The Olin Curriculum: Thinking Toward the Future

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Abstract—**In 1997, the F. W. Olin Foundation of New York established the Franklin W. Olin College of Engineering, Needham, MA, with the mission of creating an engineering school for the 21st century. Over the last five years, the college has transformed from an idea to a functioning entity that admitted its first freshman class in fall 2002. This paper describes the broad outlines of the Olin curriculum with some emphasis on the electrical and computer engineering degree. The curriculum incorporates the best practices from many other institutions as well as new ideas and approaches in an attempt to address the future of engineering education.**

Index Terms—**Curriculum development, electrical engineering education, project-based learning.**

I. INTRODUCTION

OVER the last 20 years, the National Science Foundation (NSF) and the engineering community have called for systemic changes in engineering education, including the following:

- a shift from disciplinary thinking to interdisciplinary approaches;
- increased development of communication and teaming skills;
- greater consideration of the social, environmental, business, and political context of engineering;
- improved student capacity for lifelong learning; and
- emphasis on engineering practice and design throughout the curriculum [1]–[4].

Within electrical and computer engineering (ECE), the need for such innovation is clearer now than ever, as the pace of technological change accelerates and the boundaries of ECE expand to include everything from biology to software.

Many institutions, organizations, and individuals are grappling with these questions. The NSF has funded extensive work on reform of engineering education, both at individual institutions and through the various engineering coalitions, including the Engineering Coalition of Schools for Excellence in Education and Leadership (ECSEL) [5], the Foundation Coalition [6], the Gateway Coalition [7], and the Southeastern University and College Coalition for Engineering EDucation (SUCCEED) [8]. Furthermore, as anyone surveying the various engineering education journals or the abstracts for recent engineering education conferences would agree, huge effort has been generated in this area at the institutional, departmental, and individual level, both inside and outside the United States [9]–[20].

The faculty, staff, and students at the Franklin W. Olin College of Engineering, Needham, MA, have spent the last five years investigating best practices and innovations in engineering education and in preparing a ground-up design of an engineering curriculum, which has been implemented since fall 2002. In this paper, the authors present a first version of this curriculum, with particular emphasis on ECE. Since Olin is committed to innovating and improving continually, the curriculum described in this document represents only the "initial conditions" for a trajectory of ongoing curriculum review and refinement.

II. BACKGROUND—ABOUT OLIN COLLEGE

In 1997, the F. W. Olin Foundation of New York responded to calls for innovation in engineering education by making a commitment in excess of $300 million (the largest single gift in higher education at the time) to establish the Franklin W. Olin College of Engineering, an entirely new and independent undergraduate institution dedicated to preparing technological leaders for the next century.

Design and construction of a high-tech campus on 70 acres in Needham, Massachusetts, began in 1998. It is important to note that Olin's campus is adjacent to Babson College, Babson Park, MA, a highly regarded independent business school. In 1999, the Foundation recruited an experienced management team, followed in 2000 by a founding faculty who spent two years investigating innovative approaches to engineering education across the world as part of the invention process for the first version of the Olin curriculum. As part of this process, faculty members visited over 50 different institutions, ranging from small undergraduate science and engineering colleges (e.g., Harvey Mudd College, Claremont, CA, and the Rose-Hulman Institute of Technology, Terre Haute, IN) to innovative liberal arts colleges (e.g., Alverno College, Milwaukee, WI) and business schools (e.g., Babson College and Harvard Business School, Cambridge, MA) to industrial design schools (e.g., Rhode Island School of Design, Providence) to research universities with strong, innovative undergraduate programs (e.g., Worcester Polytechnic Institute, Worcester, MA; Rensselaer Polytechnic Institute, Troy, NY; and the Massachusetts Institute of Technology, Cambridge) to schools outside the United States with notably innovative programs (e.g., Aalborg University, Denmark). This "discovery" phase of Olin's invention greatly influenced the development of the Olin curriculum, and the authors are deeply indebted both to the schools that hosted Olin

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visitors, as well as to the many other schools whose innovative approaches have contributed to this thinking.

During the 2001–2002 academic year, 30 bright recent high school graduates ("Olin Partners") joined in this work of developing and testing an innovative curriculum and campus culture. In fall 2002, these 30 partners joined another 45 recent high school graduates to form Olin's first freshman class. As of fall 2004, Olin has approximately 225 students (75 freshmen, 75 sophomores, and 75 juniors) and approximately 30 faculty members. The college intends to grow over the next decade, eventually reaching a steady-state size of approximately 600 students and perhaps 65 faculty members. To date, Olin has been extremely successful in recruiting top high school graduates; by any measure (SAT scores, extracurricular activities, etc.), Olin students are among the best in the nation.

Olin is currently chartered to offer three degrees: ECE, mechanical engineering, and engineering (or engineering and applied science).

III. CURRICULAR OBJECTIVES/PHILOSOPHY

A. Curricular Goals and the Olin Graduate

At the outset of the curricular design process, Olin's faculty identified a number of curricular goals, which proved to be touchstones as the program developed.

- The curriculum should *motivate* students and help them to cultivate a lifelong love of learning.
- The curriculum should include *design throughout*—from the day students arrive on campus to the day they graduate.
- The culmination of the curriculum should be a *senior capstone* that is authentic, ambitious, and representative of professional practice.
- Students should gain experience *working as an individual, as a member of a team, and as a leader of a team.* Students will need to do all three after they graduate, and the faculty should prepare them appropriately.
- Students should learn to *communicate logically and persuasively* in spoken, written, numerical, and visual forms.
- The curriculum should include space for a true *international/intercultural immersion* experience. As globalization continues, students need perspective beyond the confines of their own backgrounds.
- The goal is to graduate *self-sufficient, motivated individuals* able to articulate and activate a vision and bring it to fruition. An education that prepares students only to turn problem statements into proposed solutions is inadequate—education must also prepare students to recognize problems and to convince others to adopt solutions.

These goals all point toward the vision for the Olin graduate. The college's graduates should be prepared to predict, create, and manage the technologies of the future, not simply respond to the technologies of today. Such students must have not only a superb command of engineering fundamentals but also a broad perspective regarding the role of engineering in society, the creativity to envision new solutions to the world's problems, and the entrepreneurial skills to bring their visions into reality.

B. Curricular Features

During the design of the Olin curriculum, several broad features believed effective in meeting these goals were identified. First, as many have noted, there lies a significant opportunity in *integration and coordination* [7], [11], [13], [18], [21]. Integrating subject matter not only provides some gains in efficiency but also offers a means of making education inherently interdisciplinary. Interdisciplinary courses make explicit the connections both within the technical world and between engineering and society and can be highly motivational and intellectually exciting for students.

Integration of coursework and projects provides additional benefits. By combining hands-on projects with rigorous coursework, instructors allow students to apply subject matter to real problems; to consider engineering in social context; to develop entrepreneurial, teaming, and communication skills; and to practice lifelong learning skills. Finally, by educating students to deal with open-ended, authentic problems throughout the curriculum, educators create the opportunity for a senior project that is truly a capstone. This type of hands-on, integrative, interdisciplinary work is a defining feature of the Olin curriculum and will help Olin produce students who can apply their theoretical knowledge to real problems.

A second key aspect of the curriculum is an emphasis on *all four years* of the student's education [6], [22], [23]. This is reflected in the significant inclusion of engineering design experiences in the first two years and in the resources devoted to the first two years—indeed, the expectation is to devote similar (if not greater) faculty resources to the freshman and sophomore as to the junior and senior years. Historically, the resources devoted to teaching specific subdisciplinary topics in the junior and senior years of the education often far exceed those spent in the first two years. As a result, students suffered through large, seemingly irrelevant classes for two years before getting to the "good stuff" as juniors. Furthermore, in many cases, much of what students learned as juniors and seniors was already obsolete by the time they graduated. By stressing fundamentals and backing up this emphasis with resources, instructors can better prepare students to work independently as juniors, seniors, and graduates; they can improve retention markedly; and they can give students the technical tools they will need to use new technologies after they leave school.

Third, the goal is to *educate the whole person*. Students should consider their extracurricular interests, nontechnical topics, or other skills as both personally important and relevant to their technical careers. Such a philosophy is common at many liberal arts colleges and is making significant in-roads in engineering schools. Olin's curriculum is structured to allow, and indeed to encourage, such personal growth.

Finally, the curriculum should also provide *flexibility with accountability*. As much as possible, the curriculum has been based on institutionally defined learning objectives rather than specific activities. Students have significant flexibility in charting their path through the curriculum, but all students are responsible for demonstrating mastery of required material through regular assessment. Similarly, throughout the

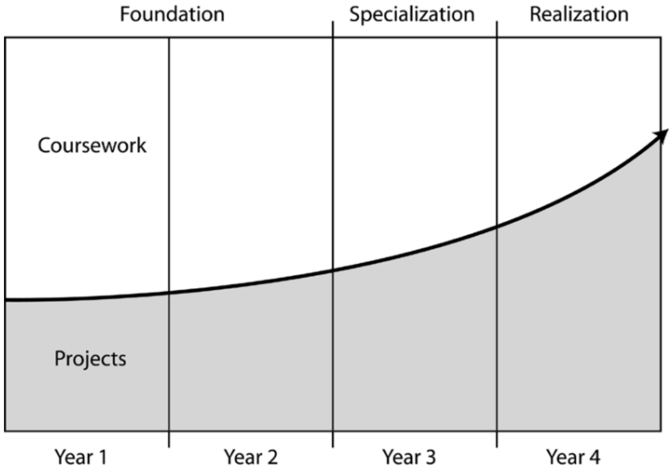

Fig. 1. Structure of the Olin curriculum. Projects are present in all four years and occupy an increasing proportion of effort as the student progresses from foundation to specialization to realization.

curriculum, student-driven activities are emphasized. Such flexibility is important for encouraging creativity in students; too often, engineering education suppresses, rather than encourages, the creative impulse. Faculty members have similar latitude (and responsibility) in deciding how to deliver learning objectives.

IV. AN OVERVIEW OF THE OLIN CURRICULUM

As shown in Fig. 1, the Olin curriculum consists of three phases: 1) the foundation, which emphasizes mastering and applying technical fundamentals in substantial engineering projects; 2) specialization, in which students develop and apply in-depth knowledge in their chosen fields; and 3) realization, in which students bring their education to bear on problems approaching professional practice. In all three phases of the curriculum, students are engaged in interdisciplinary engineering projects that require them to put theory into practice, to build upon their writing and presentation abilities, to put engineering in context, and to develop teaming and management skills. As a student progresses, these projects become increasingly open-ended and authentic.

A. The Foundation

The foundation has two core objectives: to motivate students and to give them a solid command of fundamentals. Fundamentals include not only the mathematics and physics that underlie all engineering but also subjects, such as biology, materials science, the basics of business practice, and communication and teaming skills. The foundation should provide a wealth of real engineering experiences so that students can make informed choices about majors and so that the learning of fundamentals takes place in a context of real applications.

Fig. 2 outlines all four years of student experience within the ECE program. Major portions of the first two years are taught in integrated project/course blocks, in which two or three faculty members work together to develop synchronized courses that enable tight coordination between the understanding of underlying disciplines and the application of this disciplinary knowledge to real engineering problems. In addition, such course blocks provide better tracking of student progress, lead to better learning, foster stronger student support networks, and allow for innovation in delivery.

The concept of the integrated freshman course block has, of course, been explored at many other institutions [11]. This structure provides significant student efficiencies (e.g., students learn about second-order differential equations at the same time that they need to solve those differential equations to describe physical systems); however, often concerns are expressed about excessive faculty resource costs as a result of the additional time required to teach in an integrated environment. To achieve these learning efficiencies while also avoiding excessive coordination costs, Olin opted to create relatively small integrated course blocks (equivalent to two conventional courses), which combine selected topics. Within the freshman year, the integrated course block integrates mathematics and physics with an engineering course that emphasizes fundamental and universal engineering ideas (e.g., effort and flow) and engineering tools (e.g., numerical simulation and data acquisition). The course block is taught by an appropriate multidisciplinary team. Such an approach emphasizes the connections between mathematics and physics, while simultaneously providing context by allowing students to apply the physics and math to real engineering design problems. Much of this integrated course block is taught using a project-based approach.

Although students are not required to take integrated course blocks after their first year, many interdisciplinary options are offered to sophomores, juniors, and seniors. For example, Olin offers an integrated course block for sophomores that combines science and engineering courses with courses in context, allowing students to work on engineering projects that have broader implications than the purely technical. Previous incarnations of this course block have combined biology with business through a project that examined the biotech industry, and materials science with history through a project that examined Paul Revere through the lenses of history, entrepreneurship, and metallurgy.

Students undertake open-ended design problems in integrated course blocks, and, elsewhere, design learning is particularly emphasized and explicitly developed through a formal *design stream.* All students complete multiple courses that provide a broad perspective on design. Students explore contextual factors that contribute to design decisions, learn to identify and to define problems, and develop a deeper understanding of design processes. This approach allows students to appreciate that design goes beyond simply solving a technical problem and also helps to develop a student's toolbox for future projects. Design Nature, the first course in the formal design stream, focuses on the principles and methods of engineering design. This course exposes students to a studio environment and allows them, in their first semester, to go from idea to functional prototype. Such an experience is highly motivating for students and is believed to help address retention of underrepresented groups.

Additional courses in the design stream take place in the sophomore year. User-Oriented Collaborative Design emphasizes the process of developing concepts and models of authentic products through interaction and collaboration with

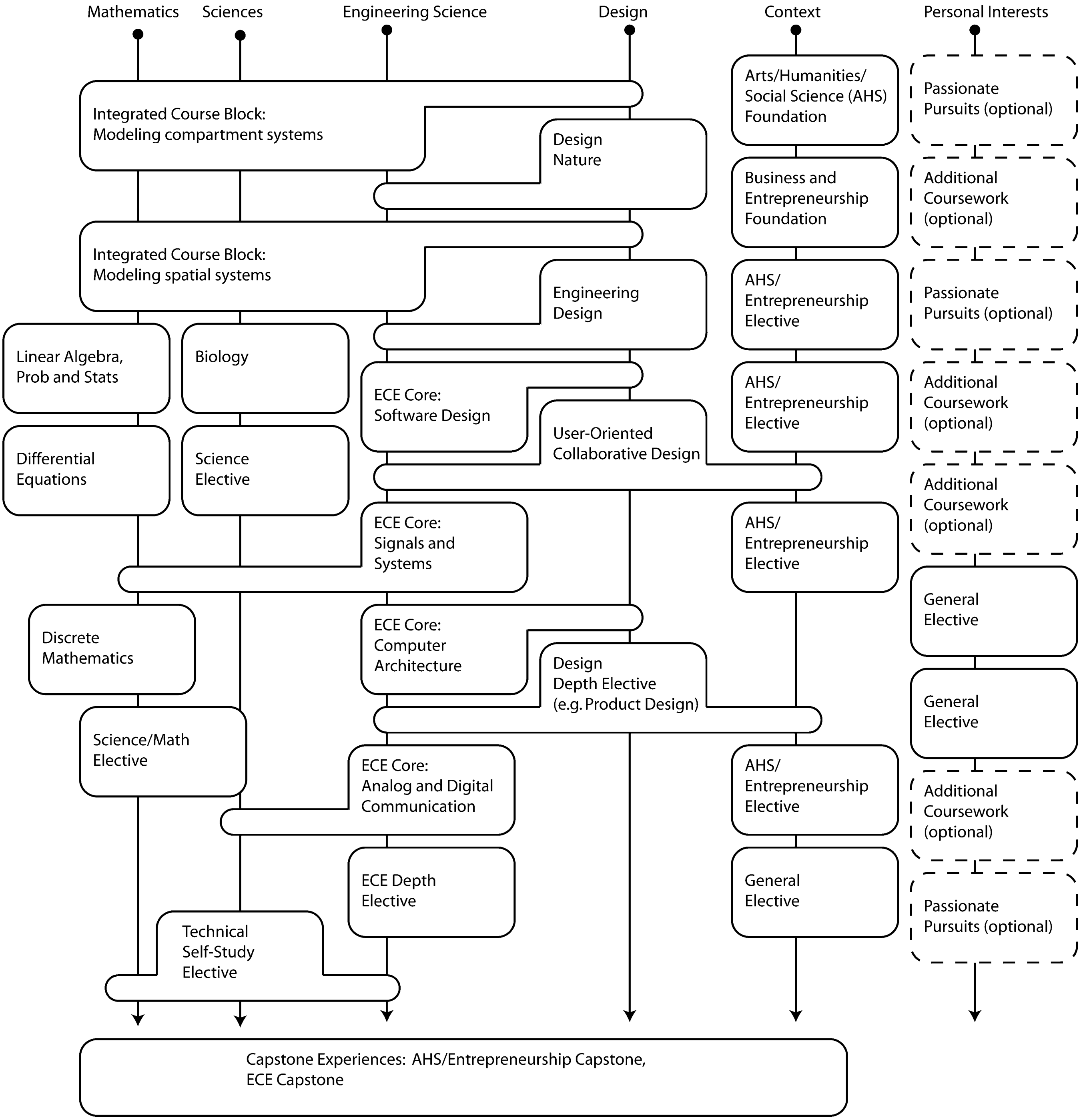

Fig. 2. Illustration of the curriculum. Student experiences cover a spectrum ranging from science and mathematics fundamentals to courses that emphasize contextual understanding. Many courses are, by design, interdisciplinary, and therefore straddle multiple "streams" in the curriculum. These streams ultimately feed into capstone experiences in the senior year.

users. Rarely is a full course devoted to this process; however, by spending this much time on user interaction early in their careers, students come to learn that engineering is more than creating designs in response to well-defined problem statements. In the same year, Principles of Engineering Design, a project-based engineering design course, gives students experience in proceeding from concept to prototype. These two courses thus offer experiences covering the spectrum from recognizing a need to creating a concept to bringing that idea to fruition. Giving students this sort of open-ended experience early in their degree program is critical so that the senior capstone is a culmination, rather than a first exposure.

Throughout their time at Olin, students will study the *arts, humanities, and social sciences* (AHS) and *entrepreneurship* in order to provide *context* for their engineering studies. Entrepreneurship is included in this list because students should not only appreciate the context in which they work but also be able to recognize and respond to human needs within this context. Thus, within the freshman year, students undertake a self-designed sequence of courses to develop fundamental competencies in these areas. The first course in this sequence is an interdisciplinary course that draws connections between disciplines, such as history, sociology, philosophy, and literature. Students also are introduced to the fundamentals of business and entrepreneurship early in their programs. Students may choose to focus their studies within entrepreneurship (taking advantage of Olin's close collaboration with Babson College) or to emphasize particular areas within the more traditional liberal arts. Regardless of their choice, all students will graduate with an awareness of the professional, ethical, social, economic, and cultural contexts in which they will operate.

Students have significant flexibility in defining their studies within required areas. The curriculum provides additional flexibility to pursue personal interests through a number of unrestricted electives and through optional activities. For example, students at Olin are also encouraged to undertake activities known as *passionate pursuits* for nondegree credit. Olin implemented this program to recognize that students' passions (whether in technical areas, artistic areas, entrepreneurship, or philanthropy) play a role in their personal and professional educations. Olin gives students the opportunity to pursue these passions by providing resources, nondegree credit, and formal acknowledgment of achievement.

B. Specialization and Realization

By the middle of their sophomore year, students will have decided upon a major. Thus, the transition from the foundation to specialization begins in this year when students will take their first "disciplinary" courses. The majority of specialization takes place in the third and forth years.

As in the foundation, project-oriented courses play a significant role in specialization. Within ECE, required project-based courses include signals and systems, software design, computer architecture, and analog and digital communications. For example, students in analog and digital communication will build an operative communications link over an unreliable channel, while students in computer architecture build, from the ground up, a working computer.

These required courses form the relatively small ECE core, which can be supplemented by a variety of disciplinary and interdisciplinary elective courses. This approach provides students with the opportunity to pursue international and/or corporate experiences, so long as these experiences contribute to the students' development in ECE. For students who pursue their elective courses at Olin, the plan is to offer elective project-based interdisciplinary courses in addition to disciplinary electives. Possibilities include courses or course blocks at the intersection between ECE and biology (e.g., a project-based course on medical instrumentation or on neurophysiology), between computer science and biology (e.g., bioinformatics), between ECE and physics (e.g., a research-driven course on experimental instrumentation), between ECE and ME (e.g., robotics), and between social science and computer science (e.g., a case-based approach to computer systems and policy). Clear opportunities to use these integrated courses to collaborate with other schools are available—for example, a joint Olin–Babson course on product design and development is currently under discussion.

TABLE I
SUMMARY OF ECE GRADUATION REQUIREMENTS

Specific Learning Objectives	**Approximate credit hours**
Foundational mathematics, science, and engineering	28
Design stream	16
ECE specialization learning objectives, to include Differential Equations, Discrete Mathematics, Software Design, Analog and Digital Communication, Computer Architecture, Signals and Systems, and additional topics of the student's choosing.	26
ECE Capstone	8
Arts, Humanities, Social Sciences, and Entrepreneurship, including founrdational material and Arts/Entrepreneurship Capstone	28
Electives (includes self-study requirement)	14

Students also pursue studies outside of ECE during their specialization. A *technical self-study requirement* asks students to identify a technical area and develop mastery of that area on their own. Such a requirement helps students develop the kinds of lifelong learning skills that they will need to succeed. In addition, students continue to take courses in AHS or entrepreneurship during their specialization.

C. Capstones

A student's final year at Olin will center on an ambitious, yearlong capstone project that occupies a large fraction of the student's time. Also appearing in the final year is a culminating project in either the arts or in entrepreneurship, which may in some cases be connected with the capstone. Although Olin's first capstone project is still a year away, it is expected to be an authentic interdisciplinary team-design project driven by a real client.

D. Graduation Requirements and Competencies

To graduate with a degree in ECE from Olin, students must master certain learning objectives. These requirements are summarized in Table I.

In addition to graduation requirements that focus on specific learning objectives, Olin is also implementing a competency and portfolio system as part of its future graduation requirements. Students must develop and demonstrate skill in a number of competency areas such as communication, qualitative understanding and quantitative analysis, teamwork, contextual thinking, design, and entrepreneurial thinking and acting. These competencies address the a–k outcomes outlined in ABET EC2000 Criteria 3 [4] and also address outcomes specific to Olin's mission.

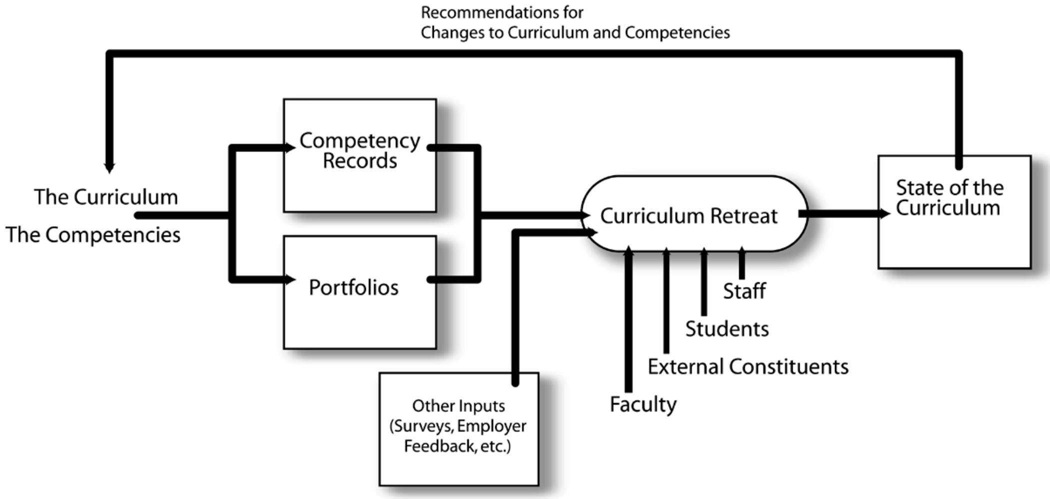

Fig. 3. Yearly process for curricular assessment and improvement. Each year, the faculty, as a whole, convenes in a retreat with external constituencies to review student work and student competency development.

All courses at Olin track development in competencies relevant to the course. In addition, all students generate electronic portfolios and present work on a regular basis for external review and competency assessment. Thus, student competency development is tracked through a large number of measurements per student. Such an approach makes students aware of their competency development and also provides Olin's curriculum revision process with extensive information on the successes and failures of the curriculum. The details of this system will be reported at a later date, as relevant assessment data becomes available.

E. After Graduation

Through its curriculum, Olin intends to prepare students for a variety of opportunities after graduation. Some fraction of these students will certainly go on to become practicing engineers in a variety of settings (corporations, nonprofits, and startups), some will choose to pursue graduate work, and others may choose to enter a profession other than engineering.

This curriculum emphasizes technical fundamentals, interdisciplinary thinking, authentic problem solving, and flexibility. Inevitably, these emphases trade off, to some extent, with disciplinary depth. This tradeoff is based on the idea that the best prepared student is not necessarily the one with an in-depth knowledge of a particular area, but rather the student with a solid grasp of the fundamentals, an ability to work with others, and a capability to learn new things.

V. ASSESSMENT AND IMPROVEMENT

As noted previously, Olin's curriculum is intended to deliver institutionally defined learning objectives and to develop student competencies. Built into the curriculum is a defined process for assessing the success of the curriculum and for reevaluating the curricular approach.

Every semester, Olin holds an exposition at which students present some of their work from the previous semester. This work is evaluated not only by faculty, but also by invited external parties (e.g., engineers from local companies or faculty from other institutions). As valuable as this sort of assessment is to students, it is invaluable to the institution because such assessment provides feedback that leads to curricular innovation. Change requires an understanding of what works and what does not.

A more formal curricular review process takes place once a year through a faculty retreat that also seeks input from external constituents, students, and staff. This retreat provides a venue for review of student competency development and student portfolios, as well as an opportunity to reflect on student development and the effectiveness of the curriculum. These outcomes are documented in a State of the Curriculum Report, which forms the basis for changes to the curriculum and the competencies.

Of course, major curricular change cannot take place every year. For this reason, Olin has adopted a "sunset" clause for the curriculum. This clause specifies that on a regular basis, the Olin curriculum will be fully reconsidered. This review is first planned in 2007. In the time between such full-scale revisions, faculty will conduct smaller scale curricular experiments,so that curricular revision can be based on experience.

VI. WHERE DO WE GO FROM HERE?

Forecasting the trajectory of the Olin curriculum for the next ten years is a challenge. While Olin will remain committed to the broad curricular philosophy outlined here, by 2013 the curriculum presented in this paper will have changed significantly, once if not twice.

Perhaps the easiest change to forecast is the need for even greater student flexibility in preparing to address the life sciences. The importance of the life sciences and nanoscale technology to electrical engineering is likely to grow even more rapidly over the next decade. Integrated courses in the junior and senior years, combined with an institutional commitment to interdisciplinary work, might allow creation of interesting and pertinent projects for students that explore these newly emerging fields. However, if the curriculum is to allow students to begin preparation for these fields, it must also provide increased student flexibility in the freshman and sophomore years to allow students to pursue additional chemistry and life sciences. Such an approach is consistent with the curriculum's commitment to student flexibility and fundamentals. Similarly, as globalization continues to be a strong force in the upcoming decade, the curriculum may need greater student flexibility so as to better facilitate international experiences.

Although the Olin curriculum may look very different in ten years, much of the thinking that has driven the development of this curriculum will likely remain valid. Electrical Engineering will continue to reach across disciplinary boundaries; thus, the curriculum must not become confined to a disciplinary silo. Technological change will continue to accelerate; therefore, a curriculum that emphasizes fundamentals makes more sense than a curriculum that concentrates on the technology of the moment. Finally, the importance of technology in society will continue to grow; engineering educators must prepare their students to be citizens as well as engineers.

VII. CONCLUSION

This paper has presented the initial vision of the Franklin W. Olin College of Engineering's ECE curriculum. Undoubtedly, this vision will change as work progresses at Olin. The outlined approach emphasizes interdisciplinary thinking, project-based (or project-reinforced) learning, flexibility, and the development of the student as a whole person through all four years of the curriculum. Through this approach, the college hopes to graduate students who are prepared to make a difference in the world by recognizing problems, by formulating solutions to those problems, and by convincing others to follow them.

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