An Integrated Engineering Curriculum - A Case Study

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I. Introduction

Mercer University was established in 1833 as primarily a liberal arts institution. Current enrollment in all schools of the university is approximately 6500. The School of Engineering was established in the fall of 1985 and currently enrolls 420 undergraduates. The school offers a four-year undergraduate degree of Bachelor of Science in Engineering with specialties in Biomedical Engineering, Electrical Engineering, Environmental Engineering, Industrial Engineering and Mechanical Engineering. Also offered is a degree of Bachelor of Science in Environmental Systems Technology, Industrial Management and Technical Communications. The Mercer BSE program is accredited by ABET using the ABET non-traditional program criteria.

In the fall of 1995, Mercer began the process of modifying its curricula in anticipation of a fall 1997 transition from the quarter system to the semester system. The faculty of the School of Engineering undertook a redesign of the entire engineering curriculum rather than make small perturbations on existing quarter-based programs. It was becoming increasingly clear that our primary customers - engineering companies - are requiring a graduate that possesses a wider range of skills than those of the previous graduates of engineering programs. One of the major outcomes of our study of today's employer requirements was identification of the need for a more well-rounded engineer who understands and appreciates the knowledge and skill areas required of other engineering disciplines outside his/her own specialty. This requirement of the new curriculum was met by structuring a core engineering program that extends across all four years with discipline specific courses relegated solely to the junior and senior year. This Core Program that we will describe in detail is the heart of our revitalized curriculum.

II. Why We Changed: Catalysts

As noted above, Mercer University decided to change from the quarter system to the semester system by the fall of 1997. While a number of our sister schools at Mercer planned to simply roll their current curriculum into the semester format, the School of Engineering faculty decided to take this opportunity to reshape our engineering program and achieve a new vision. This impetus came from both external and internal forces.

Externally, we were aware that ABET was working on a new set of criteria that would change the way our programs would be reviewed for accreditation. In addition, our colleagues at other schools and our advisors from industry confirmed our sense that engineering education needed to incorporate ways to assess its outcomes and provide mechanisms for responding to those assessments. Internally, we were not satisfied with our retention numbers. More important, we were convinced that we could help students build a better foundation, especially at the freshman level, and at the same time, motivate them to the challenges and rewards of the engineering profession. Additionally, we felt that curricular components were not integrated enough—that we did not achieve the kind of integrated knowledge set that engineers need to function in a superior way in the new millenium. Finally, we had a strong desire to develop a curriculum that will be able to adapt to the rapidly changing world in which our graduates must practice. Aware of the innovations and research into engineering education occurring at such places as Drexel, Harvey Mudd, and Rose Hulman, we knew that we could achieve a standard of excellence that would prepare our students to be leaders in the 21st century.

III. What We Changed: Content and Educational Goals

Mercer University's School of Engineering was already doing a number of things right. We had a strong common core that fostered better communication among engineering disciplines. We had integrated design experiences beginning in the freshman year and culminating in an interdisciplinary senior design project involving almost a full year of realistic engineering teamwork. We had a strong emphasis on technical communication and on team project requirements. Employers told us that our graduates compared very well in terms of engineering competence and experience, communication skills, and ability to work with teams.

The curriculum was not as successful as it could be in a number of areas, and these were targeted for improvement:

- The freshman sequence needed to include more integration of engineering, mathematics, science, and communication instruction.
- The sophomore sequence needed additional integration of topics to foster student learning in mechanical and electrical fundamentals.
- In addition to horizontal integration needs we wanted to make the curriculum flow more smoothly from freshman through senior year. This included initiatives such as a "threads" concept, and a selection of courses taught by our sister College of Liberal Arts in order to foster global awareness on the part of our graduates.
- Finally, we needed better ways to measure outcomes. This involved a wide range of initiatives that included mandatory "exhibits" (portfolios, freshman design, a junior-level gateway exam, senior design, and the Fundamentals of Engineering exam) that would demonstrate student learning not only of fundamentals but of processes

Our desire was to develop an educational product that is not only competent in engineering, but also capable of strong leadership in a demanding societal context.

IV. How We Changed: The Process

During the spring and summer of 1994, when Dr. Allen Grum was Interim Dean, we determined that we would set in place a process of thinking about the engineering curriculum. Toward that end, Dr. Marjorie Davis led a faculty workshop prior to fall 1994 on creating a common vision and communicating across personal and disciplinary differences. When Dean Mogens Henriksen came aboard in January 1995, we extended the conversation to include the impact of changing ABET criteria and increasingly different industry demands. These conversations also involved our National Engineering Advisory Board, a panel of distinguished engineering leaders from many corporate environments. During the summer of 1995, the dean and department chairs held a retreat in which we sketched out the curricular framework. To use an architectural planning metaphor, we drew an outline of the house we wanted to build and defined how it should be oriented in the world. In addition, we specified the sizes of the different rooms.

The entire engineering faculty participated in a retreat just before fall quarter 1995 to flesh out the plan for our house. At that session the faculty received the general parameters that had been developed by the leadership group. This included guidance such as number of hours required for the degree, the overall plan for an integrated core, emphasis on mechanical and electrical engineering fundamentals, global awareness, and curricular threads that would run throughout the degree program. The faculty's task was to work in interdisciplinary teams as focus groups that would flesh out the elements of the curriculum. These teams labored throughout 1995-96 under the direction of Dr. John Palmer, whose project management efforts kept teams on track and ensured regular feedback from teams to the whole faculty. We surveyed students to get their honest feedback on different elements of our curriculum, teaching styles, and expectations. A crucial area for change was the Freshman Engineering Sequence, and Ms. Helen Grady was selected to chair that pivotal committee. Negotiation became the imperative as we worked out many disagreements and conflicts, both within the School of Engineering and among our faculty colleagues in other schools that provide service courses in mathematics, physics, chemistry, and humanities/social sciences. By the spring of 1996 we had refined the curriculum and had developed enough consensus to proceed.

V. What We Constructed: the Product

The undergraduate degree program spans eight semesters and requires completion of 128 semester hours of coursework. The majority of the Freshman and Sophomore years are devoted to the Core Program courses with the remaining Junior and Senior years devoted primarily to discipline-specific courses. Core courses are included in these Junior and Senior years but to a lesser degree than the first two. The Core may be viewed as a series of courses which begin by providing students a solid foundation in mathematics, science, engineering science, writing, speaking, and critical thinking. Following this preparation, students who exhibit appropriate competency dedicate their junior and senior years to the development of proficiency and a depth of understanding in one of the areas of specialization. Prior to graduation each student must exhibit an ability to accomplish engineering design by successfully completing a project in which small groups design, build, and test realistic engineering systems. Finally, as part of their graduation exhibit requirements, students must achieve a passing score on the Fundamentals of Engineering (FE) examination.

A chronological listing of the revised curriculum is shown on the next page. Core courses are highlighted in boldface.

The Freshman Engineering Experience: A group of four courses in the Freshman year (EGR 105, 106, 107, 108) is intended to introduce the student to the engineering profession and begin development of written and oral skills. They also equip students to use software packages for computer-aided drafting, engineering calculations, word processing and presentation preparation. Finally, they introduce professional practices and systematic procedures for engineering design. In short, these courses attempt to prepare a foundation on which students can build in their follow-on courses. A significant part of this early experience is the preparation and presentation of a design project. The students are required to participate in interdisciplinary teams as they

The Revised Curriculum

Freshman Year

Fall Semester					Spring Semester				
EGR 105	**Intro to Engr**	**3**	**0**	**3**	**EGR 107**	**Intro to Engr Design**	**2**	**2**	**3**
EGR 106	**Engr Tools and Tech**	**2**	**2**	**3**	**EGR 108**	**Professional Practices**	**3**	**0**	**3**
EGR 171	**Calculus for Engr I**	**3**	**0**	**3**	**EGR 172**	**Calculus for Engr II**	**3**	**0**	**3**
EGR 171L	**Engr Analysis & Appl I**	**0**	**3**	**1**	**EGR 172L**	**Engr Analysis & App II**	**0**	**3**	**1**
PHY 170	**General Physics I**	**4**	**3**	**5**	**EGR 120**	**Engr Economics**	**3**	**0**	**3**
					PHY 171	**General Physics II**	**2**	**3**	**3**
		12	**8**	**15**			**13**	**8**	**16**

Sophomore Year

Fall Semester					Spring Semester				
EGR 330	**Intro to Differential Eq**	**3**	**0**	**3**	**EGR 250**	**Prob & Stats for Engr**	**3**	**0**	**3**
EGR 330L	**Engr Analysis & App III**	**0**	**3**	**1**	**EGR 235**	**Mechanical Fund II**	**3**	**0**	**3**
EGR 234	**Mechanical Fund I**	**3**	**2**	**4**	**EGR 235L**	**Mechanical Fund Lab**	**0**	**3**	**1**
EGR 244	**Electrical Fund I**	**3**	**2**	**4**	**EGR 245**	**Electrical Fund II**	**3**	**0**	**3**
CHM 111	**General Chemistry**	**3**	**3**	**4**	**EGR 245L**	**Electrical Fund Lab**	**0**	**3**	**1**
XXX 288	Intro to xxx I	0	3	1	XXX 289	Intro to xxx II	0	3	1
					XXX	Lab Science Elective	3	3	4
						Junior Level Exhibits			
		12	**13**	**17**			**12**	**12**	**16**

Junior Year

Fall Semester					Spring Semester				
EGR 362	**Struct & Prop of Matls**	**3**	**0**	**3**	**EGR 386**	**Engr Systems Analysis**	**3**	**0**	**3**
TCO 341	**Tech Communication**	**3**	**0**	**3**	**EGR 370**	**Manufacturing & Mgt**	**2**	**0**	**2**
XXX 3XX	Specialization Specific	3	3	4	EGR 370L	Manufac & Mgt Lab	0	3	1
XXX 3XX	Specialization Specific	3	3	4	XXX 3XX	Specialization Specific	3	3	4
XXX	GA/HSS I*	3	0	3	XXX 3XX	Specialization Specific	3	0	3
					XXX	GA/HSS II	3	0	3
		15	**6**	**17**			**14**	**6**	**16**

Senior Year

Fall Semester					Spring Semester				
EGR 487	**Engr Design Exhibit I**	**0**	**6**	**2**	**EGR 488**	**Engr Design Exhibit II**	**0**	**6**	**2**
XXX 4XX	Specialization Specific	3	0	3	XXX 4XX	Specialization Specific	3	0	3
XXX 4XX	Specialization Specific	3	0	3	XXX 4XX	Technical Elective	3	0	3
XXX 4XX	Technical Elective	3	0	3	XXX 4XX	Technical Elective	3	0	3
XXX 4XX	Technical Elective	3	0	3	XXX	GA/HSS IV	3	0	3
XXX	GA/HSS III	3	0	3					
						Graduation Exhibit			
		15	**6**	**17**			**12**	**6**	**14**

- **3 2 4** indicates 3 hours of lecture, 2 hours of laboratory, and 4 total credit hours
- GA/HSS denotes Global Awareness/ Humanities Social Science.
- XXX 3XX denotes any specialization (BME, ECE, ISE, MAE, etc) at the **3**00 level

learn the basic processes of engineering design and project management, practice group dynamics, and engage in oral and written communication. The two calculus courses (EGR 171 and 172) cover the standard differential and integral calculus skills, while the associated laboratories (EGR 171L and EGR 172L) provide the student with engineering applications of those skills. These labs, taught by engineering faculty members, also serve as additional motivation for the students by introducing real-world engineering problems and solution approaches. The remaining Freshman year courses are fairly standard. Physics I and II cover basic electricity and magnetism and wave motion and optics. EGR 120 gives the student a basic understanding of classical economics and engineering economy

The Sophomore Year: Fundamentals The Sophomore year finishes the mathematics sequence with a course in differential equations (EGR 330) along with its associated applications lab, EGR 330L. Engineering probability and statistics are covered in EGR 250. A standard chemistry course, CHM 111, rounds out the general studies content. The remaining four courses are an important aspect of giving all engineering students an appreciation and understanding of each other's discipline. The Mechanical Fundamentals sequence (EGR 234 and EGR 235 and associated laboratory EGR 235L) covers the mechanical engineering topics of statics, dynamics, thermodynamics and fluid dynamics. The Electrical Fundamentals sequence (EGR 244 and EGR 245 and associated laboratory EGR 245L) covers the electrical engineering topics of circuit analysis, electronics, and energy conversion (transformers, AC and DC machines). These four courses and the associated two laboratories play a significant role in the ability of the Core program to prepare well rounded engineers who appreciate each others' disciplines.

The Junior Year: Beginning to Specialize The Junior year begins the discipline-specific specialization. However, the Core program continues with courses in the Structure and Properties of Materials (EGR 362), Technical Communication (TCO 341), Engineering Systems Analysis (EGR 386), and Manufacturing and Management (EGR 370).

The Senior Year: Capstone The Senior year continues the discipline-specific specialization. One of the most important experiences of the senior year is obtained through the Engineering Design Exhibit, EGR 487 and 488. Here students demonstrate their ability to design realistic engineering systems to meet desired performance goals. The majority of the design projects are suggested by and are accomplished in coordination with local industry. Student teams begin by writing a formal proposal to meet a specific need. At the end of the first semester, the team presents both an oral and a written Preliminary Design Review (PDR) in which they explain the problem and defend the chosen design methodology before the engineering faculty. Each team is required to examine several design alternatives and choose, based on merit analysis, an optimal course of action. They are also required to present a detailed project cost assessment leading to the second semester construction and testing of a model or prototype of their design. At the end of the second semester they demonstrate a working system and at the Critical Design Review (CDR) they must defend their entire project, showing that it met all design and cost goals. Industry sponsors are present at the PDR and CDR and actively participate in the critique and assessment of the project progress and its success. The intent of this Engineering Design Exhibit is to give seniors a realistic experience as preparation for similar industrial requirements. Post graduation surveys of employers support the success of this methodology.

The curriculum contains a lab science/mathematics elective in the sophomore year, as well as four Global Awareness/ Humanities Social Sciences electives in the Junior and Senior years.

Curricular Threads Although the above details the structure of the Core curriculum, it is important to stress several underlying goals and concepts that are essential to making the Core program a unique and useful experience for the students. The first and perhaps most important concept that permeates the Core is that of "Threads". The concept of Threads is similar to that of a woven fabric wherein certain colors run through it thereby unifying and integrating the disparate parts of the fabric into a coherent pattern. There are four objectives of the Threads concept:

- *Integration*- integrating throughout the curriculum those elements that we deemed important instead of isolating those elements inside particular courses or departmental offerings,
- *Continuation*-continuing exposure and instruction from **freshman through senior** year so that students do not hear about the topic one time and forget it,
- *Elaboration*-reinforcing important **basic** concepts by practice, deepening competencies towards achieving real **expertise** in each of these threads,
- *Demonstration*-ensuring that every curricular checkpoint, whether examination or exhibit, contains a demonstration of the students' **mastery** of that thread as appropriate to their level; constructing a longitudinal record of the student's development in each thread. The topics that make up the threads are:
  (1) Mathematics competencies.
  (2) Communication competencies.
  (3) Computer competencies.
  (4) Engineering design competencies.
  (5) Laboratory competencies.

VI. Lessons Learned

In our visits to other engineering schools and our attendance at conferences we heard a recurring theme. Our own experiences have now verified that message. True curricular reform is time-consuming, demanding extraordinary efforts from both faculty and administrators as they try to envision and accomplish change. The Mercer School of Engineering spent from the fall of 1994 to the fall of 1997 on curricular redesign. Faculty spent hundreds of hours above their normal workload and faced difficult issues together. Though we have not found all the answers, we have learned some lessons that perhaps can help others who are embarking on this process.

Lesson #1: If true curricular reform is to occur, faculty buy-in is essential.

- No matter how hard the School tries, it will never achieve 100% buy-in. There are those faculty who are unwilling to change what they see as tried and true methods; they will try to obstruct or at least make it more difficult to change a curriculum they are comfortable with.
- While the role of the leadership group (which includes deans and department chairpersons) may be to design the overall guidelines and parameters--to lay out the outside dimensions and rooms in the house—the faculty must be trusted to "put the furniture into the rooms." Faculty retreats, workshops, committees, and opportunities for summer positions to develop portions of the new curriculum are useful means of promoting buy-in.
- Careful design of committees can overcome some of the obstacles to change. (As an example, suppose several faculty who have for years taught the freshman core are openly opposed to any change. The committee charged with redesign of the core can consist of several members of the freshman core who are willing to change along with, say, members from electrical engineering and mechanical engineering.)

- As various committees work over time developing parts of the curriculum, the faculty needs frequent feedback on the progress of the effort. Keeping everyone informed during the development process is essential to achieving a successful vote on the final product.

Lesson #2: Careful attention to management of the process and support from the administration are essential to success.

- The impetus for curriculum change will most likely come from a small group at the supervisory level. It is unlikely that curriculum change will come from a ground swell of the faculty.
- This small group must have clear authority and strong backing from the administration.
- A strong project manager is crucial to a successful change process. The project manager sets deadlines for reports, establishes tasks to be accomplished, plans for regular feedback sessions, and assures quality control.
- There is a need for strong and effective leadership deep within the organization. The School will need several working groups. The "administration" cannot chair all of these groups, nor should they. Using carefully selected faculty to chair the working groups will assist in the buy-in.

Lesson #3: True curricular reform requires substantive changes throughout the curriculum.

- Change is made easier by using new labels for courses and different kinds of time allocations. As long as an old 50-minute course is still called "Statics" and is taught in a 50 minute period, people will find it difficult to reconceptualize the course. On the other hand, if the course title is changed to "Mechanical Fundamentals" and restructured into a two-hour block of time, change is far more likely.
- Redesigning courses can be a good opportunity to introduce new learning methods such as active learning, group processes, integrated instruction, interdisciplinary design, etc.
- Development of new kinds of assessment tools for the new curriculum should be a concurrent effort with the curriculum design.

Lesson #4: Solving some problems inevitably creates others, all of which may not be solvable.

- A "different" curriculum causes some problems with transfer students who are coming from "traditional" programs. For example, a program may have a course that integrates and intermingles microeconomics and engineering economy. What does the school do with a transfer student who has completed only a traditional microeconomics course at another institution?
- Such an investment by the faculty of time and effort will understandably lead to an expectation that student performance should be markedly better in the new curriculum. To the extent that student difficulties lie outside their engineering classes (in such areas as preparation for mathematics, or motivation to study), these expectations will probably not be met.

Lesson #5: The completion of a curriculum redesign can be a source of immense satisfaction. The creative processes, the new material, and the interworking of the faculty are all experiences that result in a pride of ownership and a commitment to the common goals.

VII. Summary and Conclusions

At the time of this presentation, Mercer University's School of Engineering will have completed only the first year of teaching our new curriculum. Without a doubt it has been one of the most stressful experiences of our professional lives. Yet in spite of the enormous work effort, we feel good about what we have accomplished. We are confident that we have held to the spirit of the new ABET 2000 criteria, and that we have designed some innovative approaches without losing sight of standards and common goals. Not only is our curriculum stronger than ever, but so is our faculty—and, we hope, so are our students. Curricular reform has provided opportunities for creativity, for working together, and for achieving a shared vision that will lead to a stronger School of Engineering. We are now in a much better position to adapt to the rapidly changing world in which our graduates must practice. Most important, we believe that we are on our way to achieving a standard of excellence that will prepare our students to be leaders in the 21st century.

Biographical Information

Marjorie T. Davis Professor and Chair of Technical Communication; B.S., Troy State University, 1966; M.A., University of South Florida, 1969; Ph.D., University of Mississippi, 1974.

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