COMPOSING A NEW ECE PROGRAM: THE FIRST FIVE YEARS

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Abstract — *We have developed a new Electrical and Computer Engineering (ECE) program at Rowan University. The first class graduated in May 2000. Features include: a continuous Engineering Clinic sequence, a mixture of two-, three-, and four-credit courses, and technology focus electives. Project-based instruction is employed as a tool for motivating students and to demonstrate the relevancy of material. Multidisciplinary courses provide the opportunity for students in different disciplines to work together. Some of the approaches—and lessons learned—may be of interest to other start-ups and programs considering transformation.*

Index Terms — *new programs, curriculum design, project-based instruction, multidisciplinary design.*

INTRODUCTION

Rowan University's engineering programs are the result of an endowment by Henry and Betty Rowan. The Rowan challenge was to create quality programs to develop engineers who could compete in the new global economy. Four engineering disciplines (Chemical, Civil and Environmental, Electrical and Computer, and Mechanical) were started in 1995; the first class enrolled in 1996; the engineering building was completed in early 1998.

ABET's Criteria 2000 [1], the ASEE report, "Engineering for a Changing World," [2] and discussions with engineering practitioners provide motivation for changing the way engineering is taught. Engineering education needs to be transformed to an outcomes-oriented, student-centered, total quality environment. We need to do a much better job of demonstrating relevance of the material we teach and more actively involve students in the learning process so that they can *do*.

Unlike previous curriculum "fixes," squeezing in a few new courses can't solve the problem. Instead the entire curriculum content and structure need reengineering. Additionally, ABET's new criteria defines a process modifying the way we evaluate program results. First, desired outcomes must be defined, then diagnostic measures taken in order to assess progress toward desired outcomes. Only then should modifications to the process be made. This process of continual improvement defines a quality engineering education environment.

In this paper, we describe the development of a new ECE program to meet these challenges.

GOALS

It is tempting to generate an extensive list of goals—until serious consideration is given to how progress toward those goals will be measured. Instead, we have tried to develop a minimum set of college-wide goals, which are then augmented by each discipline. In addition, there are university-wide vision elements that we also embrace. Goals, attributes, and assessment tools condensed from an internal draft are summarized in Table I. Example assessment tools are cited for each goal. The list is not exhaustive; for example, employer feedback will be used as an assessment technique for all goals.

CURRICULUM

The structure of the curriculum is shown in Figure 1. Many of the course titles suggest content that is familiar in typical ECE programs. Features that differ substantially from traditional offerings are described next.

Electrical and Computer Engineering

The core content of the curriculum has been planned to include both Electrical and Computer Engineering as a combined degree. The early curriculum focused only on Electrical Engineering. However, it became obvious from our marketing efforts that there was strong demand from prospective students for Computer Engineering. In addition, we believe that Computer Engineering is an integral component of the practice of modern Electrical Engineering. The recent ABET Criteria 2000 guidelines for electrical and/or computer engineering make explicit distinctions between electrical and computer engineering based only on mathematics. Electrical Engineering requires differential

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TABLE I.
PROGRAM OBJECTIVES AND ASSESSMENT TECHNIQUES.

Objective	Attributes	Assessment
Create effective engineers	• Apply theory to practice • Analysis and synthesis • Handle a progression of system (design/analysis) complexities	• Design portfolio • Course materials • Employer feedback • Resume
Cultivate capable communicators	• Writing skills • Oral skills • Multimedia skills	• Informal and formal work • Self-assessment • Seminar presentations
Develop agile technologists	• Tool (computer/equipment) users and tool makers • Adapts to & learns new technologies (life-long learning)	• Course work • Project work and scope • Employer feedback • Seminar presentations
Instill entrepreneurial spirit	• Entrepreneurial attitude • Understands business process • Calculated risk taking	• Employer (Employee) feedback Intrapreneurial • Business acumen • Scope/diversity of projects
Facilitate multidisciplinary discourse	• Work in multidisciplinary teams • Contribute to out-of-discipline design projects • Communication across disciplines	• Multidisciplinary design project work • Out-of-discipline evaluation
Sensitize to contemporary issues	• Professional issues • Ethics • Societal concerns • Impact of engineering decisions	• Total project scope • Interpretation and interaction • Professional societies • Outside activities
(ECE) Impart essential ECE knowledge	• Breadth and depth in math, foundations, systems, computing • Aware of the state-of-the-art • Product design (function & form) • System design	• Exams (written, oral) • Project work • Employer feedback

equations, linear algebra, complex variables, and discrete mathematics. Computer Engineering requires discrete mathematics.

Engineering Clinics

All four engineering programs share an *Engineering Clinic* component, which is an eight-semester sequence of laboratory-based instruction. One of the members of the Rowan Advisory Board was from Harvey Mudd—the Engineering Clinic [N] was proposed as one component of the upper-division programs of study. In addition, there were some "workshops" in the curricula as well. Planning is one thing—course preparation is quite another. One of the early results of delivering of the curriculum was the transformation of the Engineering Clinic sequence into a core component of all four programs. Clinics provide the structure needed to deliver many of the hallmarks intended to define the Rowan engineering experience:

- Hands-on instruction
- Treatment of integrated topics
- Teamwork
- Effective communication
- Multidisciplinary experience
- Entrepreneurship

Each level of the Clinic sequence has a general theme:

- Fr. Clinic I: Measurements
- Fr. Clinic II: Competitive assessment
- Soph. Clinic I: Multidisciplinary design
- Soph. Clinic II: Structured design project [3]
- Jr. Clinic I, II: Small system design projects
- Sr. Clinic I & II: Large system design project

The Freshman and Sophomore Clinics are similar to Introduction to Engineering courses now found at many Universities; however, we emphasize multidisciplinary experience. Currently, our freshman year is common for all programs; Freshman Clinic also serves as an introduction to

FIRST YEAR			
Freshman Engineering Clinic I	2	Freshman Engineering Clinic II	2
Composition I	3	Computer Science & Programming	4
Calculus I	4	Calculus II	4
Advanced College Chemistry I	4	Physics I	4
General Education I	3	General Education II	3
Total Units	**16**	Total Units	**17**
SECOND YEAR			
Sophomore Engineering Clinic I w/ Composition II	4	Sophomore Engineering Clinic II w/ Public Speaking	4
Engineering Analysis I	4	Engineering Analysis II	4
Physics II	4	Dynamics	2
Statics	2	Network II	2
Network I	2	Digital I	2
		Electronics I	2
Total Units	**16**	Total Units	**16**
THIRD YEAR			
Junior Engineering Clinic I	2	Junior Engineering Clinic II	2
Clinic Consultant	1	Clinic Consultant	1
Systems and Controls I	3	Data Structures	3
Engineering Electromagnetics I	2	Digital Signal Processing	3
Engineering Electromagnetics II	2	Communication	4
Digital II: Microprocessors	2	Electronics II: VLSI Design	3
General Education III (μEcon)	3		
Total Units	**15**	Total Units	**16**
FOURTH YEAR			
Senior Engineering Clinic I	2	Senior Engineering Clinic II	2
Clinic Consultant	1	Clinic Consultant	1
Computer Arch. I	2	Seminar: Engineering Frontiers	1
Computer Arch. II	2	Elective	3
Software Engineering	3	Technology Focus Elective	3
Elective	3	General Education IV	3
Technology Focus Elective	3	General Education V	3
Total Units	**16**	Total Units	**16**
Total Program Credits: 128			

FIGURE 1.
ROWAN'S ELECTRICAL AND COMPUTER ENGINEERING PROGRAM

each discipline to give students an opportunity to sample some aspects of each before committing to their final program of study choice. Details of the freshman and sophomore Clinic experience can be found elsewhere [4-11]. Upper-division Clinics are project driven, with multidisciplinary projects and industry sponsorship as objectives. In addition they include module-based instruction to cover additional discipline-specific topics, Rowan vision elements, and to provide project-related instruction.

Laboratory Courses

The program does not contain any explicit ECE laboratory courses; however, a strong hands-on component pervades the entire program of study. First, the Clinics provide continuous laboratory experience. Secondly, some amount of laboratory instruction is provided as part of most core and elective courses. This is also a consequence of using project-based instruction as a key structural element [12]. For example, Electronics I includes a regularly scheduled laboratory period, some of which is used for formal lab instruction with the balance available for project work. Similar lab/lecture instruction models are used throughout the program. Of particular note are courses such as Electromagnetics that also have a laboratory component.

2-Hour Courses

All programs share a number of 2-credit hour courses at the sophomore level. For example, Statics, Dynamics, Network I, and Electronics I. One motivation is to allow diversity in the number of foundation engineering science courses that students take. So far, we have stopped short of a more ambitious reworking of this part of the curriculum along the lines of some of the NSF Coalitions [13], but will continue to revisit this topic. The 2-hour courses are also the result of trying to balance an overall reduction in program credit hours to 128 with the commitment to maintaining significant Clinic credit hours. Some of the 2-credit courses are taught in half a semester; others run the full 14-week term.

Electives

There are five electives (15 SCH) in the program to provide additional breadth and depth of engineering topics. Electives can serve both senior undergraduates and first-year graduate students. Examples of electives include Digital Image Processing, Digital Speech Processing, Artificial Neural Networks, Architectures for DSP, Wavelets, Wireless Communication, Fiber Optics, Instrumentation, and Design for Sustainability. Two "technology focus electives" are intended to target multidisciplinary audiences. Example tech-focus electives include Principles of Nondestructive Test and Evaluation, Controls II: Robotics, and Rocket Propulsion (taught by ME). We have "Topics" courses at the undergraduate level to provide the flexibility to teach new content without having to always deal with the 18-month University course approval process.

Seminar

Engineering Frontiers is a senior seminar taken in the final semester. There are several motivations for this course. We want students to be aware of the state-of-the-art. Entering the seminar, students will have had different experiences depending on which Clinic projects they have been on and which electives they took. We want students to investigate an area of technology that interests them; doing it as seniors should give them the background to understand significantly more. With every student giving a presentation, a great deal of state-of-the-art information is exchanged. Finally, the seminar is a chance to practice some of the skills needed for life-long learning.

Clinic Consultant

One of the unique features of the ECE program is the "Clinic Consultant." These 1-hour courses occur in all four semesters of the junior and senior years. The Clinic Consultant was originally spawned from the College's decision to reduce the Junior and Senior Engineering Clinics from 3-s.h. to 2-s.h., returning four credits to each department. Our on-going ABET planning was fortuitous; we were searching for ways to provide additional curriculum feedback mechanisms, particularly ways to feedforward as opposed to the normal feedback processes that are often the only methods available.

Minors (Computer Science, Mathematics)

Agreements with the Computer Science and Mathematics departments in the College of Liberal Arts and Sciences allow ECE students to graduate with a minor in Computer Science or Mathematics by taking just two additional classes in the respective program. The CS minor has proved particularly popular with many students in the ECE program.

Internships

ECE students are strongly encouraged by faculty and administrators to obtain summer internships in engineering industries. The College of Engineering has an Internship Coordinator who acts as a liaison between students and industries seeking interns. Internships provide opportunities for students to gain experience in their chosen profession, develop connections in industry, and apply all skills learned in school. Internships allow us to assess the students' abilities in technical skills relative to program outcomes in two ways: Evaluations of student completed by a supervisor, and student self-assessment of the internship.

RESOURCES

As of spring 2001, the ECE program has eight faculty and approximately 110 students. We have invested approximately $650k—much of it leveraged through NSF grants and other sources—to equip two primary instructional laboratory spaces – the Electronics Lab and the Design Studio.

Electronics Lab

The Electronics Lab consist of 10 complete work centers consisting of triple-voltage power supplies, two RF signal sources, a digital multimeter, a 100-MHz digital storage oscilloscope with integral logic analyzer, and a Windows/Intel computer for data acquisition. In addition to the individual work centers, additional equipment is available for specific projects. This additional equipment includes a microwave network analyzer, electromagnetic compliance tester, active load, lightwave source/detector, high-bandwidth oscilloscopes, and an digital/analog communications signal generator. This lab is used for ECE courses (Networks I, II, Electronics I, Digital I, II, etc.) as well as all four years of Engineering Clinic.

Design Studio

The Design Studio is a laboratory setting modeled after industrial electronics design facilities. Individual work centers for electronics testing, cubicle conference rooms, workstations, and rapid prototyping equipment are arranged as they might be in an industrial setting. This lab is designed for the Junior/Senior Engineering Clinics in which externally funded projects are designed, fabricated, and tested. It also houses the digital systems design equipment (logic analyzers, etc.).

The Design Studio also contains Competitive Assessment work centers. There are 5 Competitive Assessment work centers built on mobile tables. The mobile tables allow these work centers to be utilized on projects throughout Rowan Hall. The equipment on a Competitive Assessment work center consists of the same equipment available on a standard lab bench in the Electronics Lab (triple-voltage dc power supply, two function generators, a digital multimeter, a mixed-signal oscilloscope, and a data acquisition switch unit) plus a digital power analyzer. The data acquisition switch unit has a pre-wired access panel (located just above the LCD monitor) that has 24 channels of thermocouple input, 8 channels of general-purpose voltage input, two digital-to-analog converter outputs, and 16-bits of digital I/O.

OUTCOMES ASSESSMENT

The Electrical and Computer Engineering Program at Rowan has developed a variety of assessment tools. These tools help evaluate our progress toward meeting the matrix of outcomes supporting our program goals. We have adopted successful assessment strategies employed by others within the College of Engineering at Rowan and within the broader engineering education community. We have developed what we believe to be novel additional assessment tools and curricular feedback mechanisms to ensure the vitality and health of our program.

Rowan Engineering's Class of 2000 graduated in May. Of the 100 students who entered in 1996, 85 graduated in four years. We had 21 ECE graduates. Fifteen took jobs; six entered graduate school. We were visited by the EAC of ABET for the first time in Fall 2000 – we were evaluated under the new EC 2000 criteria.

DISCUSSION AND CONCLUSIONS

We have described some aspects of the ongoing development of a new ECE program that has been designed to address systemic deficiencies in engineering education. The program stresses hands-on, multidisciplinary education. One of the most unique features of the program is the continuous Engineering Clinic sequence. This lab-intensive component provides the means of achieving a number of program goals.

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REFERENCES

[1] The Accreditation Board for Engineering and Technology, *Engineering Criteria 2000*, www.abet.org/eac/eac2000.html, Oct 29, 1998.

[2] Engineering Deans Roundtable, "Engineering for a changing world," American Society for Engineering Education, Washington, D.C.

[3] Example sophomore Clinic design project from spring 1998: sun00.rowan.edu/courses/0901-202/aircraft-nde/aircraft-nde.html, May 8, 1998.

[4] R.P. Hesketh, *et al*, "Introducing freshmen to engineering through measurements," *Proc. ASEE Middle Atlantic Section Spring 1998 Reg. Conf.*, April 25.

[5] K. Jahan, *et al*, "Engineering measurements and instrumentation for a freshman class," *Proc. 1998 ASEE Nat. Conf.*, Seattle, WA, June 28 – July 1.

[6] J.L. Schmalzel, *et al*, "An interdisciplinary design sequence for sophomore engineering." *Proc. 1998 ASEE Nat. Conf.*, Seattle, WA, June 28 – July 1.

[7] J.L. Schmalzel, A.J. Marchese, J. Mariappan, and S.A. Mandayam, "The engineering Clinic: A four-year design sequence," *2nd An. Conf. of Nat. Collegiate Inventors and Innovators Alliance*, Washington, D.C., March 13-15, 1998.

[8] J.L. Schmalzel, A.J. Marchese, and R.P. Hesketh, "What's brewing in the Clinic?" *HP Engineering Educator*, 2:1, Winter 1998, pp. 6-7.

[9] A.J. Marchese, *et al*, "Design in the Rowan University Freshman Engineering Clinic," *Proc. 1997 ASEE An. Conf.*, Session #3225, Milwaukee, WI, June 15-18.

[10] R.P. Hesketh, *et al*, "Multidisciplinary experimental experiences in the Freshman Engineering Clinic at Rowan University," *Proc. 1997 ASEE An. Conf.*, Session #2326, Milwaukee, WI, June 15-18.

[11] J.L. Schmalzel, K. Jahan, Z. Keil, J. Mariappan, A. Marchese, and S. Mandayam, "An interdisciplinary design sequence for sophomore engineering," *Proc. 1998 ASEE Nat. Conf.*, June 28–Aug 01, Seattle, WA.

[12] S.A. Dyer and R.A. Dyer, "Emphasizing the interdependence of topics in required undergraduate EE courses: A case study," *Proc. IEEE IMTC Conf.*, May 19-21, 1997, pp. 1320-5.

[13] Information about the NSF Coalitions: http://www.needs.org/coalitions/index.html, particularly, SUCCEED, May 8, 1998.