REDESIGNING THE FIRST-YEAR ENGINEERING CURRICULUM

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Stevens' engineering curriculum has been revised, and part of this revision introduces engineering activities into the first semester via 3 concurrent engineering courses. This semester had previously consisted entirely of science and humanities courses. Now the first semester includes: Engineering Graphics (2-credit laboratory), Engineering Seminar (1 credit), and Engineering Design Laboratory I (1-credit laboratory).

The major goal of these activities in the first semester is to provide the students an early bonding with engineering and its style and task orientation as distinguished from science. They are aimed at initiating development of competencies that will build through subsequent design experiences:

1. Ability to design a system, component, or process to meet desired needs
2. Ability to function effectively on multidisciplinary teams
3. Ability to identify, formulate and assess alternative technical and economic solutions to engineering problems.
4. Ability to communicate effectively and persuasively, both in writing and orally.
5. Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
6. Skill in leadership

Integration of Engineering Courses

Stevens' new engineering curriculum puts high priority on at least some integration among different courses. While very tight integration is not necessarily a goal, interplay between different courses is required to be conscious, recognizable, and representative of the mutual interdependence that exists among "different" engineering subjects.

In the first semester, opportunities exist for integration of the several engineering courses. There is also potential for integration with the concurrent science courses, particularly the Introduction to Computers course (Computer Science Dept.) and the first semester of Physics which treats mechanics. The major integration in Fall 1998 was between Engineering Graphics and Engineering Design Laboratory I.

Integration of the Engineering Design and Engineering Graphics courses was in 4 respects:

First, freehand technical sketching, a frequent component of graphics courses, was undertaken in the Design Course as a natural, functional component of a product-dissection workshop.

Sketching was not significantly dealt with in the Graphics course itself.

Second, as part of the product dissection workshop, hardware (a cordless screwdriver) was related to actual working drawings from the manufacturer[1]. In this workshop, students were required to work with different types of working drawings (part, subassembly, and assembly drawings, standard parts; parts list) in order to find out about materials, dimensions, etc. of the product being dissected.

Third, tolerancing was dealt with in the Design course before a more extensive treatment in the Graphics course. A concern for the stacking of tolerances was introduced "just-in-time". This supported the requirement that the first project, a name plate or "logo", should be mountable on the vehicle chassis of Project 2; this required design of the mounting hole or slot sizes to allow assembly.

Finally, and most significantly, Project 1 (see below) was designed in the Graphics Laboratory and executed in the Design Laboratory with some of the database-processing required for production on CNC machines having been carried out in the Graphics Laboratory

In addition, some integration of the Design Laboratory with the Engineering Seminar for first-year students was possible. The Seminar course allows fairly rapid feedback of student comments in the Seminar to instructors in other courses. Fortunately, feedback concerning the Design course and Graphics courses was positive and did not indicate a need for remediation. This was not the case in at least one science course taken by the first-semester engineering students.

ENGINEERING DESIGN LABORATORY I

Overview

The design course, E 121 – Engineering Design Laboratory I, is a 1-credit course, offered to all engineering students in their first semester. It is the first in a series of one-per-semester design laboratories constituting a "Design Spine" running through all eight semesters. These design laboratories are each integrated, more or less, with other concurrent courses required of all engineering students. The first-semester course meets for 3 hours per week, and, as a 1-credit laboratory course, is not intended to require work by students outside of the laboratory periods. The course was offered for the first time as part of the initiation of Stevens' new engineering curriculum in the Fall of 1998.

As formulated by a faculty committee dealing with design content in the engineering curriculum, Engineering Design Laboratory I is intended to:

- Provide an interesting early "hands-on" experience in engineering
- Create an integrated link to engineering graphics
- Introduce and practice the engineering method
- Introduce the student to professional practice topics including effective group skills, project management and basic economic analysis.

This course is intended to introduce students to the process of design and seeks to engage their enthusiasm for engineering from the very beginning of the program. The engineering method is

[1] Kindly provided by Black & Decker (U.S.) Inc, Towson, Maryland.

used in the design and manufacture of a product. Product dissection is exploited to evaluate how others have solved design problems. Development of competencies in professional practice topics is started, primarily: effective group participation, project management, engineering economics, and communication skills. These competencies are developed throughout the design-course sequence.

Format and Support

Each class session, of which there are 6 throughout the week, includes two 24-student sections each of which has an instructor who is an adjunct faculty member and an undergraduate (peer) teaching assistant. In addition, a course coordinator (regular faculty) and a graduate teaching assistant offer planning and support for the instructors as do an Associate Dean of Engineering and the Dean himself (during the course-development phase). An Engineering Technical Services group provides support via design and construction of support equipment. The Head Institute Machinist provides an introduction to machine-shop practice.

The content of the course is in the form of two projects and associated skills development through a variety of short "workshop" sessions. These involve workshop exercises in topics such as cost estimating, product dissection, oral and written communication, etc.

Design Laboratory Facilities

The course uses 2400 ft^2 (40' x 60') of floor space newly reconstructed. The laboratory provides a 6' x 5' L-shaped work bench for each group of 3 students and is completely networked, one network connection for each of the 48 students simultaneously occupying the space[2]. Each half of the laboratory serves one section of students and is equipped with power tools, specifically with two band saws, drill presses, scroll saws, and a sanding center. In addition, each half of the lab contains a "gathering area" of about 200 ft^2. This space is provided for "chalk talks" and short presentations by the instructor; this area is equipped with white board, projection screen, overhead projector, and RGB computer-display projector. A "support area" in the laboratory allows stowage of materials and other paraphernalia in current use, while an adjoining "prep room" provides space for development of new hardware, stowage of out-of-use materials and supplies, etc.

Faculty & Staff

The course instructors are adjunct faculty drawn from industry and consulting firms. The proximity of a variety of industries allows the course to benefit from instructors of a variety of ages (30's to 60's), some relatively new to the engineering workforce, some retired from a range of engineering disciplines. Some are alumni, both recent and otherwise, though most are not. Instructors are recruited (by the Associate Dean) via alumni publications, announcements to alumni with jobs in nearby locations, personal reference by alumni and others, etc. Experience with such adjunct faculty had been positive for the four years of a similar design course for students in their second semester of the earlier engineering curriculum.

Each instructor is or has been a practicing design professional, and each announces to his class on the first day what his engineering activities have been. Selection of instructors is constrained

[2] Networking will be fully utilized next year when all incoming first-year students will use laptop computers.

by the requirement that all course sessions should be held during the regular academic day, none to be in the evening[3].

Judging from student evaluations and observations of instructors' interplay with students, the use of adjuncts who are practicing engineers has been successful. Practicing engineers, particularly some of the younger ones, seem to establish credibility quickly as "real-world" engineers.

Course Content

Table 1 shows a topical outline of the course content. The 3-hour laboratory periods are typically subdivided into periods of approximately one hour. For the sake of variety of activity, successive hours in the same laboratory period are typically scheduled for rather different activities to encourage participation and minimize monotony. Most of the activities are either multi-week projects or single- or part-week workshops; these are described in the following two sections.

Design Projects

The first project was the design and production of a "logo", a decorative plate, machined either by incising or in relief on a ¼"-thick plate of clear polycarbonate (2½" x 3¼") (see Fig. 1). The plate was to be mounted on the vehicle designed and constructed as Project 2. Solid Works™ software was used in the Graphics course to create the design. Diverse logo designs included a wide range from simply a few letters (e.g., S.I.T. or student initials) to a stylized duck (school mascot) or simple abstract shapes to simplified versions of international flags. Once formulated, the 3-D design became the basis for a drawing of the "pocket" representing the shape. The drawing was imported into MasterCam™ software, processed into a "G-code" suitable for driving a CNC Machining Center[4], and the logo was produced. Students carried out the steps but with detailed "cook-book" instructions and under close supervision by Engineering Services staff. In this process, students got experience with the need to communicate between various design and manufacturing databases, with concepts like reference planes and machining coordinates, with concern for feeds and speeds, tool path, etc.

The second project was longer and appreciably more challenging than the first. The task was to design and construct an autonomous model vehicle capable of traveling a course of approximately 40-ft length in minimum time. The straight course included low-grade and high-grade inclines (up to 38%) (up and down). The vehicle was required to use a modified power train (electric motor and transmission) from a commercial model kit[5]. The two-speed transmission of the kit was modified by strapping on a small d.c. motor to actuate the gear-change lever The vehicle was also required to use a microprocessor board[6] to take signals from a slope-detection sensor (to be designed) as a basis for deciding when to change gears. In addition, the group's logo, (produced as Project 1) was required to be mounted on the vehicle. Figure 2 shows one group's vehicle.

The design challenge was comprised of 3 components: the vehicle (chassis shape and construction, wheels including alignment, logo mounting), the microprocessor control algorithm, and the slope-detection sensor. This scope was well suited to the 3-person design groups.

3 Some design labs later in the curriculum have been and will continue to be offered in the evening. Such evening classes are found even to be preferred by some students.
4 ProLight Model 1000 Machining Center (http://www. lmcorp.com/lmcorp)
5 Tamiya "Buggy Car chassis kit", (http://www.Tamiya.com)
6 "Stamp II" board from Parallax Inc. (http://www.parallaxinc.com). This board will be reused on similar projects in future years.

Construction was achieved using a tool box of hand tools for each group, the power tools available for each section in the laboratory, and materials (wood, plastic, sheet metal, etc.) in stock. Students could supplement available materials and/or supplies by requisitioning or otherwise, for value not to exceed $15. per group. Parts or materials not in stock could be requisitioned by students (at their own expense), and in support, the course staff placed orders semi-weekly from either of two supply houses who could provide fast (one-day) delivery.

Workshops

Measurements – A worksheet was completed by: (1) filling in the answers to questions about a vernier micrometer and calipers (sizes of subdivisions, maximum measurement capacity, etc.), and (2) carrying out a series of measurements on one of the parts of the battery-powered screwdriver (to be disassembled the following week) and on a ping-pong ball. Some statistics (mean, median, mode) were included.

Product dissection – a battery-powered screwdriver[7] was disassembled, reassembled and worksheets completed (for grade) isolating several parts of the screwdriver and specifying the function(s) of the parts and how those functions might have been accomplished differently. As a preliminary and also as an introduction to engineering graphics, manufacturer's working drawings of the screwdriver were used as the basis for students to learn where to find information from the drawings and to answer a range of questions concerned with product materials, dimensions, parts numbers, etc.

Sketching – Techniques for freehand sketching were introduced along with concepts of orthographic projection into 3 principal views and into isometric views. Sketching workshops were aimed at developing manual facility with hard and soft pencils, drawing straight lines, circles and ellipses. One of the parts dealt with in the product dissection was sketched (for grade).

Cost estimating – "Design-for-assembly" concepts were dealt with in a workshop during which design groups formulated an estimate of the assembly time (and, thereby, assembly cost) for the battery-powered screwdriver. This cost was expressed as a fraction of the wholesale price of the item, leading to consideration of costs other than fabrication, e.g., overhead, profit, distribution, etc. Fabrication costs were estimated for Project 1 by assuming a machining time and tooling and capital costs as well as a plant overhead rate. An important facet of the design sequence is the early introduction of the economics of engineering design. This is intended to inculcate students with the idea that design has to be carried out in an economically-constrained environment.

Oral Communication - Guidelines for oral presentations were formulated with the students and served as a basis for the oral reports given (by each group member) to conclude Project 1.

Written Communication – Different types of written reports were introduced, the contents of each were considered, and this served as a basis for group reports submitted for Project 2. Reports and project hardware were submitted in draft and prototype form, respectively, two weeks before Project closure. One week later a "revision" session was held followed by the final written report being due and performance tests being held the last week of the semester.

Group Dynamics - No formal instruction about Group Dynamics was included in the first offering of the Design Laboratory. Nonetheless, staging of the first several activities in the course were purposely formulated so as to lead relatively easily into group activities. Students were

[7] Black & Decker Model 9072

formed into groups during the second course meeting on the basis of information they provided in writing during the first week of the course[8]. While individual students undertook product dissection during the second week, they were encouraged to confer with each other concerning the function of various parts and the possibility of other concepts for accomplishing the same functions. Thereby, students had experience working together before they encountered being mutually responsible for deliverables in later workshops.

Project Management - Students prepared (for grade) two work breakdown structures, one for practice (for building a house) and one for their activities on Project 2. They also prepared Gantt charts for Projects 1 and 2 and were introduced to concepts of parallel vs. sequential activities.

ENGINEERING GRAPHICS

In the previous curriculum, graphics was taught in the first semester of sophomore year. It took the traditional 2-D approach that is a daunting challenge to many students as they grapple with visualization. In revising the curriculum we have moved the Graphics to first semester with confidence that we will not deter beginning students. This confidence stems from the remarkable developments in CAD software. We have adopted the SolidWorks™ software package which provides the student with a familiar Windows™ interface and an intuitive solids-modeling approach. This software also offered a less severe learning curve to the novice than the other professional solids-modeling packages that were considered.

Within the first few weeks, students are able to produce 3-D renditions of parts and even assemblies of parts that were not possible even after a full semester with the old 2-D approach. The visualization barrier to engaging students in the Graphics course is essentially eliminated. Once they are comfortable with developing a solid rendition, the course then moves to the traditional 2-D representation for engineering drawings. The software generates the actual 2-D projections and the students can focus on dimensioning, tolerances etc., freed of the mechanics of actually producing 2-D drawings.

The instructors of this course each have several decades of graphics experience and are very enthusiastic and invigorated by the capabilities that the software brings to their teaching. This is truly a case of where developments in computing have changed the teaching paradigm.

ENGINEERING SEMINAR

This one-credit seminar was introduced as part of the enhancement of experience for first-semester engineering students. The Graphics and Design courses expose students to engineering from the start of their program by early immersion in the engineering method and tools and techniques of design. As a complement to this, a key goal of the seminar is to introduce students in a more global sense to the profession of engineering. It is also intended to help them succeed as students and in their later professional and personal lives.

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[8] Each student completed a "Student Record" which provided some information concerning the extent of his or her backgrounds (or lack thereof) in working with wood and metal-working tools, electronics, computer programming, project execution (e.g., science fairs), etc..

Each seminar group of approximately 24 students meets with an engineering faculty member once per week for approximately 90 minutes. The faculty members strive to curb their natural predilection to lecture. Rather, they take on the role of facilitators in order to prompt class discussion and collaborative exercises. The seminar leans heavily on the pioneering work of Ray Landis at Cal-State-L.A., and uses his textbook[1].

The learning environment at Stevens is distinguished by a large core providing significant breadth together with the necessary depth in the engineering disciplines. This manifests itself in a heavy credit requirement and leads to more contact hours than found in most engineering programs. It was necessary to designate the course as one credit in order to provide an incentive for students to take the course seriously as they juggle their commitments. To maintain their interest, variety beyond class discussion is necessary, e.g., field trips, guest speakers and laboratory visits.

The syllabus contains a significant focus on examining and trying to inculcate, through understanding, those attributes and skills that will lead to academic and personal success. This involves delving into the factors that will lead to success in engineering study and practice. It includes probing the role of attitudes and the development of success strategies such as time management.

In addition, students learn about the engineering profession in general, about specific engineering disciplines and about professional licensure. This is achieved through class discussion, reading assignments and Web searches, for example by using the ASEE and the American Association of Engineering Societies Web sites as launching points. Students also are introduced to the use of library resources for obtaining information by way of enjoyable "hands-on" exercises. Increased exposure to practicing engineers and engineering enterprises is planned for the future development of this course through a Distinguished Engineer Lecture Series and plant trips.

One of the significant benefits to emerge from the seminar is the major role that it can play in the advising system for students. In the past, students were assigned a faculty advisor for the first three semesters until they started their chosen disciplinary elective sequence, at which point they transitioned to an advisor in their chosen engineering Department. The general experience was that little interaction took place between students and advisors in the first three semesters. In the seminar, the faculty gets to know a small group of students over a full semester and this promotes much freer and extensive interaction in an advisory mode, both within class and outside one on one.

References

1. Landis, Raymond B., *Studying Engineering - A Road Map to a Rewarding Career* , Discovery Press, Burbank, CA, 236 pp., 1995.

Biographical Information

RICHARD B. COLE is a Professor of Mechanical Engineering. He coordinates Stevens ' 1st-semester design course. He holds the Bachelor's in Mechanical Engineering (Cornell), M.S. degrees in Mechanical Engineering (Stevens) and Aeronautical Engineering (Princeton). and a Ph.D in Mechanical Engineering from Stevens. He has held several offices of ASEE's Energy Conversion and Conservation Division including Chair, and Program Chair.

KEITH SHEPPARD is a Professor of Materials Science and Engineering and Associate Dean of Engineering. He earned the B.Sc. from the University of Leeds, England and Ph.D. from the University of Birmingham, England, both in metallurgy. As Associate Dean, Sheppard coordinates the development and implementation of the courses that comprise the core design sequence at Stevens.

BERNARD GALLOIS is Dean of Engineering and a Professor of Materials Science and Engineering. He received the Diplôme d' Ingénieure Civil des Mines at the École Nationale Supérieure des Mines de Nancy, France. He obtained the M.S. and Ph.D. degrees in metallurgy and materials science from Carnegie-Mellon University. As Dean he has lead the recent revision of Stevens' Engineering Curriculum and the development of associated infrastructure.

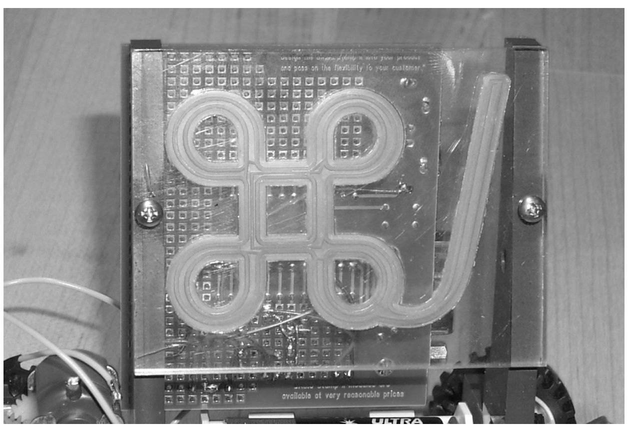

Figure 1: A CNC Machined "Logo"

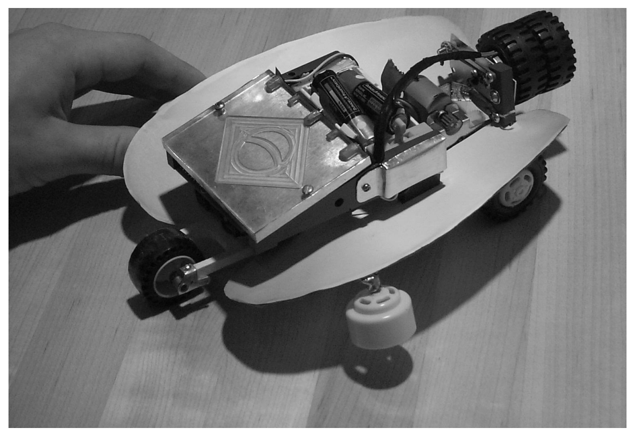

Figure 2: A Microprocessor-Controlled Vehicle

WK	HOUR 1	HOUR 2	HOUR 3
1	Course Introduction; Outlines of projects; Intro. to Engineering Design	Measuring-tools workshop (vernier micrometer, dial calipers, digital calipers); form temporary (alphabetical) groups	Introduction to freehand sketching including workshop (temporary groups)
2	Introduction to production graphics & graphics workshop (parts d'w'gs, assembly d'w'gs, std. parts); Form permanent groups	Design Analysis – cordless screwdriver	Design Analysis workshop – each student sketches and describes function and alternative implementations for one part
3	Revisit Of Design Analysis workshop - discussion of "good" and "not-so-good" responses.	Intro. to costing (screwdriver assembly)	Assembly-costing workshop
4	Machine-shop lecture	Section A: Machine-shop workshop / Intro. to Project 1	Intro. to Project 1 / Machine-shop workshop
		Section B: Project Management and Group Dynamics workshops	
5	Section A: Project Management and Group Dynamics workshops		Project 1 (Continue)
	Section B: Machine-shop workshop / Intro. to Project 1	Intro. to Project 1 / Machine-shop workshop	
6	Introduction (Demo.) to NC milling machines	Machining costing module with workshop	Project 1 (Continue)
7	Intro. to oral reporting	Design Project 1 - Production	Design Project 1 – Production (Continue)
8	Design Project 1 – Production (continue)	Testing and Orals on Project 1	Intro. to Project 2
9	Project 2 (Continue)		
10	Intro. to written reporting	Project 2 (Continue)	
11	Project 2 (Continue)		
12	First tests of Project 2 (Draft reports due)	Project 2 - Revision	
13	Project 2 - Revision (Continue) (Return of graded draft reports; feedback via written comments and consultations)		
14	Re-test of Project 2 and oral reports (Resubmit written report)		

Table 1: Engineering Design Laboratory I – Course Topics By Week And Hour
(Two 24-student sections meeting simultaneously)