniques such as simulations, discussions, videos, role-playing, film, case studies, guests, scenarios and other methods designed to make learning a personal discovery.

  CONNECT is a noncredit series of workshops and seminars focused on improving communication skills. The program approaches communication training as a complement to the existing engineering curriculum and spans the four years of the college experience. Teaching fundamental skills and providing opportunities for practice and feedback, the program includes basic graphic skills, effective listening, basic presentation skills, negotiation and conflict resolution. Gateway has focused attention on the importance of communication in every activity and has fostered a spirit of collaboration that will be essential to full participation in a cybernetic world.
- One of Gateway's major contributions to educational reform has been the introduction of a formal -- and fundamental -- process of assessment. This process will keep educational programs current and connected with the real world into

> which each student will graduate, making engineering education continuously timely and vital.

The Gateway Coalition has created a revolution in engineering education that is influencing schools not only across the nation but around the world.

# What Next?

## Years 8-10

Over the last three years of the Coalition project, Cooper Union will focus on the following strategies and actions in support of the six Gateway project areas. A complete presentation of plans -- including resources, timetable, outcome indicators, benchmarks and assessment processes -- can be found in Table 3 beginning on page 71.

### Assessment and Continuous Improvement

- Conduct an assessment for five Gateway project/courses.
- Implement an alumni survey.
- Specify feedback procedures to departments on longitudinal student tracking.
- Document teamwork competencies for the whole school (survey).
- Assess effectiveness of the uses of technology in enhancing students' learning.
- Document the impact of Gateway on engineering education at Cooper Union (survey).

### Professional Development

- Continue the regularly scheduled seminar series on learning, teaching, continuous improvement and the uses of technology.
- Continue to expand students' professional development. A team of students will be doing research on educational reform.
- Continue to expand the faculty's professional development.
- Expand activities in the area of oral and written presentations (including use of multimedia technologies).

### Underrepresented Populations

- Institutionalize the Training Seminar for Women, one element of the LEAP program funded by Gateway.

- Establish relationships with HBC’s.
- Conduct interviews for a systematic identification of causal mechanisms affecting performance of junior and senior minority students. Design a feedback method.
- Document and disseminate a report of the experiences of women in Gateway projects.
- Conduct a one-day workshop on diversity issues.

**Technology**

- Expand industry participation in projects.
- Continue “Tools of Design” workshops for students and faculty.
- Expand interdisciplinary design collaborations.
- Develop two learning labs.

**Linking and Sharing**

- Increase dissemination of teaching innovations to institutions inside and outside the Coalition.
- Continue distribution of materials through the World Wide Web.
- Increase the number of papers presented at educational conferences worldwide.
- Continue to involve industry in the curriculum.

**Curriculum Implementation**

- Increase dissemination of innovations to institutions inside and outside the Coalition.
- Continue and expand industrial partnerships in conjunction with design courses.
- Continue, expand and disseminate “Engineering in Context” materials.
- Continue development of new design projects.

## Table 3. Gateway Coalition
## The Cooper Union for the Advancement of Science and Art
## Strategic Plan Years 8-11

| STRATEGIES AND ACTIONS | RESOURCES | TIMETABLE | OUTCOME INDICATORS | BENCHMARKS | ASSESSMENT PROCESSES* |
|---|---|---|---|---|---|
| **Assessment and Continuous Improvement** | | | | | |
| **A1.** Conduct an assessment for 5 Gateway projects/courses: EID111, ME364, ESC100, ESC140 and EID 103. | del Cerro<br>Le Mée<br>Faculty | Ongoing | Enhanced student and faculty awareness of the educational process. Increased specific recommendations to improve courses (feedback loop diagrams), in ways consistent with departmental objectives. | By the end of year 8, the 5 courses will be assessed and the results incorporated in the redesign of the courses (40 students impacted). Papers documenting process. By the end of year 9, 50% of all undergraduate courses will be assessed in this manner (100 students impacted). By the end of year 10, 75% of courses (150 students impacted). | Conduct evaluation. Report to faculty for feedback. Report on improvement plans.<br>[A1, A2, A4, A5] |
| **A2.** Implement an alumni survey. | del Cerro<br>Le Mée<br>Stephens<br>Baum | Ongoing | Modified instruments, according to feedback from pre-test. Reported results to departments, for continuous improvement (feedback loop diagram). Participation of industry in the feedback process. | By the end of year 8, assessment of pre-test completed. End of year 9, the survey will be institutionalized. Number of alumni involved: 250. Year 10: creating process of constituent (industry) feedback. Number of industries participating: 5. | Documented process.<br>[A5, A6, E6] |
| **A3.** Specify feedback procedures to departments on longitudinal student tracking. | del Cerro<br>Le Mée<br>Bory<br>Hopkins<br>Baum | Ongoing | Implemented feedback loop for continuous improvement (feedback loop diagram, templates). | By the end of year 8, the exit interview questions will be modified to include new learning outcomes. By the end of year 9, the feedback system will be institutionalized. | Documentation Report.<br>[A5, A6] |

*Links to Institutional Metrics in brackets.

## Table 3. Gateway Coalition
## The Cooper Union for the Advancement of Science and Art
## Strategic Plan Years 8-11

| STRATEGIES AND ACTIONS | RESOURCES | TIMETABLE | OUTCOME INDICATORS | BENCHMARKS | ASSESSMENT PROCESSES* |
|---|---|---|---|---|---|
| **A4.** Document teamwork competencies for the whole school (survey). | del Cerro<br>Le Mée<br>Faculty | Ongoing | Systematic survey of existing teamwork practices. Issued recommendations for teamwork competencies. Increased students' teamwork competency. | By the end of year 8, documentation of teamwork in the engineering school. By the end of year 9, recommendations for teamwork procedures issued. 75% of students will be satisfied or very satisfied with their teamwork experiences. By the end of year 10, institutionalized teamwork practices. 90% of students satisfied or very satisfied. | Report on existing teamwork practices at the school. Report on teamwork assessment instruments. Dissemination to faculty and students.<br>[A2, A4, A5] |
| **A5.** Assess effectiveness of the uses of technology in enhancing students' learning. Baum | del Cerro<br>Le Mée<br>Faculty | Ongoing | A comprehensive understanding of how new technologies are affecting learning at the school. Increased student and faculty competency in the use of technology. | By year 8, this technology assessment will be conducted on 4 courses: CE131, CE142, ESC 140, and ESC100 (200 students impacted). Survey results. Process expanded to other coalition schools. By year 9, time series comparison on those 4 courses (300 students impacted). Year 10: time series comparison +4 additional courses. Institutionalized (500 students impacted). Between years 8 and 10, students' satisfaction with technology competency will increase by 20%. | Exams (grades). Questionnaires. Reports.<br>[D1, D4] |
| **A6.** Document the impact of Gateway on engineering education at Cooper (survey). | Baum<br>del Cerro<br>Le Mée | Ongoing | An understanding of the impact that Gateway projects and initiatives have had on faculty, students and the institution as a whole. | By the end of year 8, develop and implement a survey to gather information from parties. By end of year 9, issue a report on these results, listing actions and recommendations. Year 10: implement actions and recommendations. | Survey.<br>Reports.<br>[B1, B5] |

## Table 3. Gateway Coalition
## The Cooper Union for the Advancement of Science and Art
## Strategic Plan Years 8-11

| STRATEGIES AND ACTIONS | RESOURCES | TIMETABLE | OUTCOME INDICATORS | BENCHMARKS | ASSESSMENT PROCESSES* |
|---|---|---|---|---|---|
| **Professional Development** | | | | | |
| **B1.** Continue regularly scheduled seminar series on learning, teaching, continuous improvement and the uses of technology. | Baum<br>Le Mée | Ongoing | Increased number of faculty attending seminars. Increased number of courses using new technologies. Increased technology competency among faculty. | By the end of year 8, we will give 4 seminars (2 per semester). Workshop materials will be prepared for cross-coalition dissemination. By the end of year 9, 25% of faculty will attend at least one seminar. Year 10: 50% of faculty will attend at least one seminar.<br>By the end of year 8, learning labs will be constructed and faculty will have planned teaching methods. In year 9, 6 courses will make use of learning labs. Year 10: 8 courses. Year 11: 10 courses. | Workshop evaluations. Courses affected.<br>[B3, B4, B5] |
| **B2.** Continue to expand students' professional development. A team of students will be doing research on educational reform. | Baum<br>Le Mée<br>Stock<br>Lyczko | Ongoing | Increased the number of students who participate in communication and leadership seminars. Enhanced student awareness of their educational resources at Cooper and their professional opportunities. | By the end of year 8, 25% of undergraduates will participate in at least one such program. By year 9, this will rise to 50%. By year 10, this will rise to 75%. By year 11, all students will participate. Documentation of educational resources, survey of engineering programs, market survey of professional opportunities for engineering graduates, recommendations for the education of the students at Cooper Union. Students' paper. | Workshop evaluations. Student survey responses. Documented program calendar and attendance records. Compiled information of engineering educational reform from the viewpoint of the students.<br>[F7, F8, F9] |

## Table 3. Gateway Coalition
## The Cooper Union for the Advancement of Science and Art
## Strategic Plan Years 8-11

| STRATEGIES AND ACTIONS | RESOURCES | TIMETABLE | OUTCOME INDICATORS | BENCHMARKS | ASSESSMENT PROCESSES* |
|---|---|---|---|---|---|
| **B3.** Continue to expand faculty's professional development. | Baum<br>Le Mée | Ongoing | Increased the number of faculty who participate in educational-oriented conferences/symposia. | In year 8, 34% of faculty will attend at least one conference.<br>14 faculty papers presented.<br>Year 9: 37%<br>Year 10: 42%<br>Year 11: 42%. | Trip reports.<br>Published papers.<br>Presentations.<br>Dissemination.<br>[B1, B2, B3, B4, B5, E1] |
| **B4.** Expand activities in the area of oral and written presentations (including use of multimedia technologies). | Baum<br>Le Mée<br>Wilkerson<br>Pierson | Ongoing | Established a video file for each student showing progress of their presentation skills. Increased positive feedback on presentation skills from faculty, peers and industry. Papers documenting process. Web site. | By the end of year 8: sample video files for 5% of students in the Class of 2000. By end of year 9: files completed for 10% of students in Class of 2001. By end of year 10: for 20% of Class of 2002. Year 11: for 50% of Class of 2003. Positive feedback will increase by 20% from year 8 to year 10. | Video files.<br>Documented progress.<br>[F8, D1] |
| **Underrepresented Populations** | | | | | |
| **C1.** Institutionalize the Training Seminar for Women. | Baum<br>Lyczko | Ongoing | Increased number of female students participating. | By the end of year 8, program institutionalized. Number of students participating will rise by 10% yearly. Years 9, 10, 11...materials, manuals and publications will be made available to other institutions to replicate program through the Web, or mail order. | Train the trainer materials.<br>[C] |

## Table 3. Gateway Coalition
## The Cooper Union for the Advancement of Science and Art
## Strategic Plan Years 8-11

| STRATEGIES AND ACTIONS | RESOURCES | TIMETABLE | OUTCOME INDICATORS | BENCHMARKS | ASSESSMENT PROCESSES* |
|---|---|---|---|---|---|
| **C2.** Establish relationships with HBC's | Baum<br>Le Mée<br>Bory | Ongoing | Increased linkages with HBC's. | By the end of year 8, dual program will be initiated with at least one HBC. | Records of meetings.<br>[A6, C] |
| **C3.** Conduct interviews for systematic identification of causal mechanisms affecting performance of junior and senior minority students. Design a feedback method. | Baum<br>del Cerro<br>Stock | Ongoing | Increased number of students interviewed. Increased retention and graduation rates for minority students. | By the end of year 8, implement interviews and design feedback method. Year 9: implement feedback mechanism. Year 10: process institutionalized. Longitudinal tracking follow-up. | Documented process. Report on results of in-depth interviews.<br>[A5, A6, C] |
| **C4.** Document and disseminate a report of the experiences of the women in Gateway projects. | Baum<br>Le Mée<br>del Cerro | Ongoing | Production of report, papers and video documentation. Number of outside institutions that apply for information. Increased women's competencies in relevant learning outcomes (communication, teamwork, project management). | Year 8: presentation at ASEE on Women in Gateway projects.<br>Year 9: 2 presentations.<br>Year 10: 3 presentations.<br>Between years 8 and year 10, competencies in learning outcomes will increase by 20%. | Internal distribution of the results of interviews. Follow-up documenting the effect of dissemination.<br>[A5, E1, E2, E4, E5] |
| **C5.** Conduct a one-day workshop on diversity issues. | Baum<br>Le Mée<br>del Cerro<br>Stock | Spring semesters, ongoing. | Increased number of faculty attending workshop. Increased faculty awareness on diversity issues. | In year 8, 25% of faculty will attend. Full workshop materials. Conduct in other schools?<br>Year 9: 50%<br>Year 10: 75%<br>Year 11: 100%<br>Years 8 through year 10, increased positive feedback on pre- and post-evaluation sheets. | Workshop evaluations.<br>[B1, B3] |

## Table 3. Gateway Coalition
## The Cooper Union for the Advancement of Science and Art
## Strategic Plan Years 8-11

| STRATEGIES AND ACTIONS | RESOURCES | TIMETABLE | OUTCOME INDICATORS | BENCHMARKS | ASSESSMENT PROCESSES* |
|---|---|---|---|---|---|
| **Technology** | | | | | |
| **D1**. Expand industry participation in projects. | Le Mée<br>Cowan | Ongoing | Increased number of industry participants. Increased number of courses employing industry.<br>Increased use of videoconferencing. Increased student competencies in ABET learning outcomes. | In year 8, 24 students will be in courses where there is participation from industry. 3 industrial partners participating. Documented process for fostering industry participation through the use of videoconferencing. In year 9, this number will rise to 30 students. Year 10: 40 students. Between years 8 and year 10, positive feedback on ABET outcomes will increase by 20 | Industry assessment sheet. Student reports.<br>Documentation of student interactions with industrial partners.<br>Documentation of benefits of the program for parties involved.<br>[E6] |
| **D2.** Continue “Tools of Design” workshops for students and faculty. | Le Mée<br>Cowan<br>Wei | Ongoing | Familiarized students, faculty and industrial partners with modern design tools. Increased student competencies in engineering design. | In year 8, there will be one workshop; 40 students will participate. Coalition-wide dissemination? In year 9, there will be 3. Year 10: 5 workshops/events. Feedback from workshops. Between year 8 and year 10, student participation will increase by 20%; student satisfaction and competency will increase by 20%. | Progress report.<br>Workshop evaluations.<br>[A5, D5, F1, F5, E6] |

## Table 3. Gateway Coalition
## The Cooper Union for the Advancement of Science and Art
## Strategic Plan Years 8-11

| STRATEGIES AND ACTIONS | RESOURCES | TIMETABLE | OUTCOME INDICATORS | BENCHMARKS | ASSESSMENT PROCESSES* |
|---|---|---|---|---|---|
| **D3.** Expand interdisciplinary design collaborations. | Le Mée<br>Cowan<br>van der Heijden<br>Wortzel<br>Wei<br>Lent | Ongoing | Increased number of exhibitions in Brooks Design Gallery. Increased student attendance at programs offered that sharpen the aesthetic sense of engineers and explore new technologies in collaborative environments. Increased student competencies in engineering design. | Year 8: 2 courses and 2 exhibitions; 20 students will participate.<br>Year 9: 3 courses and 4 exhibitions. Year 10: 4 courses and 4 exhibitions. Feedback from workshops. Between year 8 and year 10, student satisfaction will increase by 20%; student satisfaction and competency will increase by 20%. | Qualitative evaluations of interdisciplinary groups. Progress report.<br>[A4, D1, D2, D3, D4, D5, F1, F5, F10] |
| **D4.** Develop two learning labs. | Baum<br>Le Mée<br>Faculty | Ongoing | Increased number of faculty who make use of technology in classrooms. Increased number of courses that use new technologies. Increased technology competency among faculty. | By the end of year 8, learning labs will be constructed and faculty will have planned teaching methods.<br>In year 9, 6 courses will make use of learning labs.<br>Year 10: 8 courses.<br>Year 11: 10 courses. | Number of courses and faculty using learning labs. Documentation of the use of new facilities.<br>[A4, D1, D2, D3, D4, D5, F10, F12, F13] |
| **Linking and Sharing** | | | | | |
| **E1.** Increase dissemination of teaching innovations to institutions inside and outside the Coalition. | Baum<br>Le Mée<br>Wilkerson<br>Pierson | Ongoing | Number of conferences attended. Videotaped workshops. Catalog of available videotapes made available to Gateway institutions and to the public on the Web at conferences and at symposia. | Year 8: catalog sent to all Gateway institutions and posted on the Web.<br>Year 9: presentations at one educational conference.<br>Year 10: presentations at two conferences. | Regular follow-up (by phone, e-mail) with institutions that have received our materials.<br>Assessment reports of feedback from workshop participants.<br>[E1, E2, E3, E4, E5, E6] |

## Table 3. Gateway Coalition
## The Cooper Union for the Advancement of Science and Art
## Strategic Plan Years 8-11

| STRATEGIES AND ACTIONS | RESOURCES | TIMETABLE | OUTCOME INDICATORS | BENCHMARKS | ASSESSMENT PROCESSES* |
|---|---|---|---|---|---|
| **E2.** Continue distribution of materials through the World Wide Web. | Le Mée<br>Pierson<br>Jacoby | Ongoing | GlobeTech on-line course.<br>Increased number of associations with outside institutions. | Year 8: Global Perspectives in Technology Management offered as online course. Web counter employed on Web sites. 15 Cooper students participating; 60 external students participating.<br>Year 9: continue online course, Web feedback mechanism. Year 10: online course institutionalized. Web feedback in place. Between year 8 and year 10, the number of associations and students participating will increase by 20%. | Web site hits. Number of students enrolled in online courses. Web feedback. Feedback from students.<br>[E5] |
| **E3.** Increase the number of papers presented at educational conferences worldwide. | Baum<br>Le Mée<br>Faculty | Ongoing | Increased number of papers presented. | Year 8: 14 papers; 16 faculty.<br>Year 9: 15 papers; 18 faculty.<br>Year 10: 17 papers; 20 faculty.<br>Year 11: 20 papers; 20 faculty. | Publications listing. Feedback from participants.<br>[E1, E2] |
| **E4.** Continue to involve industry in the curriculum. | Baum<br>Le Mée<br>Faculty | Ongoing | Increased involvement with advisory board. | Year 8: 23 industrial partners regularly involved.<br>Year 9: 26 industrial partners.<br>Year 10: 30 industrial partners. | Reports on advisory board meetings. Follow-up to determine effect on curriculum.<br>[E5, E6] |

## Table 3. Gateway Coalition
## The Cooper Union for the Advancement of Science and Art
## Strategic Plan Years 8-11

| STRATEGIES AND ACTIONS | RESOURCES | TIMETABLE | OUTCOME INDICATORS | BENCHMARKS | ASSESSMENT PROCESSES* |
|---|---|---|---|---|---|
| **Curriculum Implementation** | | | | | |
| **F1.** Increase dissemination of innovations to institutions inside and outside the Coalition. | Baum<br>Le Mée<br>Faculty | Ongoing<br>FIE-fall<br>ASEE-spring | Web sites<br>Papers<br>Presentations<br>Videos | Number of papers/presentations/videos presented/Web site hits on Gateway project-courses. | Project reports. Regular follow-up with institutions who have received our materials.<br>[E5] |
| **F2.** Continue and expand industrial partnerships in conjunction with design courses. | Le Mée<br>Cowan | Ongoing | Increasing number of design projects that are associated with real industrial needs. | Year 8: 5 projects will involve industrial partners.<br>Year 9: 6 projects<br>Year 10: 7 projects. | Student and industrial associate surveys.<br>[E6] |
| **F3.** Continue, expand and disseminate “Engineering in Context” materials. | Le Mée<br>Faculty | Ongoing | Expanded Web site.<br>Dissemination of CD-ROM.<br>Increased number of exhibitions. | Year 8: complete and distribute CD-ROM.<br>Year 9: expand Web site to include contents of CD-ROM.<br>Year 10: exhibition and presentation featuring CD-ROM. | Documented process. Progress report.<br>[F1, F2, F3, F4] |
| **F4.** Continue development of new design projects. | Le Mée<br>Faculty | Ongoing | Increased number of courses redesigned and taught in new learning labs. | Year 8: 6 courses<br>Year 9: 8 courses<br>Year 10: 10 courses | Assessment of the effectiveness of new technology in enhancing students’ learning. Analysis of exams. Student and faculty questionnaires. Progress reports.<br>[F2, F3, F4, F5, F6, F7, F8, F10, F12, F13] |

# Beyond the Coalition:
# The Master of Professional Engineering

## Introduction

The wonderful work that is being accomplished under the banner of the Gateway Coalition is a response to industrial pressures that began in the early 1980's. Five to 10 years from now, these exhilarating reforms will be fully absorbed into the engineering educational system and considered standard. Not too long after that, given the rapid rate of technological advancement, they will have fallen behind.

We should consider now what our next step ought to be to keep our educational system caught up with, or slightly ahead of, the times. We see the following developments as being significant:

- The conjuncture of a continuing technological explosion, a renewal and fresh thinking about the role of cities and the process of globalization in many fields.
- A tendency toward virtuality that separates people from the actual nature of things.
- The centrality of biology as the science of the 21st century; a revolution in biology and information sciences.
- The "downgrading" of certain engineering functions as these tasks are outsourced to geographic areas with cheaper labor costs.
- The simultaneous creation of a new, more advanced function as engineers are called on to handle more conceptual tasks; to communicate and interact more with management, sales and clients; and to be more closely integrated with the decision-making process.

In response to the above, we propose a three-year master's program, anchored on a strong scientific and liberal arts basis, which would develop a core of engineering culture common to all the technologies.

The structure of the engineering curriculum and the general ABET requirements show undergraduate engineering studies to cover one-and-a-half academic years. The rest is occupied by physics, chemistry, mathematics, humanities, social sciences and other disciplines. At the master level, the coursework takes approximately one year, and is concentrated in engineering. If a project or thesis is included, this may extend a few months but is generally less than two years. The total number of purely engineering studies for a master's degree is therefore less than three years. This is reasonable for a professional degree. Law students have three years of studies; physicians have four, but this includes nearly a year of internship. Pharmacy education is now moving in the same direction, requiring (like law and medicine) a broad liberal education preceding professional education. This should make sense for engineering as well.

The new technologies that formally or informally will be the engineering disciplines of the 21st century are highly scientific. The level of sophistication required in the fundamental disciplines of math, physics, chemistry and biology should therefore be of the first order. Furthermore, the humanistic and spiritual dimensions of the new paradigms emerging in science and engineering require a profound basis in the humanities, well integrated with scientific and engineering practice. This demands a deeper, wider and more experiential preparation than high schools offer and a maturity and subtlety in students that only age, experience, and reflection may give. This is imperative if we want to educate intellectual leaders for the profession rather than just technicians.

Furthermore, the master's degree is becoming established as the first professional degree. MIT and Stanford, for instance, have established special programs with the master's as a terminal professional practice-oriented degree, similar to the terminal engineering degree of European continental schools. The American Society of Civil Engineering (ASCE) in May of 1998 also recommended the master's degree as the first professional degree for the practice of Civil Engineering.

What we are therefore proposing is a new type of engineering program -- a three-year Master of Professional Engineering -- for students with a B.A. or B.S. and the proper mathematic, scientific and liberal arts background, or for students who have completed at least three years of college with a superior record in these specified disciplinary areas.

A special-track integrated-five-year program may also be conceived. However, a separate three-year program similar to the law programs would be preferable.

We are not implying or advocating that all engineering programs take this path; only a small number. We believe there is a place for two types of program: a four-year bachelor's plan (with access to the traditional master's eventually) for those who want to be technical engineers or technicians, and a three-year master's, offering a first degree for those who want to be professionals of equal standing with architects, lawyers and physicians.

The following discussion shows how such a program could be articulated.

## Mission

The mission of the Graduate Professional Engineering Program is to:

Provide innovative leadership in integrating the fields of design, invention and entrepreneurship with technological research in a well-defined range of applications.

- Provide professional education of the highest quality to produce graduates at the master's level, equipped to play leading roles as professional Engineering Designers/Inventors or Entrepreneurs/Managers.  Affiliated leading graduate schools will allow students interested in further research to complete their Ph.D.
- Be a transformer, matching the cutting edge design and technology research worldwide to local needs by keeping attuned to its intellectual, artistic, civic and business environments.
- Develop new areas of teaching, applications and research in response to the advance of scholarship and the needs of the community.
- Attract outstanding students, irrespective of race, national origin, gender, financial needs or physical disabilities.
- Advance its position to one of the world's leading professional programs in Engineering.

## Focus

To fulfill its mission as a "transformer," the program will establish strong connections with leading academic research centers in design and entrepreneurship worldwide on one hand, and local high-tech businesses and entities on the other. It will also serve as a link, a resource and an application center for the high-technology and media firms, the businesses, artists, and the civic, governmental, academic, cultural or medical establishments in the geographic vicinity or the community of interest.

Programmatically, it will focus on applications chosen in selected areas where distinctive competencies can be built depending on research opportunities, curricular needs and industrial interest. The technologies enumerated below are examples of such applications. Curricular needs, however, will naturally be the main driving force, and these should be set for the long range.

## Technologies of the Future

The next 10 to 20 years will see great advances and applications in a number of technologies. Those are the technologies for which students must be prepared and trained -- to apply them to the solution of problems and to the design of creative endeavors within the industries and activities of the region. Typical of those technologies -- offered here as examples, not a complete list -- are the following:

- *Design*. The design and construction of the Boeing 777 has set a precedent that is rapidly spreading. The trend is toward:
    - Facilitating conceptual design by means of “invention machines,” helping designers in their search for original solutions to complex engineering situations.
    - Smart manufacturing. Shoppers will link up directly to the factory floor to create individual products for individual customers, from tailoring to furniture making, as well as

  the more traditional engineering products. Rapid prototyping will upgrade to rapid manufacturing.

  - Smart construction. Buildings will be designed, checked and tested in virtual reality labs and erected in the real world with robot assistance.

- *Materials and supermaterials.* The potential for new materials designed molecule by molecule seems almost unlimited. Hundreds of new, high-performance supermaterials and composites will be used in the transportation industries (in cars, air and space crafts, vessels, rail vehicles and bikes, for example) as well as in computers, energy, communications, home appliances and construction.

- *Biotechnologies*. We are standing at the threshold of a golden age for biology. Biotechnologies are where the computer industry was 10 to 15 years ago. The "wet computer" may still be at the "pre-ENIAC" stage, but is bound to develop exponentially in the next two decades.

  Living machine systems made up of living organisms to produce food and fuels, treat wastes, purify the air and regulate climate are now at the experimental stage.

  Genetic engineering, now in its infancy, will see an exponential, if not an explosive, expansion within the same period, in such areas as medical and pharmaceutical applications (diagnostic, preventative and curative) and in agriculture.

- *Information technologies.* The "multimedia revolution" is still at an early stage. Its impact, not only on society in general but particularly on the way learning and teaching occur, and how art is created, are beginning to be appreciated. The probable effects within the next two decades are likely to be as radical as that of the printing press in the last 500 years!

  The scientific and technical development of these information technologies, per se, from miniaturization to Digital HDVT, optical and wet computers; the use of sensors, robots, and other devices; and their adaptation to the arts as well as to the solution of engineering problems, should occupy center stage in engineering schools in the next generation.

- *Energy technologies.* The use of less polluting fuels will expand and require new types of engines burning not a single fuel, but possibly several. Fuel cells, electric batteries with high energy density, and rapid-charge hydrogen generators will no doubt be in demand.
- *Ethics.* Engineers, entrepreneurs, researchers and professionals connected with these technologies will face some of the most difficult issues they have had to consider. The social, political and religious implications of their work will take on an importance for which they have to be prepared.
- *Human/machine/interaction.* A growing field of interest has developed in the last 15 years or so, and though still in its infancy and relatively ignored, promises to change the fundamental paradigm of engineering.

In both Relativistic and Quantum Physics, the role of the observer has been recognized in the establishment of “Reality.” The same kind of interaction between operator and machine has now also been established and is under intensive study. At Princeton, for instance, the Engineering Anomalies Research Laboratory and the Human Information Processing Group address the topic of human/machine interaction from the perspectives of engineering, cognitive science, psychology, linguistics and philosophy. The International Consciousness Research Laboratories and the Academy for Consciousness Studies, also based on Princeton, are pursuing a number of studies in these areas, where equal emphasis is placed on the anomalous, metaphysical and spiritual facets of the topic as on the more canonical issues of rigorous scientific methodology and comprehensive theoretical modeling.

Traditionally, engineers have been technically concerned primarily with transformation within and across the three basic layers of matter, energy and information.  For instance, Civil Engineers have dealt with large structures in matter (bridges, roads, canals, buildings) operating in low energy fields; Chemical Engineers, with transformation of matter of one substance into another (e.g., oil into gasoline or grease or into plastics of various kinds); Mechanical Engineers, with the transformation of energy from one form into another (e.g., heat into mechanical energy or mechanical energy into electricity); Electrical Engineers, with the handling of information (telegraph, telephone, radio, television, computers).  But we are now beginning to hear about Knowledge Engineering and Knowledge Engineers; i.e., of areas and people on the borders of Artificial Intelligence and Natural Intelligence, of expert systems and natural language engineering.

The next step is for the Consciousness Engineers to manifest. Now, in a sense, nothing is new.  More than 3,000 years ago when the Rig-Veda was being composed, according to the very testimony of the Poets who put these hymns together, each verse or mantra was precisely designed in terms of sound and meter to bring about specific results in the reciter and the hearer Consciousness Engineering, indeed!  We are therefore moving back toward the origin, the moment of creation, where science, engineering, technologies and the arts join again together with the humanities to once more affirm our humanity, first realized at the dawn of civilization when Language, Logos, the Word, subdued the beast in us.

## Implications for the Curriculum

The implications of these developments are crucial for the curriculum. The nature of these technologies is highly scientific, while their consequences penetrate not only the social domain, but also the metaphysical, the philosophical and the ethical orders.

The level of sophistication required in the fundamental disciplines of math, physics, chemistry and biology should therefore be of the first order. These technologies also straddle traditional disciplinary boundaries. They require an ability for synthesis that is new in the engineering curriculum. Furthermore, the humanistic and spiritual dimensions of the new paradigms emerging in science and engineering require a profound basis in the humanities, particularly in the areas of linguistics, philosophy and ethics, well-integrated with scientific analysis and engineering practice; i.e., an ability to think synthetically across many fields. It requires a level of maturity that college freshmen and sophomores do not generally possess.

In a recent article in *IEEE Spectrum* (July 1997) on “The Synthesis of Complex Systems,” Eberhardt Rechtin, a retired professor of Electrical Engineering at the University of Southern California and president emeritus of The Aerospace Corporation, makes the point that:

> *Today, in response to dramatic changes in politics and technology, growing numbers in the profession [of engineering] are being challenged to devise systems quite unlike what has gone before. It is not enough just to extrapolate from established designs and technologies and simply expand existing architectures and product lines. Creativity is in*

> *demand, not only for ground-breaking designs, but also for a rethinking of the analysis and of the engineering development and management on which their success depends.*

He continues:

> *Synthesis comes first -- though the idea is difficult for analytically trained engineers to accept, synthesis properly begins well before a set of requirements is firmed up, much less analyzed. It should begin when both requirements and design are still provisional, when each depends upon the other....In systems synthesis the basic lesson -- and the hardest to accept -- is that not all engineering problems can be or should be solved by deduction from mathematical and scientific principles. Synthesis is provisional and qualitative, a way of thinking different from the definitive, quantitative thinking of analysis. Its technique and tool reflect this difference.*

Dr. Rechtin notes that three qualitative techniques are fundamental: heuristics, metaphors and models -- heuristics being brief statements of lessons learned in the past and applicable to the present situation, while metaphors transpose the implicit behavior of a system to a more familiar context; one example is the desktop metaphor for personal computer operating systems. Models are used to present different perspectives of a proposed system to multiple shareholders so that everyone has a common frame of reference for discussion. They are a representation or abstraction of selected features of a system.

> *Heuristics, metaphors and progressive modeling are all elements of what many architects would call 'common sense.' But those techniques become contextual sense -- sense in the context of the problem -- only through experience and the ability to recognize when to apply what.*

What is really needed, he suggests, is to educate students to this new way of thinking, more akin to the architect's approach than to the traditional engineering approach.

> *This state of affairs is hard on most engineers who have been taught for at least 40 years that engineering is an applied science. Yet, the most difficult problems in syntheses -- such as perception of worth, safety, affordability and social acceptability -- resist numerical expression.*

We have therefore to educate engineering students to be architects of technologies and synthesizers of technological systems, in addition to their traditional training in the analytical approach.

It is interesting to note also that in the *American Scientist* of January-February 1997, Robert Root-Bernstein writing on "Art, Imagination and the Scientist" points out that scientists should strive to be "the imaginative and the analytical -- the artist and the scientist -- both at once."

If that is true for the scientist, *how much more for the engineer!* In the discussion that follows that article, Root-Bernstein adds:

> *The most successful [scientists] (whether measured by prizes or various citations statistics) were*

> *unusual in being skilled artists, writers, and/or musicians, making use of visual, kinesthetic and other nonverbal and nonmathematical forms of reasoning. All stated in interviews that C.P. Snow's 'two culture' problem does not exist -- at least for talented scientists!...*
>
> *One implication is that over and early specialization in science may actually harm, rather than benefit, science students. In order to see connections between different fields or imagine a field differently, one needs a broad range of skills and a practiced imagination, not just knowledge. The arts, apparently, can help.*

## Curriculum Structure

From these considerations we can begin to piece together a curriculum to educate highly selected students for a professional career as Engineering Designers/Inventors, Entrepreneurs/Managers, or Researchers in emerging technologies. A proposed outline follows:

*First year*. In our proposed three-year graduate curriculum, after the first year, students should have accomplished the following:

- Gained an introduction to synthetic thinking and system architecting, from product design to large-scale systems, through case studies and practice.
- Been introduced to engineering analysis and modeling from the "back of the envelope" to computer simulation of existing typical engineering systems; i.e., reducing a physical situation to an appropriate model for design analysis.
- Gained an appreciation for the interplay of synthesis and analysis through some design experience.

- Gained an understanding of experimental methods and have experience with experimental techniques.
- Learned the fundamental principles of engineering science (e.g., mechanics, thermodynamics, field theory, materials, basic circuits and electronics).
- Gained an ability to create and evaluate software.
- Developed powers of presentation visually, orally and in writing.
- Gained an understanding of metaphoric thinking and the use of metaphors in the humanities and social sciences (e.g., through poetry, creative writing, cultural/historical perspectives, history of technology or history of ideas).
- Demonstrated an appreciation for biological evolution and cellular processes (the cell as a factory) and of ecological cycles.

The first year is the year of acquaintance with new ways, new paradigms and new perspectives, and where a common base is established for all students. Because they are coming from different backgrounds (some may have had a rigorous pre-engineering program, some may have already obtained a first degree in math or science or indeed in literature, philosophy or business, or have a background in art or architecture), great flexibility will have to be built into the program to ensure the possibility for students to receive the complement of education they may individually require. This can be accomplished through a competency-based curriculum for which students' competencies in a given area are assessed against published criteria. Learning is individualized. Learning experiences follow a studio format, relying on prepared modules for basic material coverage and on research projects for more specialized learning. It implies on the part of the faculty pedagogical research and practice to closely integrate student learning into the curriculum progression.

The program under discussion assumes a two-semester academic year and summer internships to conform to most academic calendars across the nation. However, a more detailed study may show a trimester or a quarter calendar to be more appropriate.

Pedagogical practice and studies have shown the benefit on the effectiveness of learning of limiting the number of responses per term to five or less. In the proposed curriculum (except for the first term, for which there are six, which can easily be modified), the number of responses would vary from four to five each term. When an area of study such as Engineering Science calls, for example, for up to nine credits (equivalent to three courses), the material for each of these courses would be presented sequentially rather than in parallel. The practice is common in schools working on a trimester or a quarter system, and is to be found often in Europe. It is therefore neither unrealistic nor particularly difficult to implement. It is especially well suited to an individualized competency-based curriculum such as the one proposed here.

In terms of daily schedule, every effort should be made to schedule classes in the mornings, reserving afternoons for projects, laboratories and similar activities, while keeping the evenings open to maximize the involvement of students with cultural and other such functions that will broaden their circle of interest and contacts.

The first-year curriculum may therefore look as shown in Table 4. For convenience of comparison, traditional credit hours have been assigned to give an idea of the load involved. However, this may vary since student backgrounds would be different and would be assessed on the basis of what they know and have achieved, rather than on the basic of the courses they have "taken."

**Table 4. Year 1 Curriculum**

| | | | | Total | | |
|---|---|---|---|---|---|---|
| | **Fall** | **Spring** | **Summer** | **cr** | **% of 1st Year** | **% of All 3 Years** |
| Introduction to Synthetic Thinking and System Architecting | 3 | | | 3 | 7 | 2.5 |
| Introduction to Engineering Analysis | 3 | | | 3 | 7 | 2.5 |
| Design | 3 | 3 | | 6 | 15 | 5 |
| Experimental Methods | | 3 | | 3 | 7 | 2.5 |
| Engineering Sciences | 3 | 6 | | 9 | 21 | 7.5 |
| Basic Science/Math | 3 | 3 | | 6 | 14 | 5 |
| Humanities/Social Science Seminar | 3 | 3 | | 6 | 15 | 5 |
| Internship | | | 6 | 6 | 14 | 5 |
| **Total Credit** | **18** | **18** | **6** | **42** | **100** | **35** |

*Percentages are rounded up to total 100.*

The spring semester Humanities/Social Science Seminar would bring together engineering, art and architecture students working in groups on thematic projects. The summer internship (preferably abroad) would be combined with intensive language study and would emphasize a particular technology.

*Second year.* In the second year, the new paradigms and approaches learned in the first are applied to the full, and students begin to specialize according to technologies of their choice.

The emphasis is on detailed knowledge of these fields and on their integration. The Humanities/Social Science Seminar would address ethics and laws, globalization, geopolitics, geoeconomics and the city, and their interplay with the development of the new technologies.

After the second year, students should have accomplished the following:

- Gained an in-depth understanding of engineering science in specialized areas and of the different basic sciences and mathematics.
- Progressed further in their ability in system architecting and engineering analysis through design experience.
- Developed cooperative and communication skills.
- Gained an understanding of the ethical, legal, political, economic, environmental and cultural implications of the technologies they are specializing in.

Table 5 indicates the rough distribution proposed.

**Table 5. Year 2 Curriculum**

| | | | | **Total** | | |
|---|---|---|---|---|---|---|
| | **Fall** | **Spring** | **Summer** | **cr** | **% of 2nd Year** | **% of All 3 Years** |
| Engineering Design | 3 | 6 | | 9 | 21 | 7.5 |
| Engineering Science | 9 | 6 | | 15 | 36 | 12.5 |
| Basic Science/Math | 3 | 3 | | 6 | 14 | 5 |
| Humanities/Social Science Seminar | 3 | 3 | | 6 | 15 | 5 |
| Internship | | | 6 | 6 | 14 | 5 |
| **Total Credit** | **18** | **18** | **6** | **42** | **100** | **35** |

*Percentages are rounded up to total 100.*

Depending on students' needs and backgrounds, Engineering, Science and Basic Science/Mathematics could substitute for one another. Alternatively, Design could be substituted for either. This would be determined by students satisfying competence-level requirements in these disciplines.

The summer internship would emphasize one of the orientations (design/invention, entrepreneurship/management or research).

*Third year.* In the third and final year, students pursue a specialization in their chosen technologies and fully differentiate in their orientation towards design/invention, entrepreneurship/ management or research. The emphasis is on professional practice.

After the third year, students should have accomplished the following:

- Gained an in-depth understanding of an area of technology and be familiar with its technological and non-technological issues.
- Developed creativity and a capacity for innovation and for independent learning and inquiry in design/invention, entrepreneurship/management or research.
- Developed expertise in the synthesis, design, analysis and operation of technological systems in their industrial and commercial contexts.

In addition, *design/invention students* should have:

- Gained an understanding of international patent systems and intellectual property management.
- Developed an awareness of design research issues.

- Gained a familiarity with a wide range of design tools, software and hardware.
- Gained expertise in prototyping and testing.
- Gained expertise in all the phases of the design process, from conception to manufacturing to recycling.
- Acquired leadership qualities in design team management.
- Developed an understanding of the economy of design.
- Developed the ability to sell ideas and negotiate.

*Entrepreneurship/management students* should have:

- Gained an understanding of accountancy.
- Gained an understanding of a wide range of industrial processes and management styles, both in the united States and abroad.
- Developed abilities to analyze data, to synthesize solutions, to communicate at all industrial and business levels, to sell ideas and to negotiate.
- Gained an awareness of venture-capital and market practices.

*Students interested in research* in specialized technologies and in pursuing a Ph.D. at an affiliated graduate school should have qualified to begin thesis work at that graduate school.

Table 6, on page 97, indicates a possible curriculum for Year 3.

The Humanities/Social Science Seminar in the third year would center on cultural, philosophical and spiritual contexts. Under "Professional" would be included such topics as international patent systems for the designer or accountancy for the entrepreneurs, whereas research students might take advanced courses in a specific area of mathematics, science or engineering.

### Table 6. Year 3 Curriculum

| | | | | **Total** | | |
|---|---|---|---|---|---|---|
| | **Fall** | **Spring** | **Summer** | **cr** | **% of 3rd Year** | **% of All 3 Years** |
| Practicum/Project Options:<br>■ Design/Invention<br>■ Entrepreneurship/Management<br>■ Research | 6 | 9 | | 15 | 41 | 12.5 |
| Professional | 6 | 3 | | 9 | 25 | 7.5 |
| Other | 3 | 3 | | 6 | 17 | 5 |
| Humanities/Social Science Seminar | 3 | 3 | | 6 | 17 | 5 |
| **Total Credit** | **18** | **18** | **Employment** | **42** | **100** | **35** |

*Percentages are rounded up to total 100.*

Under the heading “Other,” students would be encouraged to explore some unconventional topic having no obvious connection with their professional pursuit. Options could range from the study of an ancient language to modern dance, politics, philanthropy, social work, the practice of a given art or whatever strikes their fancy, excites their minds or satisfies their hearts and is deemed worthy of academic interest. Students would write a proposal for such “other” projects and conclude the project with a report. Only Pass/Fail would be given.

## Students

Students will be selected on the basis of their high academic achievements and abilities. However, a special effort will be made to recruit students gifted for design and invention, for entrepreneurship and management, or for research. Students will be expected to have completed with superior standing at least two years in a pre-engineering program, but many will already have a first degree in another field, from mathematics and science to literature or philosophy, art or architecture. Many will have life experience in addition, but all will have a determination to excel. The student body will be non-traditional and non-homogeneous.

The graduates of this program should be scientific and technical innovators, agents of change, entrepreneurs and leaders, decision-makers who can make choices in accordance with a set of priorities that includes wide and varied contexts.

Theses opportunities call for a broader range of interests than is usually and currently the case among engineering students. National surveys show that, in general, engineering students:

- Like *things* more than people.
- Avoid open-ended problems and are intolerant of ambiguity.
- Have lower than average aesthetic interests.
- Have a strong drive for economic success and security.
- Have no particular interest in philosophy, history, literature, foreign languages and the fine arts.

The degree of maturity and sophistication expected of the students will therefore be considerably higher than that of the typical 18-year-old high-school graduate. This is dictated by the highly scientific nature of the technologies involved and the fact that their consequences penetrate not only the social domain but also the metaphysical, the philosophical and ethical orders.

## Faculty

In addition to a solid core of full-time and part-time faculty of professionals, four or five scholars/entrepreneurs of international reputation would be required to lead and develop the technology programs.

## Economic Impact

A study of the potential economic effect such a school might have, located in the heart of its region, should be undertaken. What potential feedback might accrue to it should be considered. The synergy of Stanford and Silicon Valley, MIT and Route 128, Carnegie Mellon and Pittsburgh high-tech firms should be studied and lessons drawn.

## Outreach

The synergetic and multiplier effect mentioned above would have a large effect on local employment and job creation. High-tech firms require not only engineers and highly-trained personnel, but a whole range of services. They are the engines of economic development.

# APPENDIX

Gateway Coalition
The Cooper Union for the Advancement of Science and Art

# Gateway at Cooper Union Projects -- Years 0-8

## Design-related projects

Brooks Design Series ★▲
Concurrent Engineering and Manufacturing -- ME 163, ME 164, ME 363, ME 364 ★▲
GlobeTech/Global Perspectives in Technology Management -- EID 372 ★▲
Engineering Design and Problem Solving -- EID 101 ★▲
Principles of Design -- EID 103 ★▲
Design, Illusion and Reality -- EID 111 ★▲
Product Design -- ME 425 ★▲
Assessing Communication Modes in Students’ Engineering Design Projects ●
Environmental Design/Manufacturing Management ▲
Tools and Techniques of Design Workshop ▲
The Engineering of Nature; Constructals ▲
Fluid Mechanics and Engineering Mechanics in Design: The Pilot Interdisciplinary Studio/Classrooms ▲
Engineering Design in Context ▲

## Other projects

Students’ Assessment of Curriculum ●
Virtual Soil Mechanics Laboratory -- ETM-11-CU2 ★▲
Assessment Program ★▲
Women’s Leadership Project ★▲
Redesigning in Practice (Became Product Design -- ME 425) ★▲
Multi-Year, Multi-University Project (Became Design, Illusion and Reality -- EID 111) ★▲

★ = Institutionalized
▲ = Ongoing
● = Complete
■ = Discontinued

## *Gateway at Cooper Union Projects -- Year 0-8*

Environmental Engineering ●▲
Fluid Mechanics ●▲
Seminar for High School Women ★▲
Remote Experiment ●■
BioTechnology Project ●
New Teaching Modes Workshop ▲
Introducing QA Concepts ●■
Coalition Survey/HPD Activities ●■
Summer Research Internship for High School Students ★▲
Integration of Math/Physics/Engineering ●■
Designing the Paperless Environment ●■
Fluids, Flows and Fields ●■
K-12 Outreach ★▲
Integration of Humanities/Social Sciences ■
VLSI Design ■
Quantum Structure ●■
GIS ●
Solid State Materials ●

★ = Institutionalized
▲ = Ongoing
● = Complete
■ = Discontinued

Gateway Coalition
The Cooper Union for the Advancement of Science and Art

## Industry Support and Involvement Year 1 to Year 7

Electrokinetics Gallery
*Collaborative Project*

Northrup Grumman
*Internship Program*

Ford Motor Company
*Recruitment and Programs*

ABB Lummus Global
*Recruitment*

ABC, Inc.
*Recruitment*

AIL Systems
*Recruitment*

Air Products and Chemicals, Inc.
*Recruitment*

Alcoa Laboratories
*Recruitment*

Allegheny Power Systems
*Klaus Bergman, Member of*
*Engineering Advisory Council*

Alliance Capital
*Recruitment*

Allaint Techsystems
*Richard Schwartz, Member of*
*Engineering Advisory Council*

Allied Signal, Inc.
*Recruitment*

American Bureau of Shipping
*Recruitment*

Andersen Consulting
*Recruitment*

Asea Brown Boveri
*Richard J. Slember, Member of*
*Engineering Advisory Council*

Automation Control Specialist
*Recruitment*

Avnet Inc.
*Leon Machiz, Member of*
*Engineering Advisory Council*

Bayway Refinery
*Recruitment*

Becton Dickinson
*Representatives participated in*
*Axiomatic Design Project-Course*

Bechtel
*Recruitment*

Bell Atlantic
*Recruitment*

Bellcore
*Recruitment*

Brooklyn Union Gas
*Recruitment*

Burns & Roe
*Recruitment*

Cambridge Technology
*Recruitment*

Central Intelligence Agency
*Recruitment*

The Chase Manhattan Bank
*Recruitment*

Citibank
*Recruitment*

Clough Harbour & Associates
*Recruitment*

CS First Boston
*Recruitment*

Consolidated Edison Co. of New York
*Recruitment*

Cytec Industries
*Recruitment*

Department of Civil Service Home Page
*Recruitment*

Department of Civil Service examinations information
*Recruitment*

Deutsche Bank
*Recruitment*

DIS Research
*Recruitment*

DMR Consulting Group
*Recruitment*

Domino Sugar Corporation
*Recruitment*

EDO Corporation
*Recruitment*

Electrokinetics Gallery
*Joint Project/Exhibition*

Exxon
*Recruitment*

Flack & Kurtz
*Recruitment*

GEC Marconi Hazeltine Corporation
*Recruitment*

General Electric
*Recruitment*

Globix Corp.
*Recruitment*

Goldman-Sachs/Information Technology
*Recruitment*

Grant Thornton
*Recruitment*

Grow Tunneling Corporation
*George A. Fox, Member of Engineering Advisory Council*

Ing Barings
*Recruitment*

Jaros, Baum, & Bolles
*Recruitment*

JP Morgan
*Philip Weisberg, Member of Engineering Advisory Council*

Kearfott Guidance & Navigation
*Recruitment*

Keyence
*Recruitment*

Lambda Electronics
*Recruitment*

Lehman Brothers
*Recruitment*

Lenox Hill Hospital
*Rock Gerard Positano, D.P.M., Member of Engineering Advisory Council*

Lewco Securities
*Recruitment*

Lockheed Martin
*Recruitment*

Lockwood Greene
*Recruitment*

Lucent Technologies
*Representatives participated in Axiomatic Design Project-Course*

McKinsey & Co.
*Recruitment*

MetLife
*Recruitment*

Microsoft
*Recruitment*

Mobile Datacom Corporation
*Joel R. Alper, Member of Engineering Advisory Council*

MTA New York City Transit
*Recruitment*

Myers-Holum, Inc.
*Recruitment*

National Action Council for Minorities in Engineering
*George Campbell Jr., Member of Engineering Advisory Council*

National Instruments
*Recruitment*

National Renewable Resources, Inc.
*Jeffrey Kossak, Member of Engineering Advisory Council*

NCR
*Recruitment*

National Security Agency
*Recruitment*

NYNEX
*Recruitment*

OTEC.COM
*Recruitment*

Petroleum Geologist
*Edward R. Hewitt, Member of Engineering Advisory Council*

Paine Webber
*Recruitment*

PairGain Technologies, Inc.
*Howard Flagg, Member of Engineering Advisory Council*

Parsons Transportation Group
*Recruitment*

Parsons Brinckerhoff Construction Services, Inc.
*Recruitment*

Plasma Physics Laboratory, Princeton University
*Russell Hulse, Ph.D., Member of Engineering Advisory Council*

Pro-Found Software, Inc.
*Recruitment*

Prudential Securities
*Recruitment*

P.W. Grosser Consulting
*Recruitment*

Radix Group International, Inc.
*Pierre L. Schoenheimer, Member of Engineering Advisory Council*

Raytheon Electronic Systems
*Recruitment*

Reuters
*Recruitment*

SAIC
*Recruitment*

Saterlee, Stephens, Burke and Burke
*Seth Dubin, Esq., Member of Cooper Union Engineering Advisory Council*

SavvySoft
*Recruitment*

Slattery Skanska Inc.
*Recruitment*

Sprint
*Recruitment*

Standard Microsystems Corporation
*Recruitment*

Star Media
*Recruitment*

State of New York
*Recruitment*

Submarine Systems
*Recruitment*

Sverdrup Civil Inc.
*Recruitment*

Symbol Technologies
*Representatives participated in Axiomatic Design Project-Course*

TAMS Consultants
*Recruitment*

Telecom Analysis Systems, Inc.
*Recruitment*

Teledyne Brown Engineering
*Recruitment*

Tigris
*Recruitment*

Total Network Solutions
*Recruitment*

Trilogy
*Recruitment*

Tyco Submarine Systems
*Recruitment*

U.S. Securities and Exchange Commission
*Marisa Lago, Member of Engineering Advisory Council*

Veterans Administration Medical Center
*Rosalyn Sussman Yalow, Ph.D., Member of Engineering Advisory Council*

Vollmer Associates
*Recruitment*

# Products and Processes

## Products

Leonardo CD-Rom
Steam Engine CD-Rom (in progress)
MYMUP Case Study Video
Women's Leadership Program Video and Instructional Materials
Concurrent Engineering Modules
Virtual Soil Mechanics Laboratory Modules
Environmental Engineering Modules
G.I.S. Modules
Water Resource Engineering Modules
Robot Arm Prototype
"On the Motive Power of Fire" Book

## Processes

GlobeTech Simulation
Design, Illusion, and Reality Course (MYMUP)
Alumni Surveys
Exhibitions
Assessment
Concurrent Engineering

## Top Five Products and Processes

Assessment
GlobeTech
Concurrent Engineering
Virtual Labs
MYMUP

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# Visits and Visitors, Year 1 to Year 7

The following individuals visited Cooper Union, met with Gateway faculty and staff, and were given tours of the facility and information on specific Gateway programs, for the purpose of future collaboration on projects and on initiating similar programs at their institutions.

**Ernest Aguayo**
Director of Educational
Initiatives, M.I.T.

**Jean Michel Alaverdov**
Albi School of Mines, Albi, France

**Armand Berner**
International Relations, Ecole
nationale d'ingéniurs de Metz,
France

**Mary Bowden**
University of Maryland, Department
of Mechanical Engineering and
Aerospace

**Woosuk K. Choi**
The Chosun Ilbo Co., Ltd.,
Seoul, Korea

**Dr. Imre Czinege MSc. (Eng) PhD**
Bánki Donát Polytechnic,
Budapest, Hungary

**Alexi Kostarev**
State Technical University of
St. Petersburg

**Ing. Norberto A. Lemoxy**
University of Buenos Aires

**MTA Representatives**
Evaluated MYMUP project
presentations

**Alfred H. Brand**
Mueser Rutledge Consulting
Engineers

**NASA Representatives**
Collaborated on project proposal

**Leon Oher**
Pauliskolan, Malmö, Sweden

**Ing. Horatio E. Podesta**
Otto Krause Engineering School,
Paseo Colón

**Roberta Zulawski**
ASME International

Gateway Coalition
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# Staff and Faculty

## Staff

**Jean Le Mée**
*Mechanical Engineering Professor and Chair, Director of Curriculum Development and Innovation, Gateway Institutional Activities Leader*

**Gerardo del Cerro**
*Assessment Director*

**Norah Pierson**
*Gateway Coordinator*

## Faculty

**Om Agrawal**
*Mathematics Professor*

**Hamid Ahmad**
*Associate Electrical Engineering Professor*

**Zikri Ahmed**
*Chemical Engineering Professor*

**Paul Bailyn**
*Mathematics Professor and Chair*

**Irv Brazinsky**
*Chemical Engineering Professor and Chair*

**Joseph Cataldo**
*Civil Engineering Professor*

**Toby Cumberbatch**
*Associate Electrical Engineering Professor*

**Fred Fontaine**
*Associate Electrical Engineering Professor*

**Samuel Gelfman**
*Physics Professor and Chair*

**Vito Guido**
*Civil Engineering Professor*

**Jeff Hackner**
*Telecommunications Director*

**Joel Hollenberg**
*Mechanical Engineering Professor*

**Robert Hopkins**
*Computer Center Director and Mathematics Professor*

**Roxanne Jacoby**
*Adjunct Mechanical Engineering Professor*

**Belka Kraimeche**
*Electrical Engineering Professor*

**Margaretha Lam-Anderson**
*Assistant Mechanical Engineering Professor*

**Jacqueline Li**
*Assistant Professor of Material Science*

**Judith Lyczko**
*Special Projects Director*

**Andrea Newmark**
*Student Advisor and Associate Chemistry Professor*

**Charles Okorafor**
*Associate Chemical Engineering Professor*

**Sam Schwartz**
*Adjunct Civil Engineering Professor*

**George Sidebotham**
*Associate Chemical Engineering Professor*

**Richard Stock**
*Internship Director and Assistant Chemical Engineering Professor*

**Cosmas Tzavelis**
*Associate Civil Engineering Professor*

**Liselot van der Heijden**
*Adjunct Art Professor*

**Chih-Shing Wei**
*Mechanical Engineering Professor*

**Winston Wilkerson**
*Audio Visual Director*

**Alan Wolf**
*Associate Physics Professor*

**Constantine Yapijakis**
*Civil Engineering Professor*

Gateway Coalition

The Cooper Union for the Advancement of Science and Art

# Presentations and Publications, Year 1 to Present

1. “Freshman Engineering Design at Cooper Union.” Presented by Cosmas Tzavelis, ASEE Middle Atlantic 1993 Fall Meeting.
2. “Solid State Materials/Quantum Structure of Materials,” by Fred Fontaine and Toby Cumberbatch, Gateway Report 1994.
3. “Rapid Prototyping and Concurrent Design.” Gateway presentation by Professor Stan Wei, 1994, 1995,1996,1997,1998.
4. “GlobeTech Project,” World Conference on Engineering Education, 1995, by Professor Roxanne Jacoby.
5. “Environmentalism in the Urban Context.” Presented by J. Cataldo, National Endowment for the Humanities, Winter 1995.
6. “Environmental Curriculum Development,” by C. YapiJakis and J. Cataldo, May 1995, at OSU.
7. “Environmental Engineering,” program presentation, August 1995, at NJIT. The environmental engineering modules developed were presented and a discussion followed.
8. “Engineering Biotechnology: Bio-instrumentation.” Report and presentation by Dan Raichel and Ron Adrezin, 1996.
9. “Smart Street Kiosk,” video and oral presentations by MYMUP students under the supervision of Professor Sam Schwartz, 1996. (Resulted in a feature story on the local news and on the Discovery Channel.)
10. “Applying OM (Operations Management) Principles to The Cooper Union,” by Professor Roxanne Jacoby and others. Presented to faculty and administration at Cooper Union, April 16, 1996.
11. “Recent Strides Towards Global Engineering Practice Education at the Nerken School of Engineering, Cooper Union,” by Roxanne Jacoby and Jean Le Mée. Presented at the 1997 ASME Conference in San Diego.

12. “An Introduction to Astronomy and Astrophysics for Urban High School Students,” by Winston Wilkerson, 86th AAVSO Spring Meeting, St. Luc, Switzerland, May 26-31, 1997. Description: Introducing astronomy and astrophysics to high school students in large urban centers, based on work with the NSF Young Scholars Summer Research Internship Program at Cooper Union.
13. “Shared Resource Module for Environmental Engineering Education,” 1998. Co-Author, Joseph Cataldo. Series of environmental shared resources modules.
14. “A Drainage Module for Environmental Engineering,” by Joseph Cataldo, 1998 ASEE Annual Conference.
15. “Use of Photo-Oxidation in the Treatment of Hazardous Waste,” by Constantine Yapijakis and M. Westbrook. Presented at the 70th Annual NYWEA Conference and Exposition, New York City, February 1998.
16. “Use of Rapid Prototyping Equipment in Teaching Manufacturing Engineering,” by C.S. Wei, 1998 ASEE Conference, Seattle, Washington, June 22-24, 1998. Description: Presented the use of an ActuPage A-2100 rapid prototyping machine in teaching concurrent design and manufacturing project courses.
17. “Development of an Autonomous Mobile Robot,” by E. Mar and C. Wei, IASTED International Conference on Robotics and Manufacturing, Banff, Canada, July 26-29, 1998. Description: Demonstrated the practicality of integrating ready-made mechatronics parts into a programmable, autonomous mobile robot.
18. “GIS Applications.” Presentation at Cooper Union Driscoll Multimedia Auditorium, October 1998.
19. “Web Based Global Technology Management Education,” by Roxanne Jacoby FIE’98 Conference, Tempe AZ, November 4-9, 1998.
20. “Assessing Communication Modes in Students’ Engineering Projects: A Case Study of the Robotics-for-Theatre Project,” by Gerardo del Cerro, Ericson Mar, Chih-Shing Wei and Carl Weiman, The Cooper Union Brooks Engineering Design Center, Studies in the Design Process and Design Education, Series A, Number 2, 1999.

21. “Manual of Practice: Cleanup of Contaminated Sites,” by C. Yapijakis. Published by Wayer Environment Federation, Alexandria, VA, January 1999.
22. “Web Based Global Technology Management Education,” by Roxanne Jacoby, EDI’99 Conference, Maui, Hawaii, March 17-25, 1999. Also, 2nd Regional Conference on Innovations in Teaching and Learning, NJIT, January 14, 1999.
23. “Pollution Prevention in the Construction Industry,” by C. Yapijakis and B. Mills. Presented at the 71st Annual NYWEA Conference and Exposition, New York City, February 1999.
24. “Sustainable Development -- Energy Generation, Use, and Conservation,” by C. Yapijakis. Presented at Earth Day Seminar, New York City, April 1999.
25. “Panel and Symposium on Art and New Media,” Art and Science Collaborations, Inc. (ASCI) CYBERART99 -- Sunday, May 9, 1999, Great Hall at Cooper Union, New York.
26. “The On-Line Art World: A Work in Progress,” by Adrianne Wortzel, The New School Special Programs, New York -- Panel and Symposium Monday, May 10, 1999.
27. “Virtual Reality in a Text-Based Environment.” Adrianne Wortzel co-authored with David Casucaberta (Spain), Jesús Adrian (Spain) and Robin Petterd (Tasmania). First Interdisciplinary Conference of The International Society of The Arts, Mathematics and Architecture, ISAMA 99; San Sebastián, Spain, June 7-11, 1999.
28. “An Undergraduate Product Realization and Prototyping Workcell,” by C.S. Wei, 1999 ASEE Conference, Charlotte, NC, June 20-23, 1999. Presented the concept of combining a 3-D scanning facility with a rapid prototyping machine to provide students with a practical product development tool set that can be readily integrated into an instructional CAD/CAM environment.
29. “Introducing Engineering Students to Global Technology Management Issues: The GlobeTech Project,” by Roxanne Jacoby, ASEE’99 Conference, Charlotte, NC, June 20-23, 1999.

30. “An Introduction to Astronomy and Astrophysics for Urban High School Students,” by Winston Wilkerson 111th Annual Meeting of the Astronomical Society of the Pacific, July 1-7, 1999, University of Toronto, Canada. Description: Introducing astronomy and astrophysics to high school students in large urban centers, based on work with the NSF Young Scholars Summer Research Internship Program at Cooper Union.
31. “Globe Theater: Robotic Pageants,” by Adrianne Wortzel. Leonardo, The International Society for the Arts, Sciences and Technology, M.I.T. Press, Vol. 32, No. 2., August 1999. Description: Sayonara Diorama, an electronic multimedia performance with robots and actors; live, with remote participants over the Internet.
32. “Water Quality: Reflection of Land Use,” by C. Yapijakis. Unesco Monograph, Paris, France, August 1999.
33. “Rewrapping the Real World: Using Hyper-Narrative in Virtual Spaces to Create Uncommon Realities,” co authored by David Casacuberta (Spain), Robin Petterd (Tasmania), Adrianne Wortzel (USA). Presented at the International Society for Electronic Artists, Sao Paulo, Brazil, August 25-29, 1999.
34. “Knowledge-Building Environments in Engineering Education,” by Gerardo del Cerro. Presented at “Collaborating in the Design and Assessment of Knowledge-Building Environments in the 2000’s,” Computer Supported Collaborative Learning Conference, Stanford University, Palo Alto, CA, December 1999.
35. “New York City Watershed Management Plan -- The Problems and Advantages,” by C. Yapijakis. To be presented at the WEF Conference, Vancouver, Canada, 2000.
36. “Combined Fixed-Film and Slurry Aerobic Treatment of Industrial Wastes,” by C. Yapijakis and R. Forstner. Accepted for the Annual NYWEA Conference and Exposition, New York City, February 2000.
37. “Assessment as Learning: Assessing a Freshman Design Course,” by Gerardo del Cerro. Accepted for Best Assessment Processes III, Rose-Hulman Institute of Technology, Terre Haute, IN, April 2000.

38. “Design Principles for Freshman/Sophomore Engineering and Technology Students,” by Jean Le Mée, Gerardo del Cerro, and John Razukas. Accepted for the ASEE Conference, St. Louis, June 2000.
39. “Engineering Design in Context: Design Projects and Exhibitions Designed to Stimulate Students’ Interest in the History of their Profession and their Obligation to Inform the Public About the Work of Engineers,” by Jean Le Mée and Liselot van der Heijden. Accepted for the ASEE Conference, St. Louis, June 2000.
40. “Evaluation of the Impact of Multi-Educational Methods in an Environmental Engineering Class,” by Gerardo del Cerro and C. Yapijakis. Paper accepted for the ASEE Annual Conference, St. Louis, MO, June 2000.
41. “For a New Type of Engineering Program,” by Jean Le Mée. Accepted for the ASEE Conference, St. Louis, June 2000.
42. “GlobeTech,” by Roxanne Jacoby. Accepted for the ASEE Conference, St. Louis, June 2000.
43. “Interdisciplinary Senior Design Projects -- Bringing Reality into the Classroom,” by C. Yapijakis. Accepted for the ASEE Conference, St. Louis, June 2000.
44. “The Virtual Soil Mechanics Laboratory,” by Vito Guido and Gerardo del Cerro. Accepted for the ASEE Conference, St. Louis, June 2000.

# Gateway Coalition
# The Cooper Union for the Advancement of Science and Art
# Institutional Metrics Years 0-11

| | ACTUAL PERFORMANCE | | | | | | PROJECTED PERFORMANCE | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Year 0 (1992) # or $** | % | **Year 5 (1997) # or $** | % | **Year 7 (1999) # or $** | % | **Year 8 (2000) # or $** | % | **Year 9 (2001) # or $** | % | **Year 10 (2002) # or $** | % | **Year 11 (2003) # or $** | % |
| **A. Assessment and Continuous Improvement** | | | | | | | | | | | | | | |
| 1. Undergraduate programs with explicitly documented mission statements and educational objectives, outcomes and assessment processes. | 0 | 0 | 2-Jan | 30 | 7/7 | | 7 | 100 | 7 | 100 | 7 | 100 | 7 | 100 |
| 2. Undergraduate programs with explicitly stated educational objectives, outcomes and assessment processes. | 0 | 0 | 15 | 7 | 40 | 20 | 100 | 50 | 130 | 65 | 160 | 80 | 180 | 90 |
| 3. Gateway dollars spent on assessment initiatives for the past year and its percent of total assessment expenditures. | 0 | 0 | $25,000 | 33 | $35,000 | 33 | $35,000 | 33 | $35,000 | 33 | $35,000 | 33 | $35,000 | 33 |
| 4. Undergraduate courses that apply alternative assessment processes (beyond traditional classroom tests) to measure student learning outcomes. | 0 | 0 | 10 | 5 | 30 | 15 | 50 | 25 | 100 | 50 | 150 | 75 | 160 | 80 |
| 5. Undergraduate students that have participated and benefited from the use of alternative assessment processes, such as self and peer evaluation, portfolios, etc. | 0 | 0 | 120 | 25 | 350 | 70 | 392 | 80 | 441 | 90 | 490 | 100 | 590 | 100 |
| 6. Is longitudinal tracking in place? If yes, is it done as part of the University's central student information system or as an independent local process within a department or the College? | No | | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| 7. Which Cohorts (class of 97, class of 98, alumni, etc.) are being tracked longitudinally? | 0 | | 90-94 | | 90-98 | | 90-99 | | 90-00 | | 90-01 | | 90-02 | |
| **B. Professional Development** | | | | | | | | | | | | | | |
| 1. Senior (tenured) faculty attending educational-oriented conferences/symposia, such as ASEE and FIE, in the past year. | 3 | 8 | 6 | 17 | 10/35 | 30 | 12 | 34 | 13 | 37 | 15 | 42 | 15 | 42 |
| 2. Junior (non-tenured) faculty attending educational-oriented conferences/symposia, such as ASEE and FIE, in the past year. | 1 | 16 | 2 | 33 | 3/6 | 50 | 4 | 67 | 5 | 83 | 5 | 83 | 5 | 83 |

# Gateway Coalition
# The Cooper Union for the Advancement of Science and Art
# Institutional Metrics Years 0-11

| | ACTUAL PERFORMANCE | | | | | | PROJECTED PERFORMANCE | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Year 0 (1992) # or $** | **%** | **Year 5 (1997) # or $** | **%** | **Year 7 (1999) # or $** | **%** | **Year 8 (2000) # or $** | **%** | **Year 9 (2001) # or $** | **%** | **Year 10 (2002) # or $** | **%** | **Year 11 (2003) # or $** | **%** |
| 3. Formal in-house faculty development seminars and workshops conducted during the past year.. | 1 | | 3 | | | | 6 | | 6 | | 6 | | 6 | |
| 4. Senior (tenured) faculty who have attended at least one formal professional development seminar or workshop in the past year. | 6 | 17 | 13 | 37 | 20/35 | | 22 | 63 | 25 | 71 | 26 | 74 | 27 | 77 |
| 5. Junior (non-tenured) faculty who have attended at least one formal professional development seminar or workshop in the past year. | 1 | 14 | 3 | 43 | 4/6 | 66 | 5 | 83 | 5 | 83 | 5 | 83 | 5 | 83 |
| 6. Gateway dollars spent on faculty development initiatives for the past year and its percent of total faculty development expenditures. | 0 | | 0 | | 5,162 | 2 | 3,000 | | 2,000 | | 1,000 | | 0 | |
| **C. Underrepresented Populations** | | | | | | | | | | | | | | |
| **D. Educational Technology** | | | | | | | | | | | | | | |
| 1. Undergraduate lower division courses that use multimedia or internet-based materials to supplement student learning. | 0 | 0 | 4 | 20 | 5/20 | 25 | 6 | 30 | 8 | 40 | 10 | 50 | 10 | 50 |
| 2. Undergraduate upper division courses that use multimedia or internet-based materials to supplement student learning. | 0 | 0 | 5 | 8 | 30/60 | 50 | 36 | 60 | 42 | 70 | 45 | 75 | 45 | 75 |
| 3. Undergraduate lower division courses that incorporate distance learning applications such as videoconferencing or Web-based communication with learners/instructors outside the classroom. | 0 | 0 | 0 | 0 | | | 1 | 5 | 3 | 15 | 5 | 25 | 5 | 25 |
| 4. Undergraduate upper division courses that incorporate distance learning applications such as videoconferencing or web-based communication with learners/instructors outside the classroom. | 0 | 0 | 3 | 5 | 6/60 | 10 | 8 | 13 | 12 | 20 | 15 | 25 | 15 | 25 |

## Gateway Coalition
## The Cooper Union for the Advancement of Science and Art
## Institutional Metrics Years 0-11

| | ACTUAL PERFORMANCE | | | | | | PROJECTED PERFORMANCE | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Year 0 (1992) # or $** | **%** | **Year 5 (1997) # or $** | **%** | **Year 7 (1999) # or $** | **%** | **Year 8 (2000) # or $** | **%** | **Year 9 (2001) # or $** | **%** | **Year 10 (2002) # or $** | **%** | **Year 11 (2003) # or $** | **%** |
| 5. Meetings conducted with external institutions, faculty, staff, industry, etc., using technology-enhanced communication such as videoconferencing and other collaborative software. | 0 | | 15 | | | | 40 | | 60 | | 75 | | 75 | |
| 6. Gateway dollars spent on technology for a classroom/ educational delivery initiative for the past year and percent of total educational technology expenditures. | 0 | | 0 | | 15,713 | 5 | 5,000 | | 2,000 | | 2,000 | | 0 | |
| **E. Linking and Sharing** | | | | | | | | | | | | | | |
| 1. Papers presented at educational-oriented conferences, such as ASEE and FIE, in the past year. | 3 | | 5 | | | | 14 | | 15 | | 17 | | 20 | |
| 2. Papers published based on Gateway-related technical and educational initiatives. | 0 | | 8 | | | | 12 | | 13 | | 15 | | 17 | |
| 3. Faculty and administrators who interacted with local advisory board members during the past year. | 5 | 14 | 10 | 29 | 15/35 | 40 | 16 | 46 | 18 | 51 | 20 | 57 | 20 | 57 |
| 4. Presentations describing Gateway and its activity to visitors to our institution during the past year. | 0 | | 2 | | 3 | | 5 | | 8 | | 10 | | 10 | |
| 5. Formal linkages with other institutions for the purpose of exporting our Gateway initiatives. | 0 | | 1 | | | | 3 | | 4 | | 5 | | 6 | |
| 6. Number of industrial partners involved in supporting academic objectives. | 12 | | 17 | | | | 23 | | 26 | | 30 | | 30 | |
| **F. Curriculum Innovation** | | | | | | | | | | | | | | |
| 1. Freshman students having an engineering design experience or course during past year. | | 100 | | 100 | 145/145 | | | 100 | | 100 | | 100 | | 100 |
| 2. Undergraduate freshman/sophomore courses with cooperative team learning integrated into the classroom experience during the past year. | 1 | 5 | 1 | 5 | 3/20 | 15 | 5 | 25 | 9 | 40 | 10 | 50 | 10 | 50 |

## Gateway Coalition
## The Cooper Union for the Advancement of Science and Art
## Institutional Metrics Years 0-11

| | ACTUAL PERFORMANCE | | | | | | PROJECTED PERFORMANCE | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Year 0 (1992) # or $** | **%** | **Year 5 (1997) # or $** | **%** | **Year 7 (1999) # or $** | **%** | **Year 8 (2000) # or $** | **%** | **Year 9 (2001) # or $** | **%** | **Year 10 (2002) # or $** | **%** | **Year 11 (2003) # or $** | **%** |
| 3. Undergraduate junior/senior courses with cooperative team learning integrated into classroom experience during the past year. | 2 | 3 | 8 | 13 | 30/60 | 50 | 36 | 60 | 42 | 70 | 45 | 75 | 45 | 75 |
| 4. Junior/senior undergraduate courses that are interdisciplinary -- team-taught by faculty from different engineering or other disciplines. | 2 | 3 | 4 | 7 | 6/60 | | 7 | 12 | 8 | 13 | 9 | 15 | 10 | 17 |
| 5. Freshman/sophomore course credits in which the course encompasses an integrated approach among several disciplines of engineering. | 35 | 5 | 7 | 10 | | 10 | 7 | 10 | 14 | 20 | 21 | 30 | 28 | 40 |
| 6. Freshman/sophomore course credits in which the course encompasses an integrated approach of engineering and math, physics, chemistry or biology with engineering as the core topic. | 0 | 0 | 0 | 0 | 0 | 0 | 3.5 | 5 | 7 | 10 | 13 | 15 | 17 | 20 |
| 7. Freshman/sophomore course credits in which the course encompasses an integrated approach of engineering and the humanities or social sciences. | 3 | 4 | 6 | 9 | | | 9 | 13 | 12 | 18 | 12 | 18 | 15 | 21 |
| 8. Freshman/sophomore engineering students participating in formal instruction involving oral and written communication. | 120 | 50 | 120 | 50 | | | 240 | 100 | 240 | 100 | 240 | 100 | 240 | 100 |
| 9. Freshman/sophomore engineering students participating in formal instruction involving professional issues of ethics and social responsibility. | 0 | 0 | 0 | 0 | | | 240 | 100 | 240 | 100 | 240 | 100 | 240 | 100 |
| 10. Courses represented by items F1-F9 are part of the regular (institutional issued) course/program catalog. | All | 100 | All | 100 | All | 100 | 53 | 62 | 68 | 80 | 77 | 90 | 81 | 85 |
| 11. Gateway dollars spent on curriculum innovation and institutionalization initiatives for the past year and percent of total curriculum innovation-related expenditures. | 0 | 0 | $186,400 | 85 | $123,482 | 41 | | | | | | | | |
| 12. Freshman/sophomore courses taught by engineering faculty. | 7 | 35 | 7 | 35 | | | 7 | 35 | 7 | 35 | 7 | 35 | 7 | 35 |
| 13. Senior (tenured) faculty teaching freshman/sophomore engineering courses. | 8 | 23 | 8 | 23 | | 23 | 15 | 43 | 15 | 43 | 15 | 43 | 15 | 43 |

# Selected Indicators for Gateway Program Areas

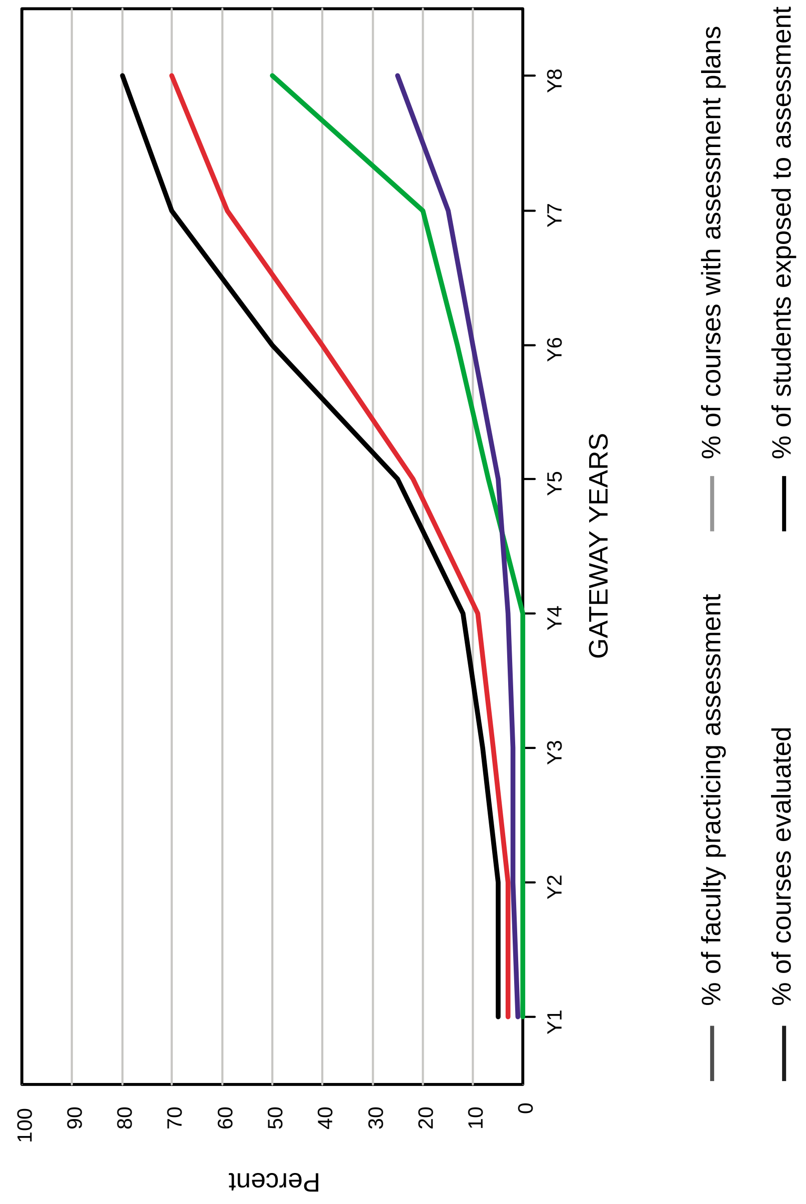
The graphs included in this section represent a visual summary of the work and accomplishments of the Gateway Program at Cooper Union. The graphs show the evolution of selected indicators for each of the main areas of the program between Gateway Year 1 (1992-1993) and Gateway Year 8 (1999-2000).

| **Main Areas of the Gateway Program** | **Indicators Included in the Graphs** |
|---|---|
| Assessment and Continuous Improvement | *Assessment at a Glance*<br>**A-22** Percent of faculty practicing assessment<br>**A-22** Percent of courses with assessment plans<br>**A-22** Percent of courses evaluated<br>**A-22** Percent of students exposed to assessment (self, peer and course assessment)<br>*Longitudinal Tracking*<br>**A-23** Retention Rates<br>**A-24** Total Graduation Rates<br>**A-25** Graduation Rates in 4 Years<br>**A-26** Drop Out Rates<br>**A-27** At a Glance -- All Students<br>**A-28** At a Glance -- Female Students<br>**A-29** At a Glance -- Male Students<br>**A-30** At a Glance -- Hispanic Students<br>**A-31** At a Glance -- African-American and Caribbean Students |
| Professional Development | **A-32** Number of faculty attending educational conferences and symposia<br>**A-32** Number of faculty attending professional development seminars |

| <u>**Main Areas of the Gateway Program**</u> | <u>**Indicators Included in the Graphs**</u> |
|---|---|
| Underrepresented Populations | **A-33** Freshman Enrollment: all students; number of women, Hispanic, African-American and Caribbean students enrolled<br>**A-34** Degrees Granted: all students; number of degrees granted to women, Hispanic, African-American and Caribbean students |
| Educational Technology | **A-35** Percent of courses using multi-media and Internet materials<br>**A-35** Percent of courses using an integrated approach to engineering<br>**A-35** Percent of courses using collaborative software |
| Linking and Sharing | **A-36** Number of papers and presentations on Gateway innovations by Cooper faculty and staff<br>**A-36** Number of industry partners involved in curriculum reform<br>**A-36** Number of formal linkages with other institutions with the purpose of exporting Gateway innovations |
| Curriculum Innovation | **A-37** Percent of courses using collaborative learning<br>**A-37** Percent of courses using interdisciplinary approaches<br>**A-37** Percent of courses that include training in communication skills |

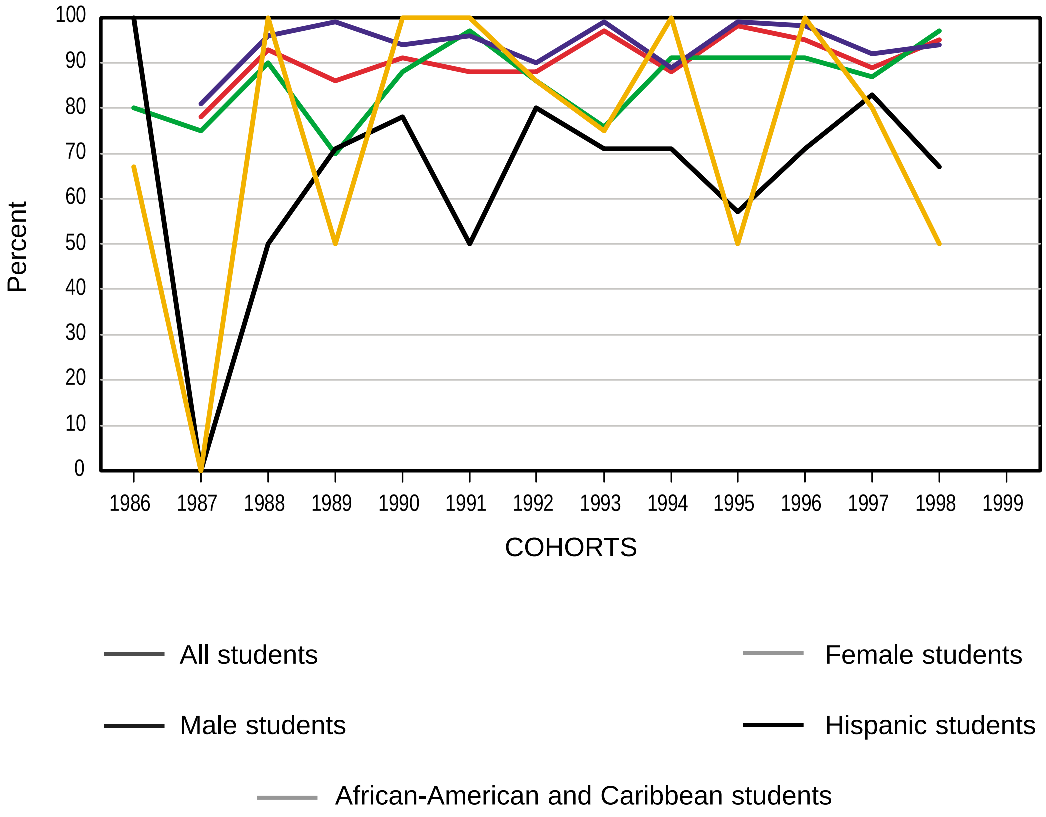
The indicators shown in the graphs are based on the information provided in the *institutional metrics* document beginning on page A-16, as well as on Gateway's yearly measurements and reports.

# Assessment at a Glance



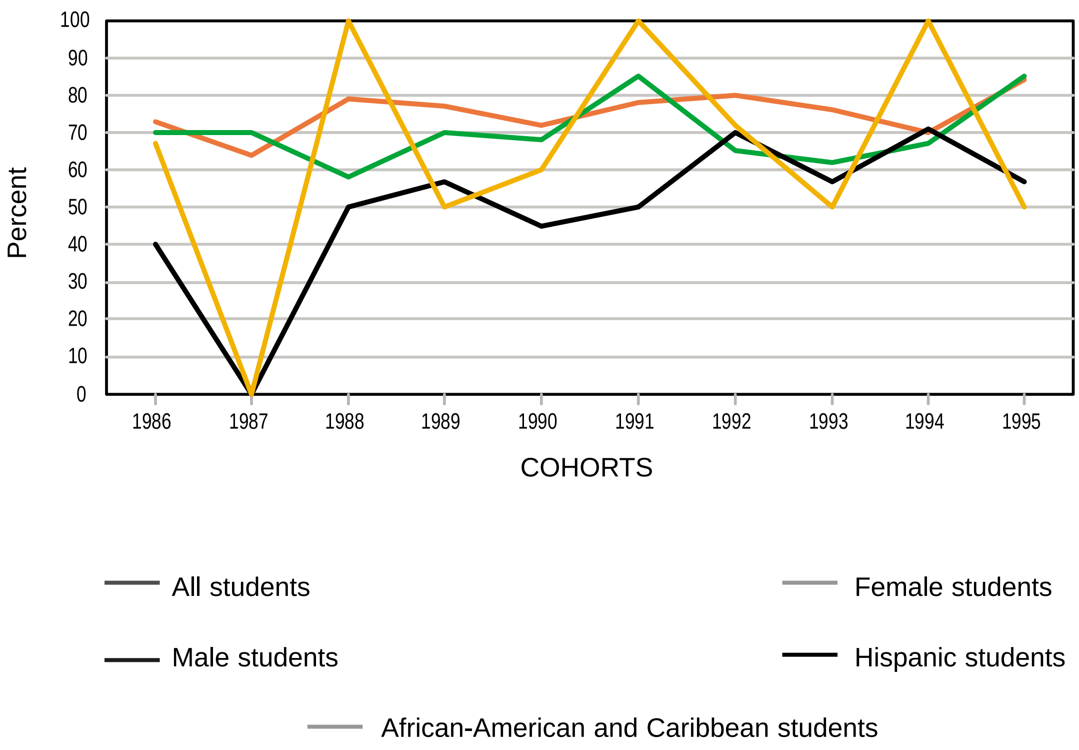
## Retention Rates

% Returned for 2nd Year



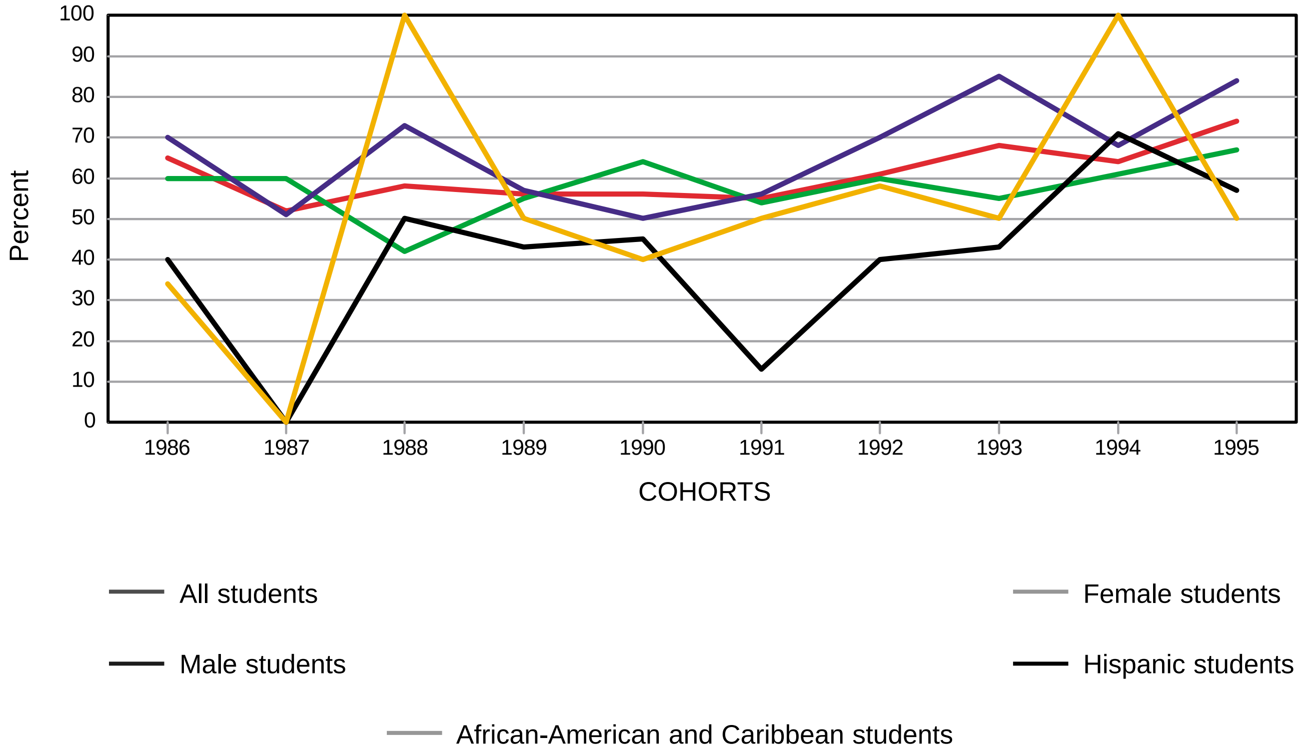
# Total Graduation Rates

% of Graduates Over Entering Cohort



# Graduation Rates in 4 Years

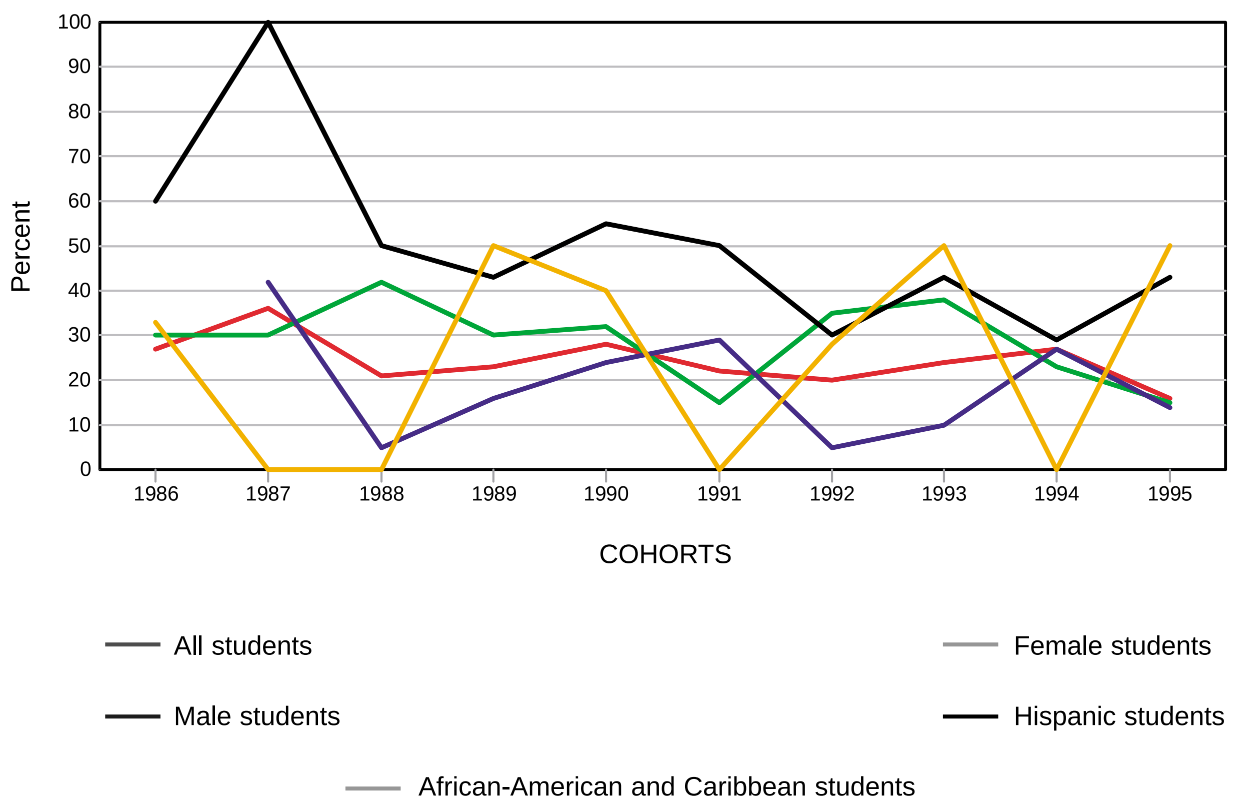
% Graduating in 4 Years Over Entering Cohort



<u>Longitudinal Tracking</u>

## Drop-Out Rates

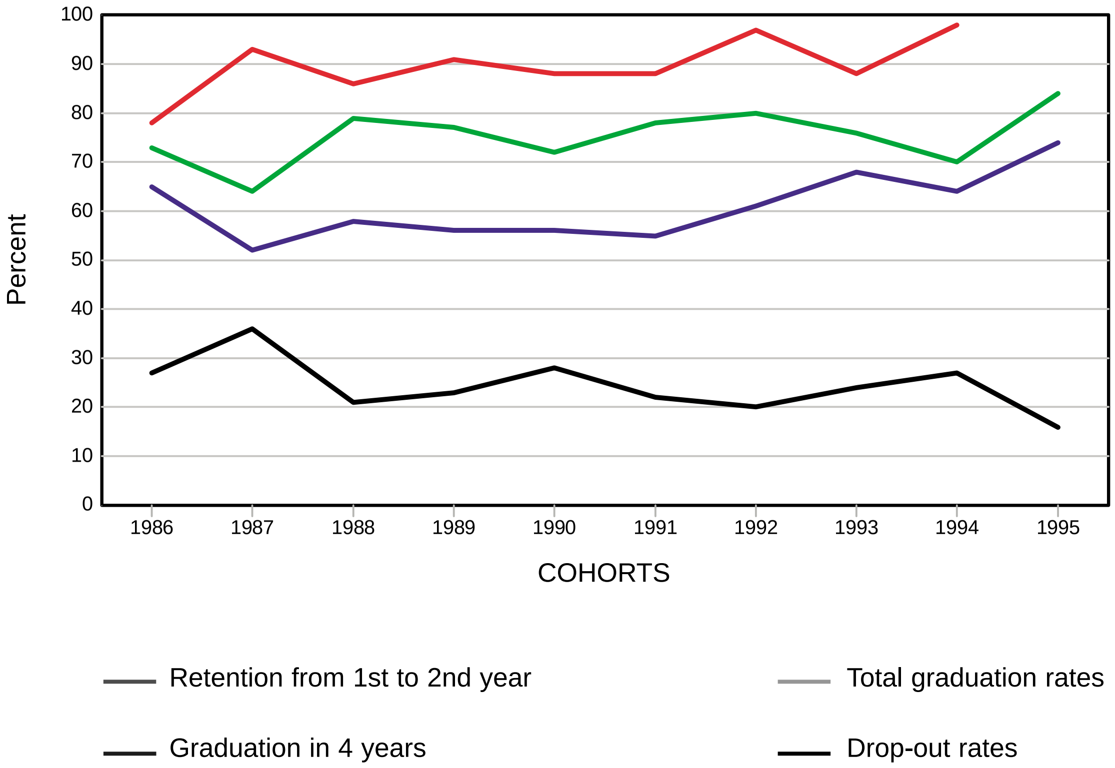
### % of Drop-Outs Over Entering Cohort



<u>Longitudinal Tracking</u>

# At a Glance

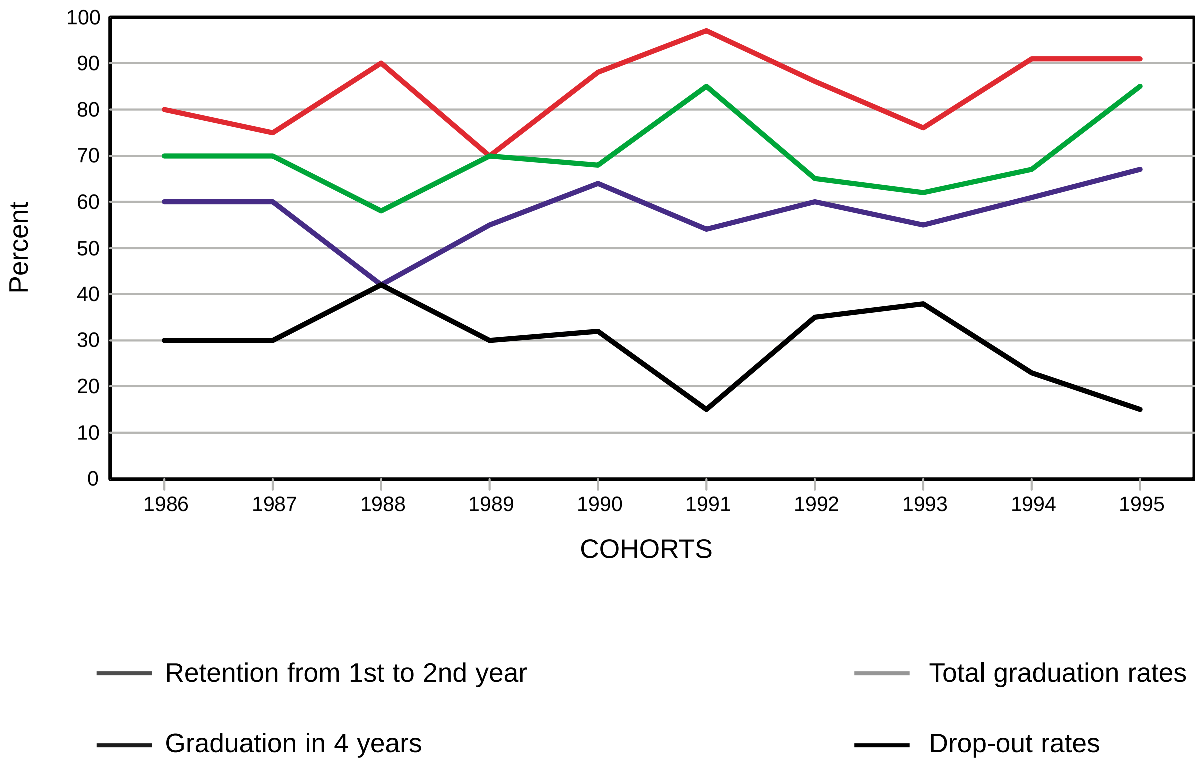
## All Students



Longitudinal Tracking

# At a Glance

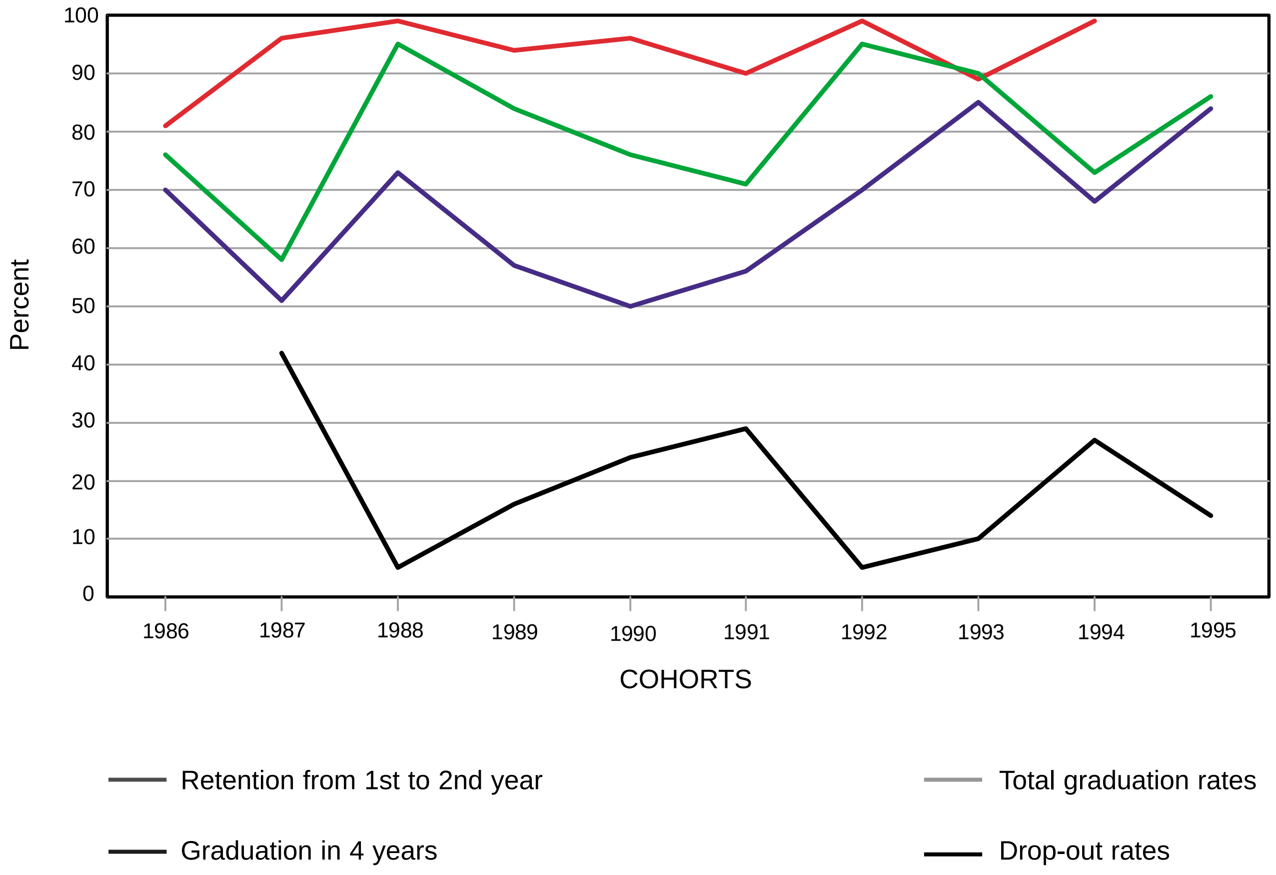
## Female Students



Longitudinal Tracking

# At a Glance

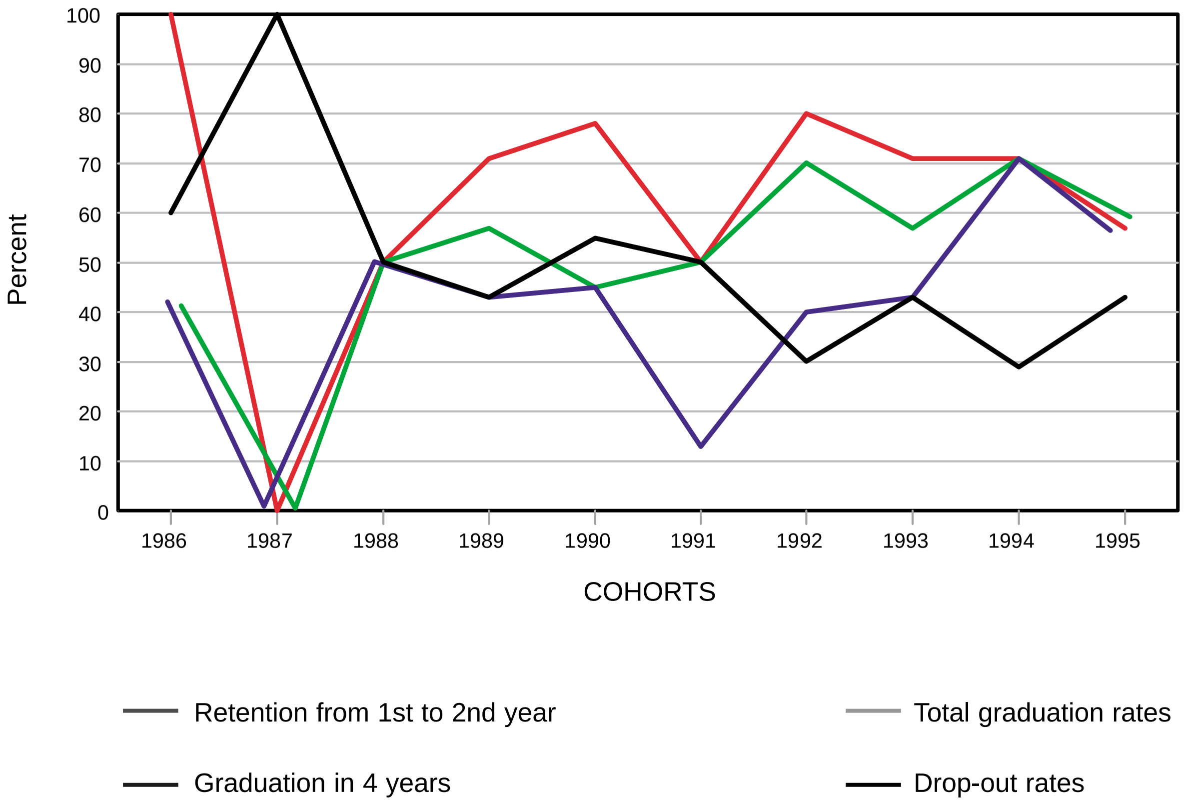
## Male Students



Longitudinal Tracking

# At a Glance

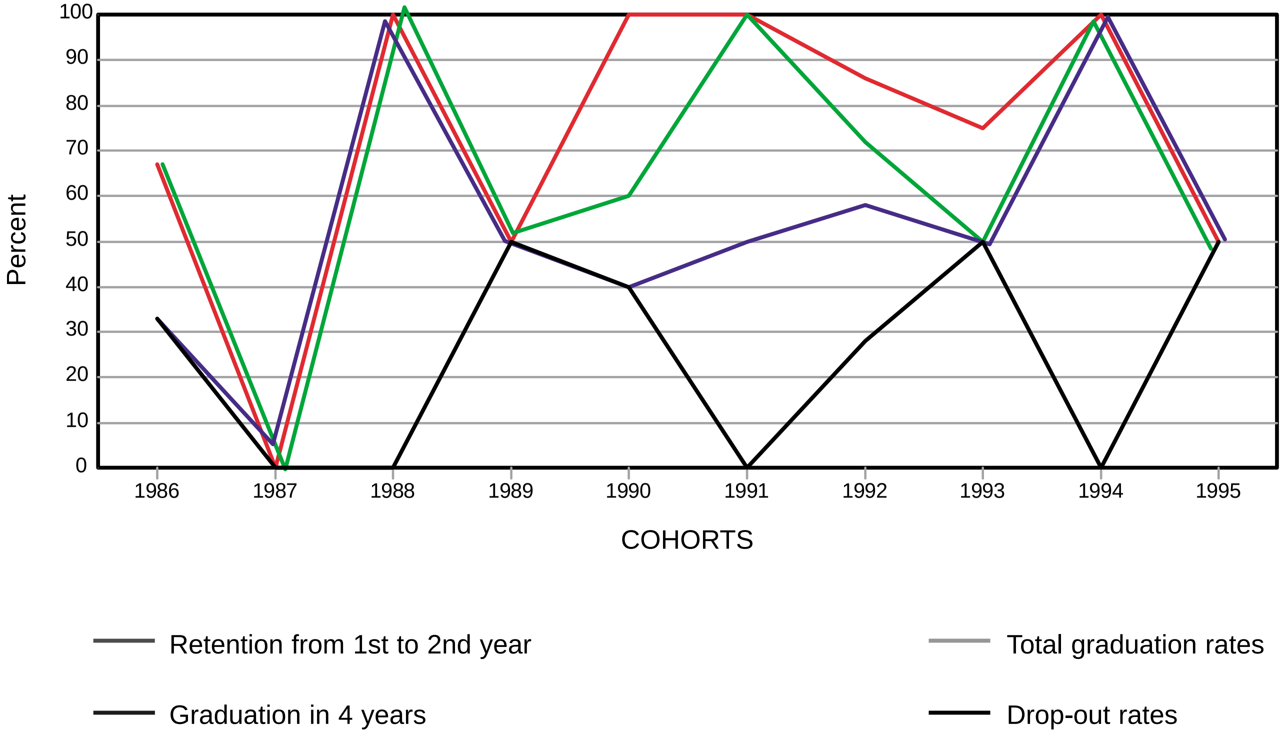
## Hispanic Students



Longitudinal Tracking

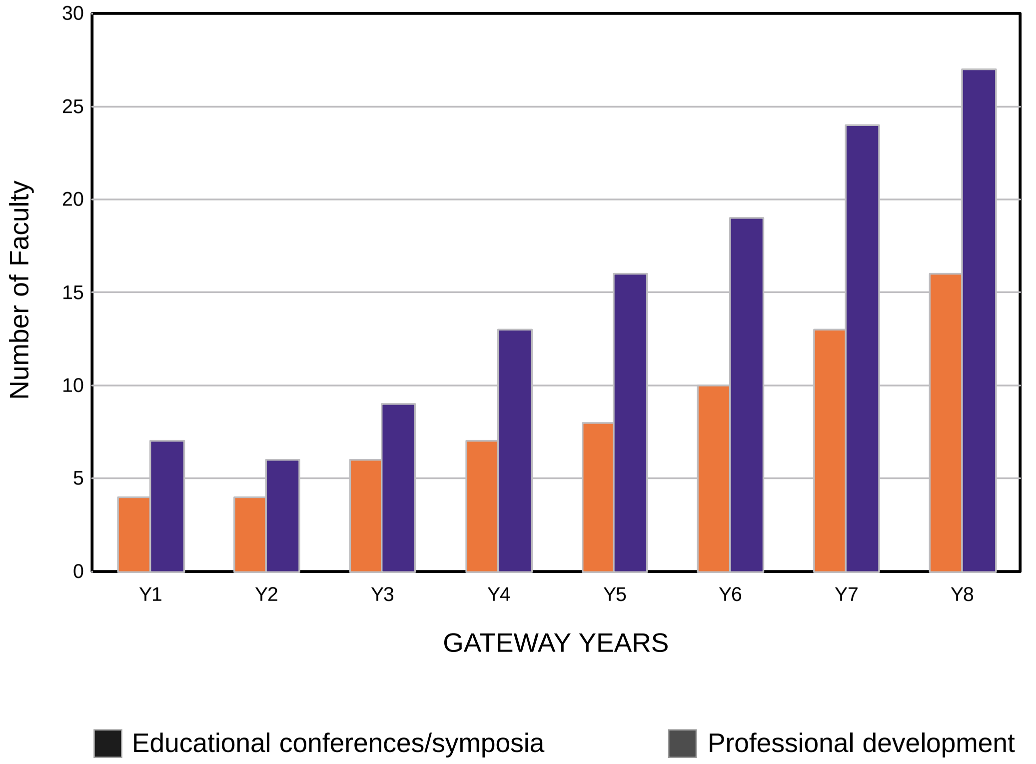
# At a Glance

## African-American and Caribbean Students



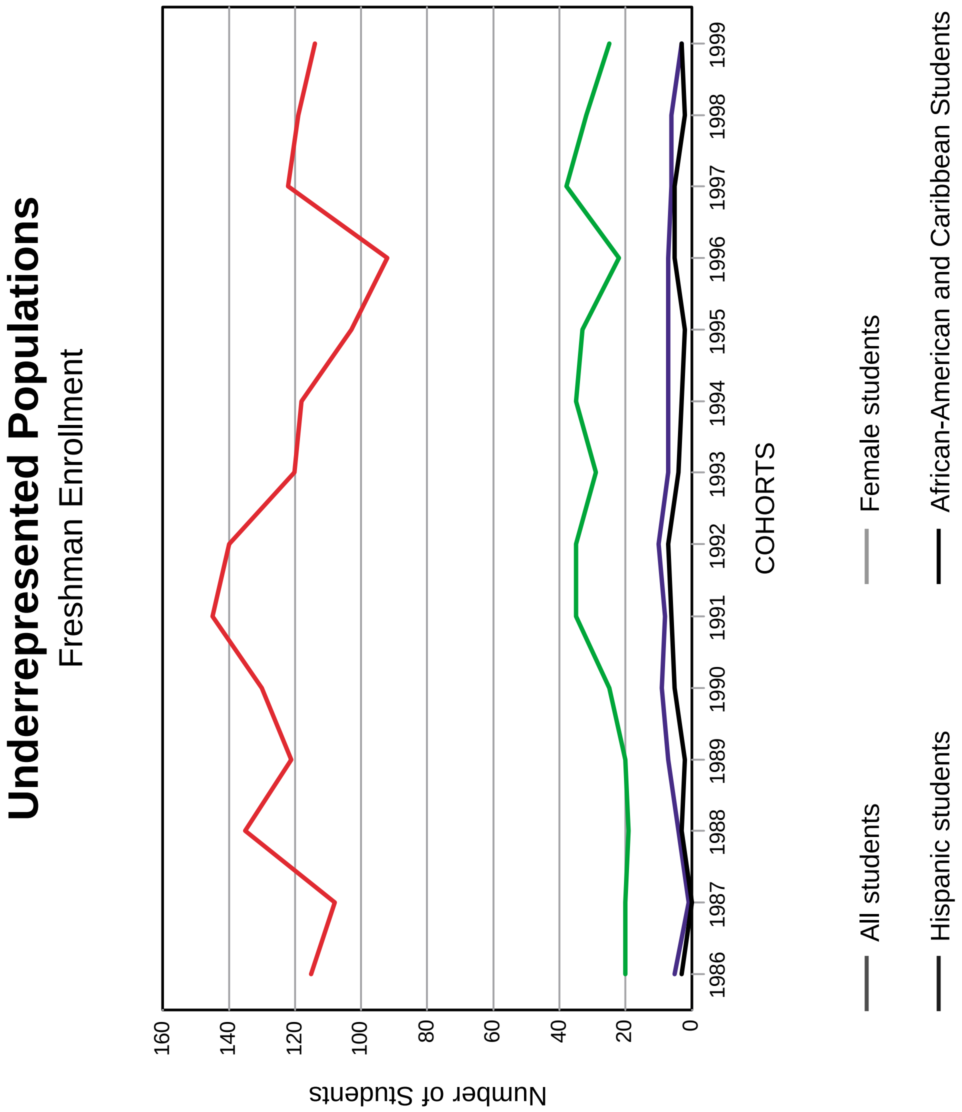
# Professional Development

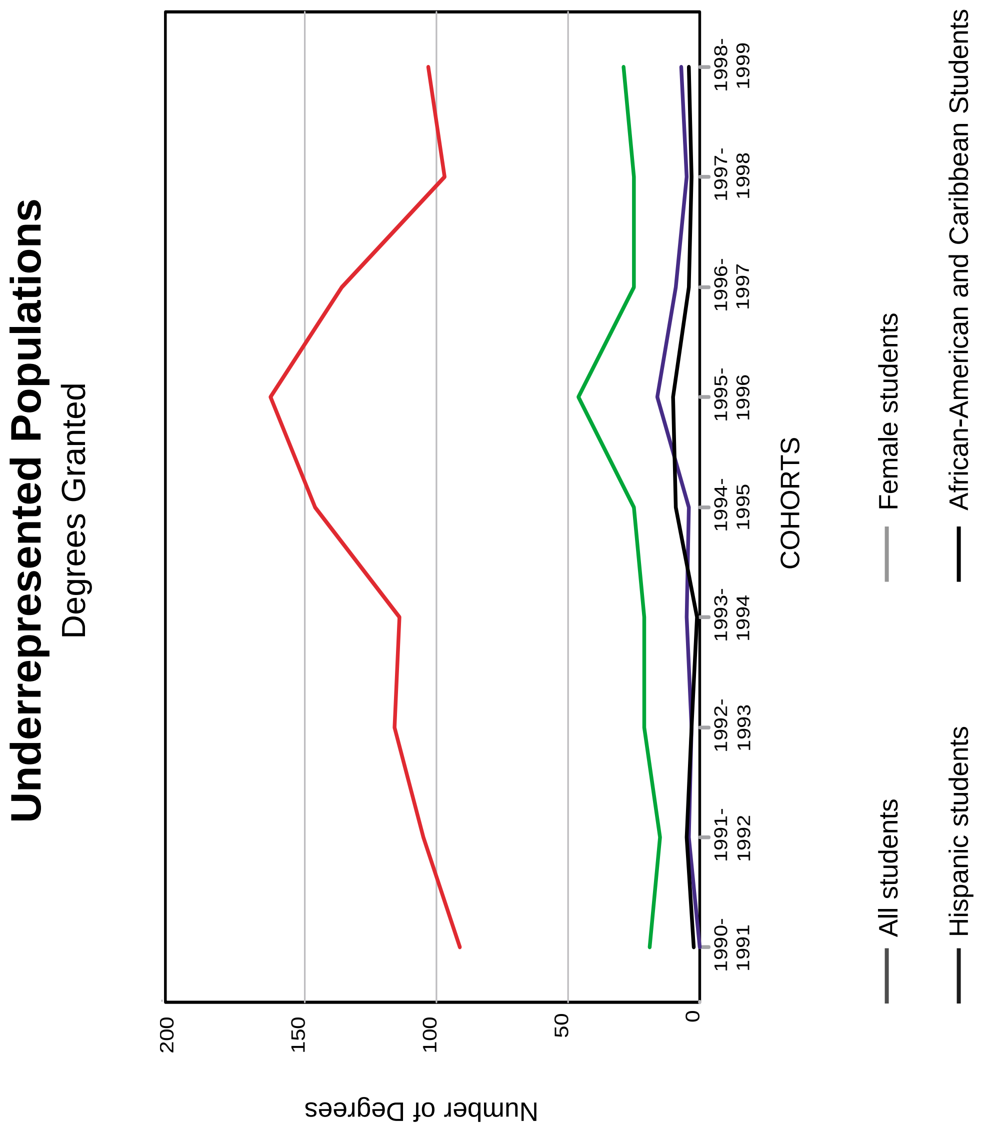
Faculty Attending...



**Underrepresented Populations**

Freshman Enrollment



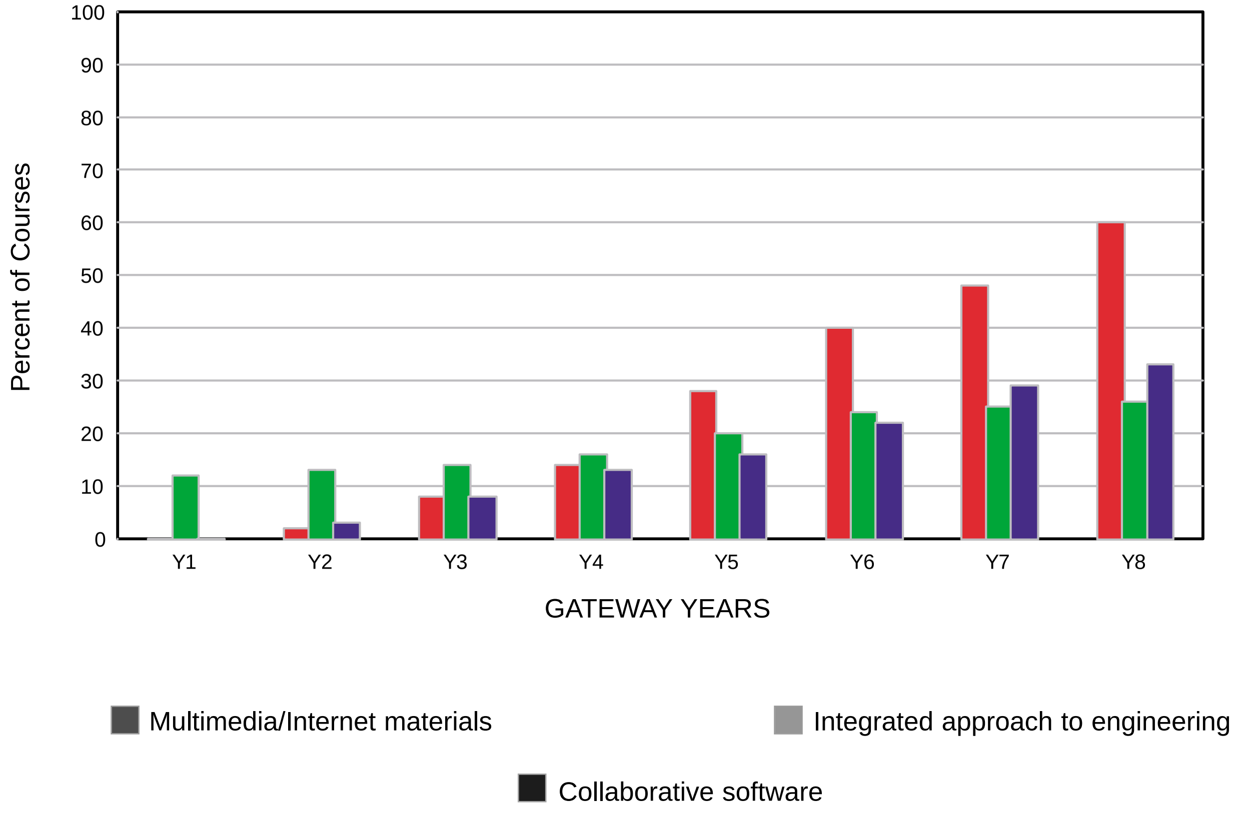


**Underrepresented Populations**

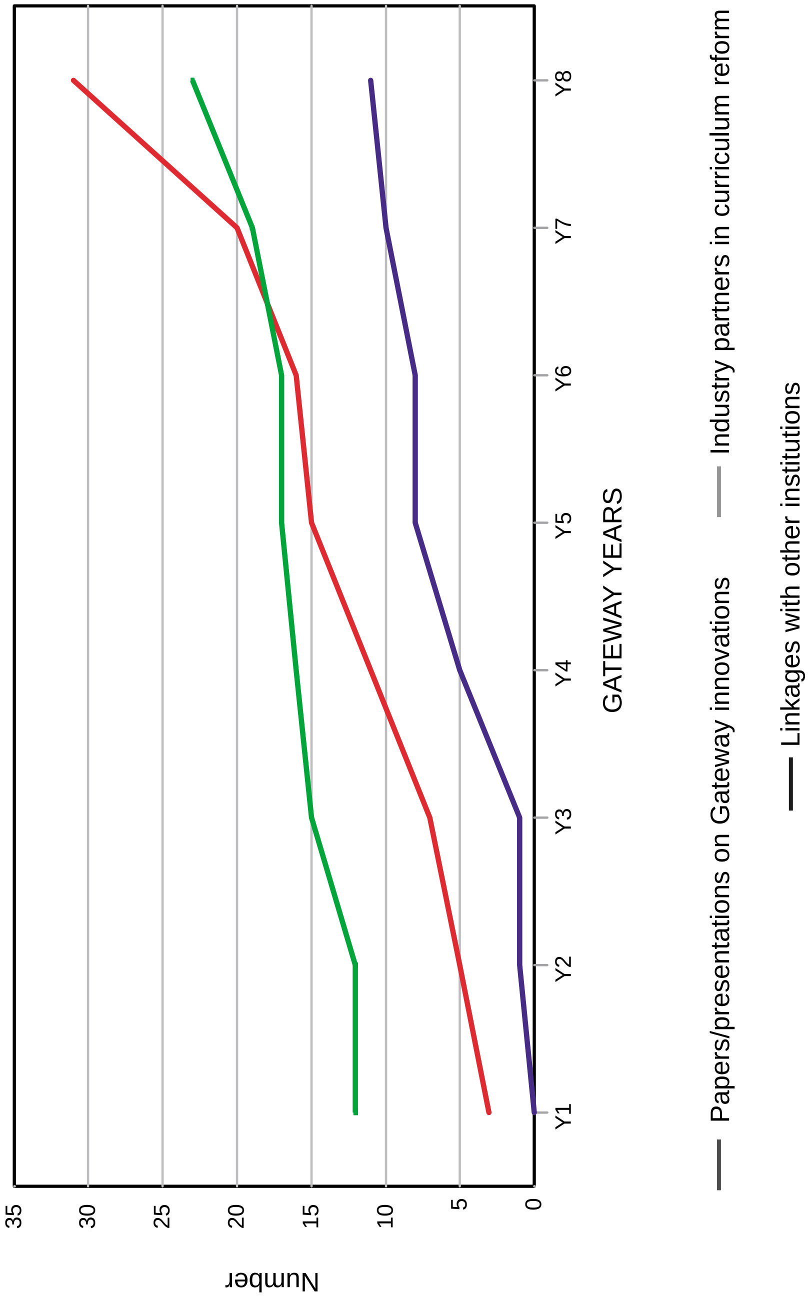
Degrees Granted

## Educational Technology

% of Courses Using...



# Linking and Sharing



## Curriculum Innovation

% of Courses Using...