A Case Study: Development of a Practice Oriented Engineering Program with Implications for Regional Economic Development

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Introduction

This paper describes an engineering program planned for implementation at East Carolina University in fall 2004. The program presents a unique design synthesis of concentration areas required to enhance regional economic development and the best practices identified from the work of the National Science Foundation (NSF) Engineering Education Coalition (EEC) program. The paper begins with an examination of the economic development issues of eastern North Carolina to provide context for the primary motivation of the program initiation. It then discusses the NSF EEC program and the major educational findings that impact on the new engineering program design. Building on the background from these sections, it then presents an overview of the new program, its curricular structure, and general objectives as a unique synthesis of the regional economic development needs and EEC innovations.

Eastern North Carolina Economic Issues

In the last ten years, there has been a major shift in the economic base of eastern North Carolina. For generations, the regional economy was driven by agriculture and in particular tobacco production. In recent years, this economy has made a major transition to a manufacturing, military, and government / service based economy. Figure 1 indicates that over 85% of the total regional payroll comes from these sectors and the largest component is manufacturing.[1]

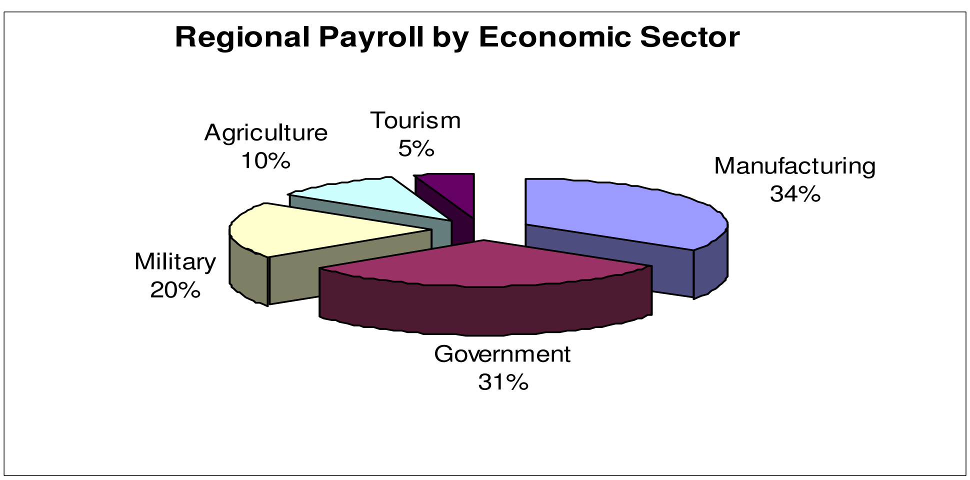

Figure 1 Economic Development Overview of Eastern North Carolina

This manufacturing sector is composed primarily of small plants with less than 300 total employees. Some are satellite operations of large, well known corporations. Many are small, locally owned, specialty manufacturers. Examples of this group include boat manufacturers and their related suppliers. In spite of their different character, these manufacturing operations face a common challenge, unique to this region. Since they function in a highly competitive, global environment, it is essential to maintain a dynamic approach to adoption and implementation of state of the art technologies and methods. Their ability to compete in technology is in large part dependent on site specific engineering talent. In employing the needed technical talent, these plants must control overhead costs and cannot support large engineering staffs with a range of specialists in narrowly defined fields. Finding this talent also presents issues. Local, national and global firms all have difficulty attracting and retaining engineering talent in a region that is primarily comprised of small towns and cities.

Development of local engineering talent, with roots in the region, was perceived as an important element in solving this issue. However, the dynamic character of such technology-dependent and, typically, resource limited enterprises requires a unique kind of technical problem solver to work in general and, often, emerging disciplines. In this highly competitive environment, technologically-based challenges cannot be neatly categorized along traditional disciplinary boundaries with highly specialized domain experts. Instead of the traditional engineering disciplines, these operations require engineering generalists with a strong theoretical background, broad knowledge in a range of areas, and specific skills in problem solving to give them a sound but flexible base for managing and implementing technology change and operations. Such engineers must be able to anticipate, create, implement, and manage new technologies.

NSF Coalition Curricular Results

Discussion of the need for major revision of engineering education started in the mid-1980s and culminated with an extensive National Science Foundation (NSF) program in 1989. The Engineering Education Coalitions[2] (EEC) initiative funded six coalitions in a multi-year effort to pursue three primary goals:

- Increase both the quality of engineering education and the number of degrees awarded in engineering, including a focus on women and underrepresented minorities;
- Develop, implement, evaluate, and disseminate new approaches impacting all areas of undergraduate engineering education;
- Establish new linkages among all U.S. engineering institutions.

Each of the six coalitions was obligated to disseminate the results of their work. As a result, there is an extensive body of papers and web sites that document the details of coalition efforts. For example, the Foundations Coalition produced a summary report that included a comprehensive reference section containing publications describing its work and accomplishments.[3]

A particularly detailed summary that examined the overall results of the EEC program and its six coalitions was completed in 2000.[4] This report employed a variety of tools to gather information including surveys and interviews with students, faculty, and administration about the successes of the programs at coalition schools. In the conclusion section, this report identified recommendations for best practices in new engineering curricular models and the bullets below summarize these points.

- Implementation of "engineering up front": the exposure of freshmen to hands-on, real-world engineering practice early in their undergraduate education, ranging from 'professional level' laboratory facilities to realistic design projects. Many engineering programs have postponed this experience until the junior or senior year.
- Integration of students working in teams rather than independently, including cooperative learning, especially in the earlier undergraduate years. Although the study found an emphasis on a team approach as a difficult process (including problems related to team composition, organization, methods in addressing weak performers, and grading), students rated it highly as a valuable "real world" experience that gave them an advantage in the job market.
- Increased use of contemporary educational technology, with computer-based methods of delivering courses increasingly taking the place of traditional lectures.
- Coordination of engineering topics with other disciplines, such as physics, writing courses, and social science / humanities.
- "Just-in-time" teaching: concurrent lecture and laboratory courses are sequenced so that lecture topics are covered just as they become needed in the laboratory. In previous models, lecture and laboratory courses might have proceeded independently.
- Inclusion of senior design projects with industrial partners that provided a real and substantial exposure to the work place and the actual experience of engineering were highly valued.

These curricular concepts of the new engineering education model were integrated with the economic development needs to develop the new engineering program proposal.

Engineering Program Focus

The proposed Bachelor of Science in Engineering (BSE) at East Carolina University (ECU) was developed to address three principal goals: 1) Support the economic development requirements of eastern North Carolina by creating professionals to meet the general engineering needs of eastern North Carolina's private and public sectors, 2) Develop engineering problem solvers to work in general and emerging disciplines not addressed by traditional engineering disciplines, 3) Attract, retain, and graduate general engineering students, especially eastern North Carolina students including women and underrepresented minorities. ECU's BSE program's approach to achieving these goals differs from traditional engineering program approaches in three primary ways: 1) the type of engineer produced, 2) the curriculum philosophy/structure followed, and 3) curriculum implementation.

The need to address emerging technology management and implementation needs, which cross traditional disciplinary boundaries, is reflected in the first three proposed BSE concentrations:

- Systems Engineering, which produces a technical generalist who can formulate, solve, and implement solutions to a wide variety of problems in a multitude of contexts. Such engineers are especially appropriate for smaller manufacturers that need engineering expertise, but cannot afford a large staff of specialists.

- BioMedical Engineering, which produces professionals who can contribute either to the manufacture and production of biological and medical products, or who are prepared to go to medical school or graduate programs in biomedical engineering.
- Engineering Management, which produces a technical professional with a core set of business and management knowledge that can effectively propose, budget, and manage technical projects and programs. Such projects include plant management, as well as the direction and coordination of the design, installation, operation, and maintenance of equipment and technology-based systems.

In these concentration areas, students must integrate their science core and engineering fundamental knowledge with organizational and teaming skills, financial and marketing skills, and understanding of marshalling of the resources needed to accomplish a specific goal. Most important, the engineers ECU seeks to produce also receive the basis and values to be life-long learners, able to adapt and master changing technologies, methodologies, and organizational structures. By producing graduates with these competencies, the ECU program hopes to lead in providing professionals with the engineering skills sets necessary to address the dynamic, global, evolving, competitive challenges characteristic of the economies and societies of the emerging twenty first century and confront the economic development challenges of eastern North Carolina.

The underlying curriculum philosophy of ECU's BSE rests on a design-oriented, project-based interdisciplinary focus that emphasizes core science and fundamental engineering principles to position graduates for an engineering career in a world of rapid technological change. The general engineering curriculum provides a broad background in the core sciences, mechanics and structures, information technology, engineering design and decision-making and focuses on a systems approach to engineering. It is enriched by the use of computer-aided engineering tools and course experiences involving a design-build-test-evaluate ("closed-loop") cycle that echoes the real world. This learning experience begins at the freshman year and proceeds continuously through the senior year. The senior year culminates in a client driven, commissioned project course in which student teams solve real-world problems posed by external sponsors/clients.

Moreover, the chosen philosophy emphasizes developing in the students a central intellectual touchstone and knowledge base for general engineering problem solving and design. This base provides the foundation which will permit an engineer to rapidly acquire specific domain knowledge in the context of the general framework of applied science. In effect, the program targets the skill to acquire new knowledge quickly and integrate such knowledge into a broad world view. As an analogy, this desired skill might be viewed as the ability to add trees to an individual's forest. This paradigm arises from the belief that much of today's engineering education results in engineers with highly specialized, domain specific knowledge that "stove pipes" the perspectives and worldviews of graduates. This stove piping is a result of the highly serial process of traditional engineering education and its emphasis on greater and greater specialized domain knowledge.

The paradigm pursued by ECU's BSE emphasizes a more parallel, iterative approach of science and engineering principles linked through an experiential environment of application and feedback. This approach immerses students in a multi-experiential environment where the need to learn basic knowledge, apply problem solving methods, solve real problems, and make tradeoff and compromises are part of a total education milieu. This approach recognizes that the constantly changing world of technology requires the individual to rapidly adjust to shifts in technological, economic, and operational imperatives.

ECU's philosophy does not overlook an appropriate level of specialization and requires students to pursue a focused concentration area of study beyond the foundation program. The focused concentration serves a two-fold purpose. First, it provides a marketable identity for graduates in the job market. Secondly, it provides students with an opportunity to apply and use their general education as a basis to progress to a more specialized knowledge domain. This experience is not meant to emphasize narrowing specialization as much as to demonstrate acquisition and integration of more specialized knowledge in the context of an ever expanding breadth of knowledge. Figure 2 reflects the conceptual view of this process.

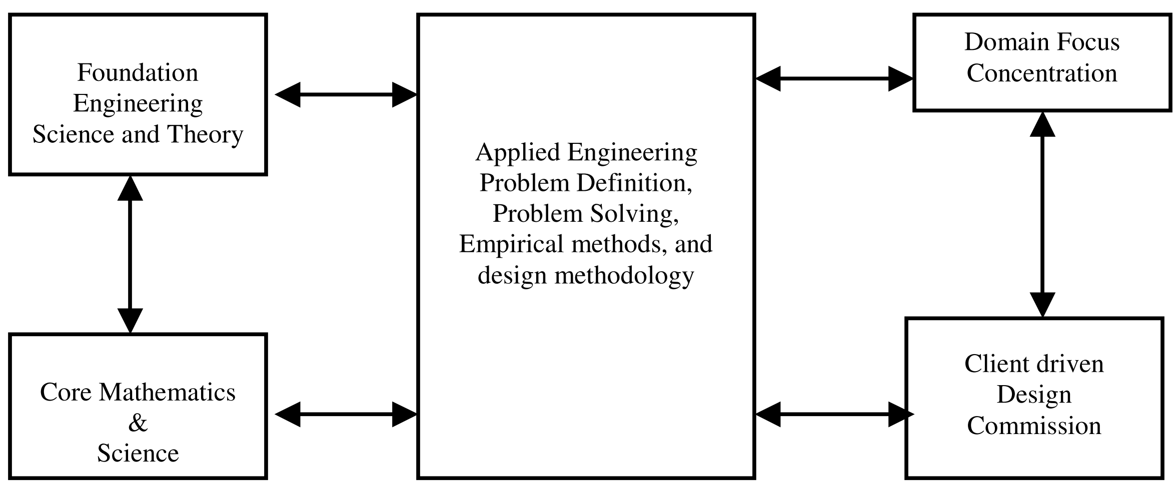

Figure 2. ECU's BSE Proposed Curriculum Process

Curriculum Implementation Plan

ECU plans to implement its proposed BSE curriculum through a concept and program identified as the **Integrated Collaborative Engineering Educational Environment**, or **ICE^3** (pronounced "ice cube"). The ICE^3 program is the primary curricular vehicle to implement the NSF ECE innovations and emphasizes a broad but highly integrated foundation of engineering fundamentals and engineering sciences necessary for a general engineer. The broad foundation in engineering fundamentals and the program's emphasis on general problem solving, the integration of systems, technology, and people provides the basis for establishing a professional who will be able to adapt to changing technologies and contexts.

- ICE^3 provides collaborative learning communities where students, faculty, and employers with common interests work as partners to improve the engineering educational experience.

- ICE^3 establishes cohorts of students and teachers working in a structured environment with formal industry participation. This experience spans multiple terms and multiple courses each term, with an identifiable curricular focus devoted to the endeavor.
- ICE^3 emphasizes engaging students in engineering from the day they matriculate; making the study of engineering more attractive, exciting, and fulfilling; developing students as emerging professional leaders; and increasing the diversity of academic backgrounds and the number of women and underrepresented minorities.

The ICE^3 concept and structure, as its name implies, strives to create an environment and infrastructure to foster the connections necessary for students to be successful as students and as engineers. Most engineering education approaches are based on fragmented disciplinary courses taught from specific disciplinary perspectives. In contrast, the ICE^3 approach fosters the emphasis on learning a broad but highly integrated foundation of engineering fundamentals and engineering sciences necessary for a general engineer. The broad foundation in engineering fundamentals and the program's emphasis on general problem solving, the integration of systems, technology, and people provides the basis for establishing a professional who will be able to adapt to changing technologies and contexts. More important, the proposed engineering program strives to create life-long learners who are able to continually build on the solid basis provided by their general engineering degree education.

The proposed conceptual architecture for the BSE curricula is shown in Figure 3 below. During the first year, ICE^3 courses (identified by the prefix ICEE) address engineering fundamentals including engineering graphics, data analysis, and design analysis involving static forces, stress, shear, business planning and project planning. Topics are focused around several design, build, and test projects. These projects introduce students to the engineering design process and allow them, on a reduced scale, to experience the same decision-making process as practicing engineers. The second year ICE^3 courses focuses on advanced topics in engineering fundamentals and engineering science including dynamics, thermal systems, fluid systems, and the design and analysis of electrical circuits. Projects introduce students to leading teams and proposing plans. In addition, the first two years of ICE^3 courses are coordinated and integrated with ICE^3 cohorts in courses from math, English, and physics. During the third and fourth years, students remain involved in ICE^3 through courses that include emphasis on systems analysis and problem definition, information systems, and senior design capstone courses.

An important integral part of ICE$^\mathbf{3}$ is ECU Engineering, Inc., a dynamic, student run showcase of ECU capabilities that will be designed and managed to attract project opportunities. All engineering students will participate in projects and senior students mentor and/or lead the project teams. This initiative brings students together to engage in effective formulation and solving of real world engineering problems every semester through graduation. Students move up through the ECU Engineering, Inc., organization as they progress through their academic program. The final stage in this progress is a capstone senior project as a final experience, where students will propose and manage their project with ECU Engineering, Inc., assets, including other students. Continuous involvement in ECU Engineering, Inc. will be required every semester and will be incorporated into ICE$^\mathbf{3}$ courses and learning communities.

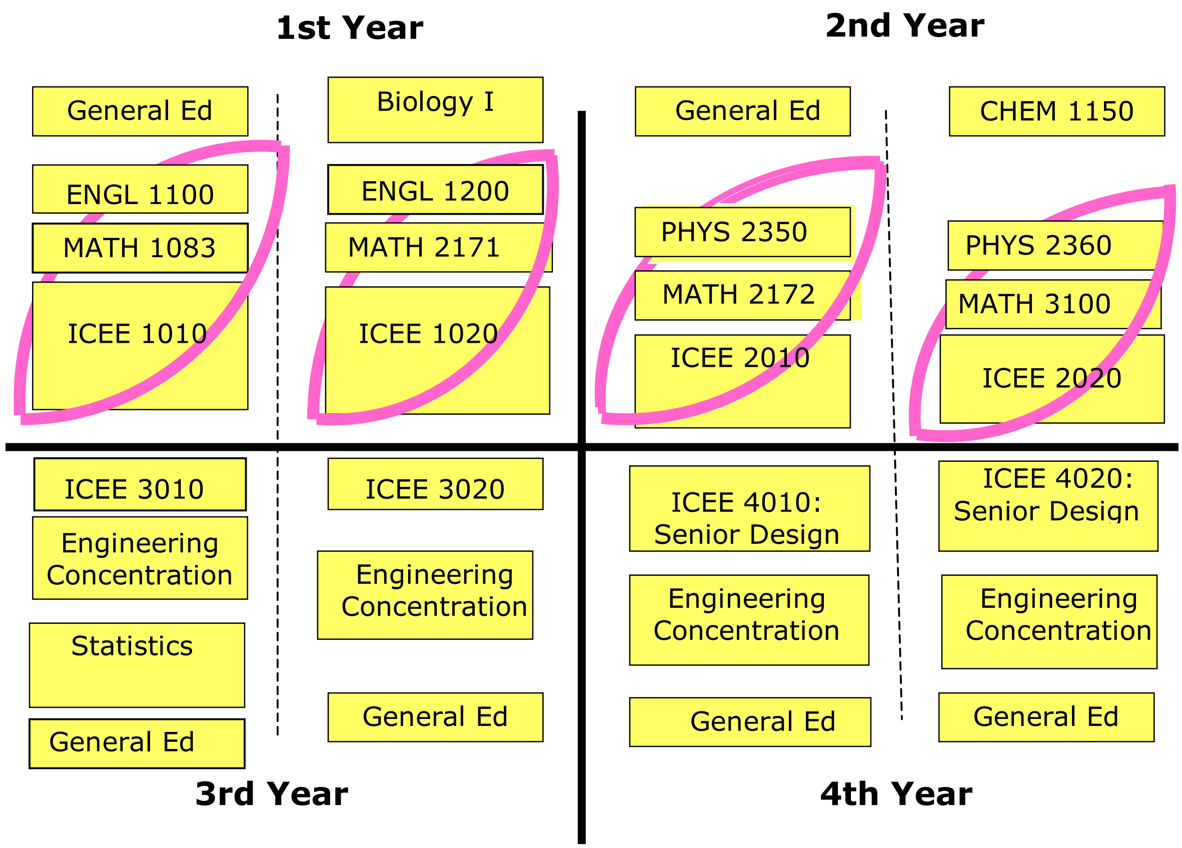

Figure 3. Conceptual Architecture for BSE Curricula

Summary

The ability of regional economies to compete in technology driven sectors depends to a great extent on access to engineering talent. Specifically, the engineering talent must be attuned to the often unique requirements and constraints of the region's sector. Finding, recruiting, and retaining such sector specific and regionally focused engineers can be a major problem for many enterprises and regional economies across the nation. Further confounding the problem is the dynamic character of such technology-dependent and resource limited enterprises where technology-based challenges cannot be categorized along traditional engineering disciplines. The problem is especially acute in a region primarily composed of rural villages, small towns, and minor cities. Development of engineers, with roots in the region, is an important element in addressing this situation. However, the kind of engineer to develop and how to develop the engineering talent of a region remain the challenges.

East Carolina University has planned implementation of an engineering program to meet the unique demands associated with the economic sectors of eastern North Carolina. The proposed engineering program's goal is to provide unique technical problem solvers to work in general and, often emerging disciplines, with a flexible base for managing and implementing technology change and operations but with a strong, theoretical engineering background. The proposed engineering program builds on over a decade of results and experiences identified by the Engineering Education Coalitions funded by the NSF. The proposed program is composed of a broad foundation in engineering fundamentals with an emphasis on general problem solving and the integration of systems, technology, and people. The program's goal is to produce professionals, who are life long learners and will be capable of adapting to changing technologies and contexts. These individuals will be able to continually adapt by building on the solid basis provided by their general engineering degree education. Not least, the program attempts to meet the needs for engineers and engineering education in the region it serves.

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BIOGRAPHICAL INFORMATION

PAUL KAUFFMANN received a Ph.D. from Penn State in Industrial Engineering, and a MENG in Mechanical Engineering and a B.S. in Electrical Engineering from Virginia Tech. He is Department Chair of Industrial Technology at East Carolina University and research interests include technology management and managerial decision methods. During his industrial career, he held positions as project engineer, plant manager, and engineering director.

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