# Core Engineering Renaissance at Rensselaer:
# Engineering Discovery – A Pilot First-Year Course

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## Introduction and Motivation

Are engineering schools meeting the needs of today's young women and men not just to study engineering, but to become engineers? Are they showing young students, even before they enter college, what it means to be an engineer and how engineers can help people and contribute to society? Do our young students share with us in the responsibility for their education and are they prepared for a process of lifelong learning necessary for the technical leadership required to face an unpredictable future? Do engineering students view the required fundamental courses in science, mathematics, and social science as disconnected courses that must be taken as part of some rite of passage into the study of engineering, or as the interrelated fundamental body of knowledge essential for the practice of engineering? These questions are being asked nationwide by students and parents, university faculty, government administrators, and industry executives. Unfortunately, the answers indicate an urgent need for a systemic change – incremental change is not an option. Recent times have seen no clear path forward and an apparent absence of focused, action-oriented leadership. New generations of students, with different backgrounds, interests, skills, and needs, must be enthused about the profession of engineering and better prepared, in both technical and non-technical areas, to creatively advance technology and solve the problems the 21$^{st}$ century will present. Renaissance engineers**,** men and women who get involved in public policy, stand for practical and cooperative solutions, work to change the world to make it a better place, and improve the quality of life for all the people of the earth, are needed. To create them requires a new approach to engineering education.

The U.S. is in a competitiveness-and-innovation struggle with the rest of the world, primarily India, China, and Japan. The U.S. is also facing a critical shortage of engineers. Several factors have contributed to this. Among them are: (a) There has been a 37 percent decline in engineering interest by college-bound high school students over the past 12 years; (b) The U.S. now ranks 17$^{th}$ among nations surveyed in the share of its 18-to-24-year-olds who earn natural science and engineering degrees. In 1975, it was third. Engineering B.S. degrees peaked in 1985 at 77,572 (2.2% women), and plunged to 60,914 (1.7% women) in 1998[1]; (c) The U.S. has become overly dependent on the global workforce while no longer dominating the global marketplace for technical talent as it once did[6]. Who then will take us into the future? Science and engineering together are the engines for economic growth and national security. Universities are failing to attract women, underrepresented minorities, people with disabilities, and perhaps, most importantly, those students who were never exposed to the excitement and fulfillment of an engineering career.

## What are the Essential Requirements for a 1$^{st}$-Year Engineering Curriculum?

The freshman year is critical for keeping promising students on the engineering track. A first-year engineering curriculum is a bridge between high school and the in-depth study of the engineering disciplines. This bridge, at most universities, is very rickety and many students fall off and into other fields of study. Other students, who make it across the bridge, struggle to see the links among all the areas of science, mathematics, and social science they have been required to study and the links to the practice of engineering. Once students cross this bridge, they have many roads to choose from to the various engineering disciplines. Are they prepared to decide? What then should this bridge be like? What should happen as students cross this bridge? We have attempted to identify the essential requirements for a common integrated and connected first-year engineering curriculum:

- <u>Experience Engineering</u>
  Students need a hands-on, minds-on exciting set of experiences that shows what engineering is and what engineers do; students need to see, hear, and do. Courses need to foster curiosity and professionalism in the students.
- <u>Responsibility of Students and Faculty</u>
  Students need to share in the responsibility for their own education and meet well-defined standards and goals. They need to come to class prepared, ready to learn and dynamically interact. Faculty need to mentor students, not spoon feed them. Active, integrative, project-based learning needs to replace passive, lecture-based instruction. There must be an emphasis on inquiry-based learning and preparation for life-long learning.
- <u>Fundamental Body of Knowledge</u>
  There is a common fundamental body of knowledge essential for all engineers; before a person studies in a particular discipline, he/she must first begin study to become an engineer. From a review of thirty five peer institutions, it is clear that the predominant fundamental body of knowledge, which engineers build upon in upper-division course work, lies in the sciences (primarily physics), mathematics, and social science. There is also a distinctive engineering fundamental body of knowledge for each engineering discipline, which the upper-division courses focus on and which this first-year engineering curriculum provides a foundation for. The freshman year begins the process of understanding and applying the fundamental body of knowledge, which will continue in the sophomore year through a set of department-defined courses in engineering, mathematics, science, and social science.
- <u>Integration of Mathematics, Science, and Social Science into Engineering & Connection of Engineering Back to these Areas</u>
  Students must be shown and understand the relevance and importance of science, mathematics, and social science in the practice of engineering. Links, both in course content and among professors, must be created among these areas. The societal aspects of engineering (e.g., ethical, environmental, social impact) are a key part of this integration.
- <u>Expose Students to the Engineering Disciplines</u>
  Throughout the freshman year, students must be shown what engineers in the various disciplines do, so they can make an informed choice. Faculty from the various engineering departments must take an active role in the development and delivery of this first-year curriculum.
- <u>Assessment</u>
  We need to know what students are being taught in the high schools in physics, chemistry, biology, and mathematics, and we need to more effectively assess their individual level of preparation before they begin their first-year studies. We need to continually assess how well they are understanding the fundamental body of knowledge in engineering, science, mathematics, and social science, and most importantly, integrating and applying all of it. We need to assess at the end of the freshman year how well the students have integrated all they

have learned and use that assessment to identify areas of weakness for student and program remediation. This assessment information will also be invaluable to the engineering departments as they begin preparing these entry-level engineers for engineering specialization. A student must become competent (not just earn good grades) and develop an understanding and retention in this broad, fundamental body of knowledge.

- Embedded Skills
  Students need to begin to develop a set of skills essential for all engineers: design, problem solving, computing, measurement, technical communication, leadership, ethics, professionalism, teamwork, and social awareness. These skills need to be embedded in all the courses, not just the engineering courses, and this then needs to continue throughout their remaining years of study in their chosen discipline.
- Conceptual Understanding
  It is known that students who can correctly solve problems and receive high grades often cannot explain the basic physical principles underlying their solutions[9,2]. The Kolb Learning Cycle[8], shown in Figure 1, consists of four components: concrete experience, reflective observation, abstract conceptualization, and active experimentation. A considerable body of research has shown that learning is significantly enhanced when students engage all of these cognitive processes[5,7].

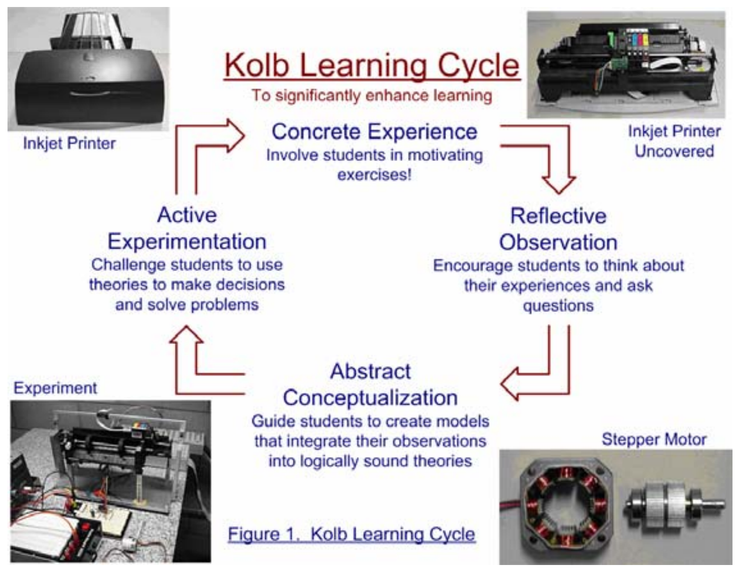


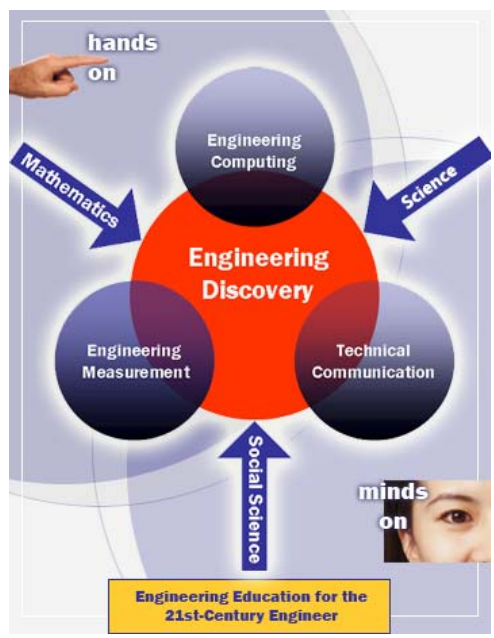

Figure 1. Kolb Learning Cycle

**Background on Rensselaer**

Rensselaer's commitment to student-centered learning and its innovation in undergraduate engineering education is well known. Between 1993 and 1998, Rensselaer won the Pew Award for the Renewal of Undergraduate Education, the Boeing Outstanding Education Award, and the Theodore Hesburgh Award for Faculty Development, the only technological university to win all three of these prestigious honors. Crossing low walls between schools, and combining the traditional laboratory-centered education with powerful computing technology and team-centered, interactive learning, Rensselaer pioneered the use of studio classroom environments that are collaborative, learner-focused, supported with sophisticated technology, and directly analogous to career work and learning. In the NSF-sponsored and award-winning (2001 ASME Curriculum Innovation Award, 2000 NEEDS Premier Award for Excellence in Engineering Education) Project Links - Mathematics and its Applications in Engineering and Science, modules were created that integrated mathematics, science, and engineering. We are building on both previous successes and on-going work in undergraduate engineering education at Rensselaer. Rensselaer is determined to maintain its leadership role in undergraduate engineering education.

To help develop our concept for a 1st-year engineering curriculum, a two-day workshop of representatives from the Engineering Science programs at all the two-year schools from New York State, including a representative from the New York State Secondary School Mathematics, Science, and Technology Office, was held at Rensselaer on April 24-25, 2003. The purpose of the workshop was to present our proposed Core Engineering Renaissance, to listen to the participants' comments and input, and to discuss ways that course content and modules developed at Rensselaer can be transferred to the two-year engineering science programs and also used to educate high school teachers about the engineering profession. That interaction is on-going and is providing significant feedback.

The introduction of new, outcomes-based accreditation criteria, Engineering Criteria 2000 (EC 2000) by the Accreditation Board for Engineering and Technology (ABET), and the establishment of the NSF Engineering Education Coalitions, to stimulate the creation of bold, innovative, and comprehensive models for systemic reform of undergraduate engineering education, are considered seminal events in engineering education[10,11]. Many engineering schools have made significant changes in their undergraduate programs that encompass many of the attributes discussed above. Almost all engineering schools remain on the quest to inform and enthuse students early about what engineers do, find a means to motivate them to study in a mature way, and evoke the curiosity which continually asks: How does this work? Both the nature of our young engineering students, in terms of background (more computer-oriented, less hardware-oriented) and pedagogical needs (more interactive and hands-on, less lecture-based), and the nature of 21st-century problems requiring a more integrated, multidisciplinary, fundamentals-based approach to problem solving, necessitates a revolutionary, systemic change in undergraduate engineering education. The forces of economic globalization and the competitive world market for engineering work, require a more highly adaptive workforce and Rensselaer is prepared to lead the revolution to meet this need.




**<u>Objectives of the Core Engineering Renaissance</u>**

The figure at the right captures much of what we are attempting to accomplish in the Core Engineering Renaissance. The principal objectives of this program, in order of priority, are as follows:

⇒ <u>Fundamental Body of Knowledge for a First-Year Curriculum</u>

Identify that portion of the fundamental body of knowledge, essential for the practice of engineering, which is appropriate for a first-year curriculum.

- The fundamental body of knowledge essential for all engineers primarily resides in the areas of science and mathematics. It consists of the fundamental laws of nature and the principles of mathematics which engineers have been applying for decades to solve problems facing mankind. While problems requiring incremental improvements in existing systems can often be effectively addressed without a solid foundation in this fundamental body of knowledge – the problems of the 21$^{st}$ century will be more effectively solved by those competent in this fundamental body of knowledge.

- Students will learn this fundamental knowledge in their mathematics, science, and social science courses, and apply it in newly-developed engineering discovery courses, the focal point of our proposed program.
- The integration of this fundamental body of knowledge will be multidirectional. Links, in both course content and faculty interaction, will be created between the science, mathematics, and social science courses and the engineering discovery courses. Where appropriate, links will also be created among the science, mathematics, and social science courses, to further emphasize the importance of integration and connection.

⇒ <u>First-Year Program of Study and Transition to the Second Year</u>

Develop a first-year program of study with the essential characteristics previously identified and a transition into the second-year, discipline-specific course of study.

- Students will see, starting at the freshman orientation and throughout the first year, a team of mentors, from mathematics, science, social science, and engineering, who know what each other is teaching in their courses, when it is being taught, why it is relevant to the practice of engineering, and how to connect and integrate content from other courses into their own course. This requires genuine educators, committed to this effort, with the resources, primarily time, to make this happen. Individual departments in science, mathematics, and social science will retain ownership of their respective courses, as it is most important for students to hear and work with professors from these diverse fields. Problems of the 21$^{st}$-century will best be solved by multidisciplinary teams with different points of view and approaches, all contributing to the optimal solution.
- A set of modules of instruction, in electronic, interactive form, for both self-study and in-class use, will be developed in key skill areas essential for the practice of engineering: problem solving and design, technical communication, professional development, measurement systems, and computing, all with a balance between theory and application. These modules will be easily transferable to other universities and two-year schools, as well as useful in informing secondary school teachers about the practice of engineering.
- The focal point of the first-year curriculum is the Engineering Discovery course**s**. The key element of these courses will be the discovery by the students, through a sequence of hands-on, minds-on engineering system investigations of increasing sophistication and complexity, of the application of the essential fundamental body of knowledge and the basic engineering skills to the solution of engineering problems.
- In the second year, once students have selected their engineering discipline for specialization, the engineering departments, in their curricula, will continue the delivery and emphasis of the fundamental body of knowledge in science, mathematics, social science, and engineering, customized to their own needs and integrated in their own courses. The transition to the second-year department curricula will be smoother and more effective, as students will be better prepared and highly enthused, as well as better informed about their discipline of choice. The engineering departments, through active participation in the development and delivery of the first-year program, will also be better prepared for both continued instruction in the fundamental body of knowledge and the start of the discipline-specific instruction.

⇒ Assessment Plan

We will develop and implement an assessment plan consistent with the ABET EC 2000 outcomes-based criteria, which will serve the first-year engineering program, including the science, mathematics, and social science components, and the engineering departments during the upper-division courses through the capstone experience.

- This will allow us to better attract to the engineering profession a more intellectually diverse and greater number of students, to better retain students once enrolled in the engineering program, to better infuse enthusiasm and passion for engineering into our students as they progress through their program of study, and to better graduate engineers well prepared to solve the complex problems they will face in the 21st century.
- This assessment data, in the form of publishable results, will be used to review and redesign our programs and to ensure the sustainability of our program.
- The dissemination of these assessment results in regional and national workshops will be an effective way of bringing together representatives from universities and two-year engineering programs, as well as secondary school teachers and state education representatives, to jointly address the crisis in engineering education facing the U.S. today.

⇒ Shared Ownership

The saying "No one has ever washed a rented car" applies here; shared ownership is essential. Through shared ownership with the engineering departments, we will introduce first-year students to the engineering disciplines in a meaningful way, so the students can make an informed choice of which discipline appeals to them.

- At the end of the first year, students should have the answers to the questions "What does an engineer do?" and "What kind of an engineer do I want to be?"
- Faculty from the various engineering disciplines will be essential to the development and delivery of the Engineering Discovery courses.

⇒ Recruitment and Training of Faculty

A sustainable system of recruiting and training engineering faculty from the engineering departments, as well as practicing engineers from industry, to mentor the young engineers in the Engineering Discovery courses will be developed.

- Engineering school faculty, at predominately research universities, are increasingly more scientist than engineer; many have little experience in the practice of engineering. These scientist-engineers are enthusiastic and most capable. However, they need to be mentored and given appropriate incentives and time for training, so they can mentor students in the Engineering Discovery courses. Practicing engineers will be a terrific asset to the mentoring process.
- Master teacher and faculty mentor appointments, honored positions in the School of Engineering, will be created to effectively implement the proposed Core Engineering Renaissance.

**Engineering System Investigation Process: The Focal Point for Engineering Discovery**

The Engineering System Investigation Process is the cornerstone of modern engineering practice[3,4] and so this is the process upon which our Engineering Discovery courses are based. Design concepts must be evaluated through modeling, analysis, prediction, and experimental verification.

This process is not formally presented to the students initially; they discover this process as they proceed through system discovery projects, each more sophisticated and complex than the previous one. Students will apply this process throughout their careers as engineers, and we begin here to introduce them to this essential process – not to do so would be an act of gross neglect. Students engage in all aspects of the process and integrate the fundamental body of knowledge in science, mathematics, and social science as they proceed. They also apply their basic engineering skills in problem solving, computing, measurement, and technical communication, as well as develop the attributes of teamwork, leadership, and professionalism. The Engineering System Investigation Process is shown in Figures 3 and 4 and described below.

⇒ Physical System

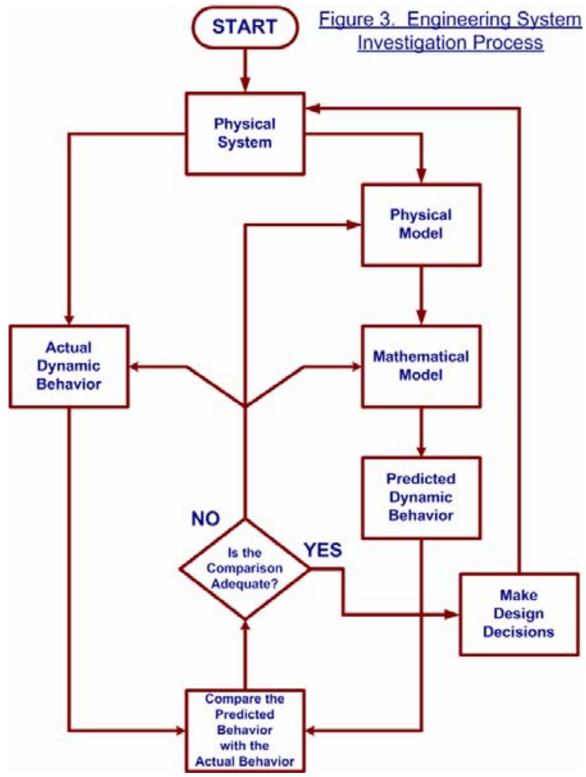


Figure 3. Engineering System Investigation Process

- The process starts with an actual physical system or product. In Engineering Discovery, it will be an existing engineering system, modern and exciting, with the predominant element representing several broad areas of engineering specialization, e.g., mechanics and materials, electricity and magnetism, chemistry and biology. In Figure 4, to illustrate the process, a simple spring-mass system is used.
- The physical system must be completely understood. How does it work? What materials does it use? What problem was it designed to solve? What need was it meant to satisfy? Who was the customer? Why was it designed the way it was? Why is it innovative? What alternative designs were considered?

⇒ Physical Model

- This step is the key step in the entire process. Unfortunately, it is the least understood and the most poorly taught. By the use of simplifying assumptions and engineering judgment, learned through much repetition which starts here, we develop a physical model, a slice of reality, which is not an actual piece of hardware, but an approximation of the actual system capturing the essential elements of the actual system in as much detail as the need for the model requires. There is a hierarchy of models possible – from the less complex, less realistic, more easily solved design model to the more complex, more realistic, less easily solved truth model – depending on the particular need for the model, e.g., design iteration, control system design, final verification before hardware implementation. Always ask the question "Why am I modeling?" remembering that a model only has to satisfy the defined need for the range of operation being considered.
- Even a system as simple as a spring-mass system (Figure 4) requires many simplifying assumptions to create a physical model which we can then begin to analyze, e.g., massless, frictionless, linear spring; rigid support structure (i.e., environment independent of system behavior); rigid attached mass; one-degree-of-freedom motion (vertical); spring always in tension throughout the motion as spring does not compress.

⇒ Mathematical Model
- The laws of nature (physics, chemistry, biology) are applied to the physical model (not the physical system) and the mathematical equations describing the system are derived.
- Here is where the fundamental body of knowledge in science is applied in the process.

⇒ Model Parameter Identification
- The physical model has elements, not necessarily corresponding to actual physical components in the physical system, with characteristic parameters (spring constant, mass, resistance, inductance, thermal conductivity, fluid viscosity, thermal capacitance, etc.) whose numerical values must be identified. This is done either by numerical calculation, referencing standard handbooks, using vendor information, or through experiment.

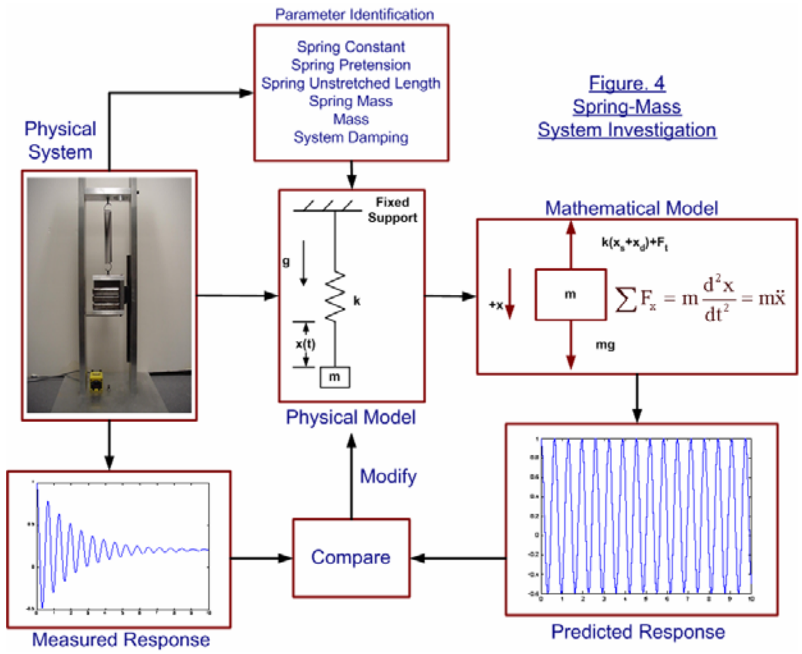



Figure. 4
Spring-Mass
System Investigation

⇒ Mathematical Analysis: Predicted Behavior
- The mathematical equations are solved either numerically by computer simulation or analytically to predict the behavior of the engineering system. The purpose of modeling is to gain insight into the behavior of the engineering system. Using a simpler model that allows for an analytical solution often leads to greater insight into system behavior than numerical solutions of a more complicated model.
- This step is only half the story, for computer simulation or mathematical analysis without experimental verification is at best questionable, and at worst, useless.

⇒ Experimental Analysis
- Experiments are performed on the engineering system to validate the predicted system response.

⇒ Comparison: Mathematical Predications vs. Experimental Observations
- If the model predictions compare favorably to the experimental observations, then the model is adequate. If not, the physical model must be modified to capture the system characteristics which are important and were not initially included. In the spring-mass system, shown in Figure 4, any energy dissipation in the system was initially neglected in the physical model and this led to a discrepancy between the predicted response and the measured response.
- Parasitic, or secondary, effects (e.g., saturation, nonlinear effects, time delays, hysteresis, Coulomb friction, gear backlash) are added to the physical model to determine if each effect is significant, or if cumulatively they have adverse effects.
- Eventually, a truth model, which is as realistic a model one could develop, is used to validate system performance prior to hardware implementation. This often eliminates the

need for hardware prototyping. The advantages over the build-and-test approach are staggering.

⇒ Design Changes

- If the model is adequate, but performance is inadequate, then design changes are in order and the whole process then starts over again for the revised engineering system.

**What is the Engineering Discovery Concept?**

The overall goal of Engineering Discovery is to allow students to complete their first year with the capacity to answer the following questions:

- What does an engineer do and what makes engineering challenging and exciting?
- How is the fundamental body of knowledge in science, mathematics, and social science used in the practice of engineering?
- What basic skills are required of all engineers?
- What kind of an engineer do I want to be?

In the Engineering Discovery courses, the students will work in teams and actively participate in engineering system investigations and discover this process through a series of projects of gradually-increasing sophistication and complexity. They will be evaluated both individually and as a team. They will apply the fundamental body of knowledge in science, mathematics, and social science and develop competence in a wide range of skills, including problem solving, measurement, technical communication, and computing. The emphasis will be on the process and the discovery of that process as the students proceed through the series of projects.

In Engineering Discovery, all engineering students will investigate two or three systems in series. The products or systems selected for investigation will be changed on an annual basis and chosen to be familiar to all students. The pedagogical objectives and basic structure of the investigations will be carefully specified so as to ensure integration of fundamental knowledge and uniformity of course design. The principal goal for each of these projects is to allow a student to gain a glimpse of the structure of engineering knowledge, the potential depth of theoretical science and mathematical knowledge behind engineered systems, and to become familiar with engineering practices and design processes.

The Engineering Discovery course concept is unique and is intended to expose the profession of engineering to the student in the first year. It has tremendous potential for re-shaping engineering curricula locally and throughout the country. It is much more than reverse engineering or re-engineering. It involves the use of existing commercial products or systems to first discover the underlying scientific and mathematical principles upon which the device, system, or product operates. It will challenge them to discover in real products the work and creativeness of engineers in the different disciplines. It will build naturally on their secondary school backgrounds and show them the applications of their basic science, mathematics, and social science preparation in real products and systems, while expanding that base with first courses in calculus, physics, chemistry/biology, and social science. They will be required to take responsibility for their learning and in the process learn to learn at a very early stage of their higher education. They will learn how to model and analyze systems to discover how they work and what basic physical principles are involved. They will learn measurement and experimental skills to validate their analytical predictions. They will develop reporting and presentation skills, computing skills, teamwork and leadership skills, and learn to think and develop the curiosity inherent in most really successful engineers. There will be significant guidance given in the discovery and investigation process to assure understanding; significant peer learning will also take place. As they develop confidence and background, the students will take more and more of the discovery experience on their shoulders and will identify the area of engineering most desirable and suited to each.

## Essential Engineering Skills

A set of modules of instruction, in electronic, interactive form, for both self-study and in-class use, are being developed in key skill areas essential for the practice of engineering: technical communication, measurement systems, and engineering computing, all with a balance between theory and application. These modules will be easily transferable to other universities and two-year schools, as well as useful in informing secondary school teachers about the practice of engineering. The module contents will be applied throughout the Engineering Discovery courses.

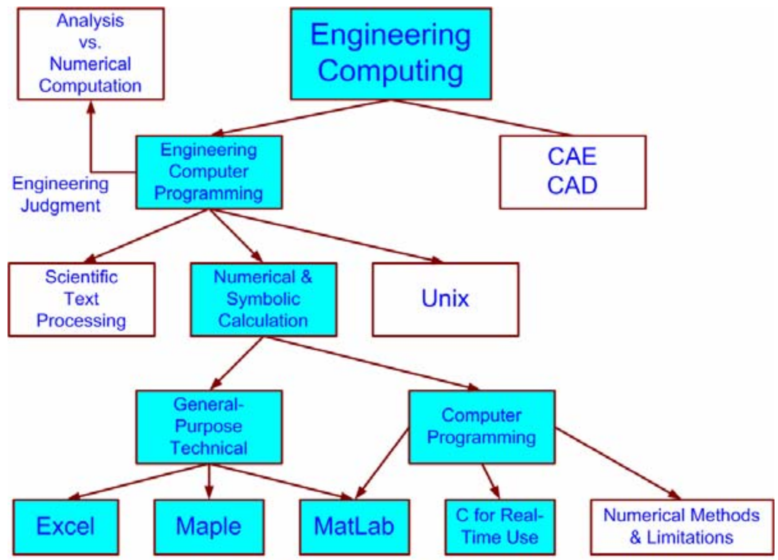


Figure 5. Engineering Computing

⇒ Engineering Computing

The focus in this module will be on engineering computing, of which engineering computer programming is a small part. The elements of the engineering computing module are shown in Figure 5, with the shaded portions being the focus for the first year.

⇒ Engineering Measurement

Engineering measurement is a key component of almost every modern engineering system. Students, with the aid of National Instruments software and hardware, will learn the fundamentals of engineering measurement. This module, shown in Figure 6, will use table-top engineering systems, derived from the engineering systems used for discovery, to understand the physical principles underlying some common sensors (e.g., motion,

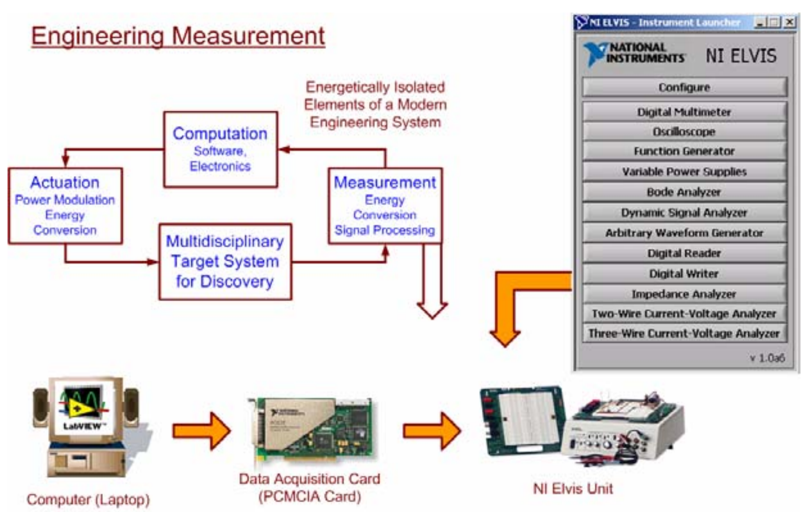


Figure 6. Engineering Measurement

temperature, force, flow), the desirable and undesirable inputs to a measuring system, and the signal conditioning and modification often necessary. National Instruments ELVIS units, complete with software and data acquisition cards, are being used.

⇒ Technical Communication

We are developing a compilation of best practices, exemplars of oral, written, and graphical communication produced by practicing engineers who are recognized within their organizations as being highly effective communicators. This information is being analyzed and used to help faculty design communication assignments and assess the communication skills of the students. Figure 7 shows the coverage in this module.

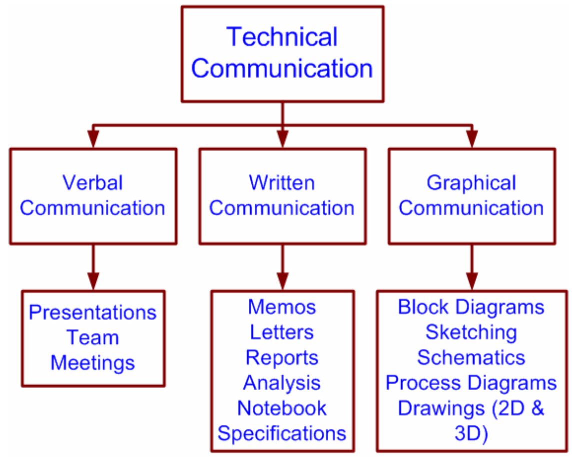



Figure 7. Technical Communication

**Coordination with the H & SS First-Year Studies Program**

Rensselaer already has in place one of the nation's most innovative programs for introducing the humanities and social sciences to aspiring engineers, scientists, and other technical professionals. Known as the First Year Studies (FYS) Program of the School of Humanities and Social Sciences, the program is based on a topics approach that offers students a highly accessible introduction to social phenomena such as world regions, economic globalization, human identity, and the culture of technology from multiple disciplinary perspectives. All sections within First Year Studies courses are conducted in seminar-style discussion sections limited to twenty-five students. All students enrolled in FYS sections must be first-year students. Core Engineering is working with the FYS program to certify courses that meet the technical communications, social competence, and pre-professional orientation requirements of the Core Engineering program, and to establish an internal curriculum innovation grant program to help develop new FYS courses that meet Core Engineering requirements. Core Engineering will require student enrollment in these courses.

**Project Assessment Plan**

The emphasis on outcomes-based assessment in specific response to the ABET EC 2000 requirements provides an opportunity to coordinate the work of Core Engineering with second-year and upper-division courses controlled by the departments, and to do so at the level of actual student achievement and outcomes as depicted in Figure 8. What we propose to put in place is a system of evaluation consisting of incoming-student assessments, a post first-year assessment, and a senior-level outgoing assessment for each graduating class. The post first-year assessment will generally be offered as an Engineer-In-Training type exam, and will be designed to measure the degree of competence versus simple possession of knowledge across a range of defined areas corresponding to the fundamental bodies of knowledge targeted for delivery through the Core Engineering program. Assessment reports will be used to collect course-specific, departmental, and overall Core Engineering curricular performance along the lines of our stated goals.

Comparison between incoming and end-of-first-year student assessments will be used to compile real-time assessments of students in terms of the knowledge acquired. These assessments will be used both to provide a current report of student capabilities as they enter departmental programs in their second year, and to provide feedback on curricular changes as they might be required in the first-year program. As individual instructors will be certified to teach in the program on a three-year, recurring basis, the outcomes assessment will be used to maintain high standards of undergraduate instruction. The formal, senior-level outgoing assessment will be used to gauge the performance of the overall Rensselaer engineering curriculum.

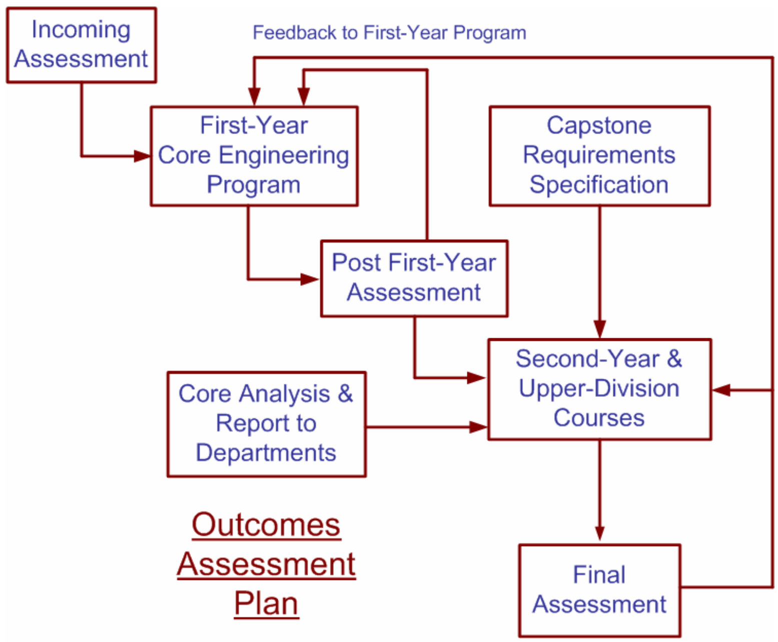


Figure 8. Outcomes Assessment Plan

Separately, Core Engineering will generate a Capstone Experience Requirements Specification which will be used by each of the departments. The expectation will be for each of the departments to deliver the requisite content in their second-year and upper-division curriculum that completes Core Engineering-defined competencies. Department-specific versions of the capstone experience, as formally required by ABET EC 2000, will be designed in consultation with Core Engineering so that student ability to apply the fundamental bodies of knowledge to real-world problems, as specified by Core Engineering, will be subject to a real test in the context of final student projects. Implementation of this assessment program will be conducted in cooperation with the O.T. Swanson Multidisciplinary Design Laboratory (MDL), which currently provides capstone experiences for four of the eight departments within the School of Engineering.

**Pilot Programs: What Has Been Done and What Is Planned?**

This past fall we launched *Engineering Discovery*, a four-credit freshman-engineering pilot course, that explores the fundamental concepts and principles of engineering through a series of hands-on, minds-on exercises on actual engineering products and systems, such as an ink-jet printer, a wind turbine, a fuel-cell system, a household electric toaster, or a room humidifier. Students discovered the engineering system investigation process, as well as the relevance of science, mathematics, and social science to the practice of engineering. A careful investigation of the toaster reveals applications of heat transfer, mechanics, materials selection, and electronics, as well as the integration of several subsystems to accomplish the toasting process. Engineering problem solving, engineering measurement, engineering computing, and technical communication skills were all integrated and developed throughout the course. *Engineering Discovery* was offered to all undeclared-major engineering freshmen of the Class of 2008 (approximately 250 of the 700 freshman-engineering students); 110 students accepted the invitation. Thirty students took the course in the fall semester, while the remaining 80 students will take the course in the spring semester. Extensive assessment of our current freshman-engineering program and this pilot course is being conducted throughout the 2004-05 academic year.

As seen from the article in the student newspaper, we are on our way. We will have much to report at the ASEE Annual Conference in June 2005.

## Core engineering pilots Engineering Discovery course

GREG POLINS
***Staff Reporter***

A new engineering course, "Engineering Discovery," is being offered to freshmen for the first time this semester. This pilot course was offered to all freshmen who entered with undeclared engineering as their majors, which was approximately 250 students; of those, 110 students elected to take the course. The course is being offered as a four-credit elective for one section this fall to 30 students; the remaining 80 students will take the course in the spring semester.

According to the course's website, Engineering Discovery is a class designed to expose students to a variety of engineering principles and answer questions such as, "What does an engineer do and how does an engineer think?" The class is meant to blend the areas of science, mathematics, and social sciences so that students can see how each area impacts the other.

Dr. Kevin Craig, director of Core Engineering, has worked on implementing Engineering Discovery for over two years. He sees this course as a way for RPI to maintain its leadership role in and improve the quality of undergraduate education.

The class is being taught in three different parts, with each part having two different professors. The engineering measurements section is being taught by Craig and Dr. Bill Mielke; the engineering discovery section is being taught by Dr. Henry Sneck and Dr. Donald Bunk; and the engineering computing part is being taught by Craig and Dr. Mike Kupferschmid.

The course will be taught in a hands-on manner, investigating systems that encompass a variety of engineering disciplines. This year, the class will focus on investigating multi-disciplinary engineering systems such as a toaster and room humidifier. In the upcoming years, Craig hopes to expand the program to include highly complex systems such as a fuel cell, which offer much more range in the sub-system disciplines students can study.

If the pilot Engineering Discovery course goes well, plans are being made to expand the course to include all engineering freshmen within two years. At the current moment, plans include expanding the course from covering 16 percent of the engineering freshmen this year, to 50 percent next year. Depending on the response over the next few years, Engineering Discovery could also expand to a two semester course, with one semester focusing on an overall system and the second semester focusing on the several sub-systems contained within that first system.

Craig's hope is for Engineering Discovery to build "a bridge between high school and the in-depth study of engineering principles." As the course is developed, the teaching material may be used to introduce engineering principles to high school students. "I want to create a culture of mentoring," Craig said. The material developed during the teaching of Engineering Discovery will be uniquely suited for the needs of high school seniors that are interested in engineering, but unsure of the profession as a whole.

This plan addresses a critical need in undergraduate engineering education, especially during the first year, namely – to enthuse students about engineering by having them experience what engineers do and how engineers think and to expose students to the application of the essential fundamental body of knowledge in science, mathematics, and social science to the practice of engineering. Our proposed approach is visionary, challenging, and full of risks, but the risks are worth taking for the expected benefits. Is the approach the correct one? Our answer is a resounding yes and during the past year a consensus has emerged among departments in the School of Engineering, as well as the Departments of Mathematics, Chemistry, Physics, Biology, and Science & Technology Studies, that this proposed plan of action is necessary and on target.

Rensselaer has taken bold, innovative steps in the past in undergraduate engineering education – interactive learning, studio classrooms, integrated laptop computers – and, in every case, we have put in place a multidisciplinary team to accomplish the objective and we have been successful. We will be successful again, here, with this plan, and the outcome will be a model, with a set of instructional materials, that hopefully will revolutionize the first-year undergraduate engineering experience. We sincerely believe this and we are confident that we can execute this plan. We have committed to this project a group of experienced, enthusiastic faculty who are eager to devote the time and energy to make this a success and we will develop a plan to sustain the program into the future. The success of this plan will be demonstrated through our outcomes assessment, through the dissemination of our model and the supporting educational materials to other institutions, and through the illumination of our high school teachers and students about the engineering profession, but mostly through our graduates who will lead this nation into the future.

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## Biographical Information

KEVIN CRAIG
Kevin Craig is Professor of Mechanical Engineering at RPI. He teaches and performs research in the area of mechatronics and has graduated 32 M.S. and 20 Ph.D. students in this area. Craig has conducted hands-on, integrated, customized, mechatronics workshops for practicing engineers at companies such as Xerox and Procter & Gamble, and for the ASME. From 2002 – 2004, he served as Director of Core Engineering at RPI. He is a fellow of the ASME and a member of the IEEE and ASEE.

PAMELA THEROUX
Pamela Theroux is Research Assistant Professor and Assistant Director of Educational Research & Assessment in the Center for Innovation in Undergraduate Education (CIUE) at Rensselaer Polytechnic Institute. Dr. Theroux holds a Ph.D. with Distinction from Columbia University in Sociology, with Masters Degrees in Sociology & Education and International Educational Development from Columbia University Teachers College. As a sociologist, she studies the associations between teaching and learning within the context of formal and informal educational environments. Focusing on the social ecology of learning and cognitive processes broadly defined, she is interested in the concept of teaching-learning across domains, learning as a social process, and the importance of connections among educating networks. Of particular interest are the complexities of students' contemporary social-biographies in conjunction with education policies and practices, and the social challenges and policy implications changing patterns have on educational outcomes.

RICHARD SMITH
Prior to his appointment as Associate Dean for Academic and Student Affairs, Dr. Smith was Professor in the Department of Mechanical, Aerospace, and Nuclear Engineering at Rensselaer. He joined the Department in 1977, following a brief tenure at Rice University. During 1977-78, he was a Fulbright-Hayes Senior Research Scholar visiting the Polytechnic Institute of Bucharest, Romania. From 1983-91 he served as Associate Head for Graduate Studies of the Department. In 2004, he completed a three year term as Program Director for Thermal Transport and Thermal Processing in the Chemical and Transport Systems Division of the U.S. National Science Foundation.