A New Sophomore Engineering Curriculum -- The Rose-Hulman Experience

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INTRODUCTION

Beginning with the 1995-1996 academic year, Rose-Hulman began offering a new sophomore engineering curriculum as part of its participation in the Foundation Coalition. The Rose-Hulman/Foundation-Coalition Sophomore Engineering Curriculum consists of two parallel course streams -- applied mathematics and engineering science -- and integrates material both across and within these streams. At present this curriculum is required of all electrical and computer engineering majors and is an option for mechanical engineering and civil engineering majors. The purpose of this paper is share our experiences during the development process and to introduce the curriculum. Before discussing our efforts, a few words about the Foundation Coalition are in order because of its role as a catalyst in our curriculum development efforts.

FOUNDATION COALITION

The Foundation Coalition was formed in the fall of 1993. It consists of seven institutions committed to reexamining and restructuring undergraduate engineering curricula to create an enduring foundation for student development and life-long learning. The framework for this change is provided by examining and reevaluating how faculty and students interact in the classroom, how students can be challenged and helped to see new links between topics, how technology can be used to improve learning, and how assessment can play a role in improving the educational process.

The members of the Foundation Coalition are committed to developing undergraduate engineering programs that will produce graduates who are committed to life-long learning; can work in teams; are demographically representative; can communicate effectively, understand and can apply the fundamentals of mathematics and the physical and biological sciences; can synthesize diverse knowledge bases to create solutions to pressing problems; can define problems, develop and evaluate alternatives, and implement solutions; and can use computers for analysis, design, and communication. One of the unique features of this coalition is each member's commitment to implementing first-year, second-year, and upper-division curricula that support these goals.

The Foundation Coalition is funded in part by the Engineering Education Coalitions Program of the National Science Foundation. The seven member institutions are the University of Alabama, Arizona State University, Maricopa Community College District, Rose-Hulman Institute of Technology, Texas A&M University, Texas A&M University at Kingsville, and Texas Woman's University. Because the members of the

Foundation Coalition represent a diverse group of institutions, they provide an excellent platform for testing curriculum innovations.

CURRICULUM DEVELOPMENT PROCESS

‘Anyone who has attempted curricular change and innovation that crosses departmental and discipline boundaries knows that this is a significant undertaking with many hazards and frustrations. In addition to our new curriculum, we believe that the process used to develop and gain approval for our curriculum may be of interest to the larger academic community. Although we are still learning, we believe we have begun a process that will reduce the resistance to this type of change.

From initiation of the Foundation Coalition grant to the implementation of the new curriculum took almost exactly two years. In Fall 1993, the Foundation Coalition was funded by NSF. Soon the Rose-Hulman faculty began thinking about the impact of the Foundation Coalition goals on our curriculum. These discussions culminated in a two-month series of Friday afternoon meetings_ where interested faculty discussed issues of curriculum innovation. In Summer 1994, a faculty team the ideas from the previous year and produced a high-level design for the content and structure of a new sophomore engineering curriculum. ‘. In Spring 1995, the final proposal was approved by the faculty. During Summer 1995, a team of faculty and students did the detail design of the courses and the curriculum, and the first sections of the curriculum were taught in Fall 1995.

There were three crucial phases in our curriculum development process. The first phase was the summer of 1994 when a team often faculty members representing mathematics and all of the engineering disciplines (mechanical, electrical and computer, civil, and chemical) worked on the high-level design of the curriculum. This team had to decide what material should be in the curriculum and how it should be structured. A major reason for this team’s success was the time spent up front on team training and learning about curriculum design and active learning. The skills and attitudes developed during the early team meetings paid off handsomely in building a smoothly functioning team that survived the lengthy meetings required for consensus decision making. This training has also had a ripple-effect in other areas of the Institute.

During the summer of 1994, the team met for two months and developed a process development flow chart for our activities, formulated a platform of beliefs about engineering education and our curriculum, identified existing courses that covered pertinent material, prepared a list of topics covered in each existing course, discussed and pruned the list of topics, discussed possible organizing principles, and finally prepared course packages. One of the most significant activities of the summer was learning about our existing curriculum and what we currently taught. One way to visualize the work of this team is to imagine joining with your colleagues and writing down all of the important topics in your respective courses on index cards, one topic to a card. Then imagine coming together as a group and throwing all of the cards on the table. Next imagine sifting through the cards, selecting out the important topics, looking for new ways to group and link the topics, and finally discarding topics that have lost their significance. This was an eye-opening activity.

In Fall 1995, the team reported back to the Institute that the curriculum it was proposing had the following characteristics:

- It replaces the present engineering science and mathematics courses now taken by all disciplines with a series of courses that focus on engineering science, engineering practice, and mathematics.
- It is built on the belief that there is a core body of knowledge and experience that all engineering students should see by the end of their sophomore year, including Conservation and Accounting of extensive properties as key fundamentals and Modeling of the real world as a key engineering activity.
- It places increased emphasis on Engineering Practice, e.g. the design process, the importance of communications, the role of economics in engineering decisions, and the importance of teamwork.
- It stresses the importance of linking material across the curriculum through careful sequencing, coordination, and integration of topics.

During the 1994-1995 academic year, the second phase of the process, the curriculum was approved. This process included extensive consultation with faculty and staff. First, the faculty team prepared a summary document that included a Rationale for considering curriculum change, a Platform of beliefs, a Curriculum Scope that illustrated our vision, and finally a Curriculum Package that set forth a proposed curriculum. This document was distributed to all faculty. Then, the faculty team met with the nine academic departments in the Institute and with students to listen to their concerns. A written summary of the comments and concerns was prepared and distributed following each meeting. After contacting and listening to all of the stakeholders, the faculty team reconvened to consider what they had heard and make a final proposal. Following a marathon evening meeting, the faculty team reached a consensus proposal. Although we entered our final session with divergent views, we successfully crafted a consensus that the entire team supported. I stress the word consensus because throughout our work the faculty team used this approach in making important decisions. Once the final curriculum proposal was reviewed by faculty and staff, the curriculum was approved. Approval of the curriculum was facilitated by the willingness of the electrical and computer engineering department to make it a requirement for all of their students starting in Fall 1996. This also reduced the pressure on the faculty working on the curriculum to recruit students.

The third phase of the development process was the work of a fifteen member team during the summer of 1995. This team finally put flesh on the bones of the Rose-Hulman/Foundation-Coalition (RH/FC) Sophomore Engineering Curriculum. Learning from our earlier experiences with an all engineering faculty team, this new team was expanded to include faculty from physics and chemistry plus the four engineering disciplines. This team also included three students. The non-engineers and the students were an especially productive and helpful addition to the team. The early part of the summer was spent educating new team members and reeducating old team members about team training. In addition the team investigated issues related to the curriculum, e.g. the conservation and accounting concept[1] as developed by Charles Glover and colleagues at Texas A&M, writing goals and objectives for curriculum and course development, use of Bloom's taxonomy for educational objectives, active and cooperative learning strategies, formative and summative assessment, and technology in the classroom. The team also discussed how to balance faculty autonomy and the desired curriculum interdependence. By the end of the summer this team produced a set of goals and standards for the curriculum and a course packet for each course. Each course packet contained course goals, course objectives, topics to be covered, a course schedule (syllabus), links to other courses, and suggested materials. This activity was funded in part by a Curriculum Development Grant from the Lilly Endowment.

Students who participate in the RH/FC Sophomore Engineering Curriculum should

‘develop a strong background in engineering science,
.....develop an understanding of modeling,
.....be able to apply a common problem-solving approach built around the application of conservation and accounting principles and constitutive relations,
.....continue to develop effective communication skills,
.....be proficient in applying standard statistical procedures and quality control concepts,
.....develop a strong background in mathematics,
.....be encouraged to be inquisitive and self-motivated learners,
.....develop an appreciation for engineering as a profession and begin to develop an identity as an engineer.
.....be able to work effectively in teams and recognize the importance of individual responsibility in team efforts,
.....be able to apply computer tools appropriately,
.....be comfortable working with ambiguity,
.....be familiar with the overall design process,
.....be able to locate and retrieve both technical and non-technical information,
.....be introduced to safe and effective use of instruments,
.....appreciate the role of creativity in engineering,
.....develop a recognition of the benefits of the new curriculum, and
.....be encouraged to have fun learning.

Figure 1- Curriculum Goals

OUTCOMES OF THE CURRICULUM DEVELOPMENT PROCESS

Curriculum Goals

During the third phase of the development process, goals were established for the new curriculum. These are listed in Figure 1. Course goals and objectives that supported the seventeen curriculum goals were then developed for each course in the curriculum.

Curriculum Structure

The RH/FC Sophomore Engineering Curriculum is designed around a coordinated series of eight courses in engineering science and mathematics that consciously stress the links between the various topics. The structure of the curriculum is illustrated in Figure 2. The curriculum is organized into two course streams -- applied mathematics and engineering science -- that are taught in a coordinated fashion. The material in each course stream has been selected and sequenced to enhance student learning by reinforcing and revisiting topics both across and within the two streams.

By comparison, a more traditional discipline-directed curriculum selects core engineering science and mathematics courses cafeteria style from existing courses. Figure 3 illustrates how engineering

	Sophomore Year Courses		
	Fall	Winter	Spring
Applied Mathematics	Applied Mathematics I	Applied Mathematics II	Applied Mathematics III
Engineering Science		Fluid& Thermal Systems	
	Conservation & Accounting Principles	Electrical Systems	Analysis & Design of Engineering Systems
		Mechanical Systems	

Figure 2- RH/FC Sophomore Engineering Curriculum

students in this type of curriculum might encounter the material now included in the RH/FC Sophomore Engineering Curriculum. As illustrated, the core engineering science courses are spread over a period of seven quarters. This has the advantage of freeing up space in the early quarters for discipline-specific courses. If, however, you believe that there is an engineering science and mathematics core that all students should know before beginning upper-division courses, this approach is flawed.

	Year	Soph			Jr			Sr		
Course	Quarter	F	W	S	F	W	S	F	W	S
Differential Equations		X	X							
Statistics/Probability				X						
Dynamics			X							
Thermodynamics								X		
Fluid Mechanics							X			
Circuits		X								

Figure 3- Discipline-Directed Approach

The new RH/FC Sophomore Engineering Curriculum consists of eight courses (30 quarter credit hours) taken during the sophomore year (Figure 4). Although courses carry either a mathematics (MA) or engineering science (ES) designation, the course development was a coordinated effort among many faculty, and it is the intent of the curriculum developers that the courses be coordinated as a single curriculum. In fact, one of the innovative features of this curriculum at Rose-Hulman, is a new management structure. Because the ES courses do not belong to any department and to insure continued coordination between the MA and ES courses, a curriculum team leader who has many of the responsibilities of a department head has been appointed to serve as an advocate and administrator for the curriculum.

-The mathematics courses begin in the fall (MA211)with a discussion of matrix algebra and first and second-order differential equations. This material is motivated by applications of conservation of mass, charge, and linear momentum in the concurrent engineering science course and is then applied again in the winter quarter courses. In the winter (MA 212), the focus shifts to statistics and probability reinforced with laboratory experiences in the concurrent engineering science courses. In the spring (MA 2 13), the emphasis moves to systems of differential equations, Laplace transforms, and mathematical approximations (i.e. Fourier and Taylor series). This material is applied immediately in the concurrent engineering science course.

The engineering science courses follow a 1-3-1 pattern beginning in the fall (ES 201) with an overview and introduction to the concept of conservation and accounting. Conservation and accounting is an idea that runs through many engineering sciences, e.g. dynamics, thermodynamics, fluid mechanics, and circuits, and is introduced here

FALL QUARTER .... 8 Credit Hours
MA211 - Applied Mathematics I (4)
ES 201 - Conservation& Accounting Principles (4)
WINTER QUARTER .... 13 Credit Hours
MA 212- Applied Mathematics II (4)
ES 202 - Fluid& Thermal Systems (3)
ES 203 - Electrical Systems (3)
ES 204 - Mechanical Systems (3)
SPRING QUARTER ....9 Credit Hours
MA 213- Applied Mathematics III (4)
ES 205 - Analysis& Design of Engineering Systems (5)
TOTAL .... 30 Credit Hours

Figure 4- RH/FC Sophomore Engineering Curriculum

first because it is our belief that these ideas provide a useful unifying framework for the study of engineering science.

A more focused study of fluid and thermal systems (ES 202), electrical systems (ES 203), and mechanical systems (ES 204) occurs during the winter quarter. In electing to have three concurrent courses, the team felt that it was important for students to see how the general ideas from ES 201 are applied in discipline-specific areas. It also is a recognition that there are discipline-specific analysis techniques that students must be familiar with; however, we believe conservation and accounting background provides a better foundation for moving into these applications. Each of the winter courses has three laboratory experiences.

. . . .. Participation in a coordinated curriculum that deliberately stresses the links between engineering science and mathematics.
. . . .. Developing a common foundation of engineering science and mathematics knowledge for future learning.
. . . .. Learning to apply a common framework for problem solving based upon an understanding of conservation and accounting principles and constitutive relations.
. . . .. Learning to handle open-ended and multidiscipline problems.
. . . .. Learning in an active and cooperative fashion.
. . . .. Learning to work in teams.
. . . .. Using computer technology, where appropriate, across the curriculum.

Figure 5- Advantages for Students

In the spring (ES 205), the focus shifts to basic systems concepts used in the analysis and modeling of simple multidiscipline and complex single-discipline engineering systems. Time is also spent introducing the overall design process and giving students experience with developing product specifications.

Advantages of the Curriculum

We believe that there are several advantages for students participating in this program. Some of these are listed in Figure 5. Our experience would indicate that there are also significant advantages for faculty who participate in this collegial experience of developing and teaching a coordinated curriculum.

CONCLUDING REMARKS

We are just completing our first year of implementation and have begun a series of assessment activities. We look forward in the future to sharing more details about the curriculum, about our experiences as faculty and about the experiences of our students.

BIBLIOGRAPHY

1 Glover, C. J., K. M. Lunsford, and J. A. Fleming, *Conservation Principles and the Structure of Engineering*, 5th Ed., McGraw-Hill, Inc. (College Custom Series), New York, 1996.

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