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Re-Inventing Engineering Education
One New School at a Time

Introduction

Few engineering schools have the opportunity to start from scratch and address the calls for reform in engineering education that came from the National Science Foundation, the engineering community at large, and the National Academy of Engineering through its 2004 and 2005 reports, The Engineer of 2020 – Vision of Engineering in the New Century and Educating the Engineer of 2020 – Adapting Engineering Education to the New Century.[1,2] The Franklin W. Olin College of Engineering (http://www.olin.edu/), which opened to its inaugural freshman class in fall 2002, graduated its first students in 2006, and achieved ABET accreditation for three degree programs (electrical and computer, mechanical, and general with concentrations in bioengineering, computing, materials science, and systems) in 2007, is one such school, and the U.A. Whitaker School of Engineering (http://www.fgcu.edu/eng/index.html) at Florida Gulf Coast University (FGCU, http://www.fgcu.edu/), which graduated its first students in bioengineering, civil engineering, and environmental engineering in May 2009, is another. They are similar in that both FGCU (a public university) and Olin (a private college) focus on excellence in undergraduate education and have multi-year contracts for faculty rather than a tenure system. One big difference between the two is that Olin began with a commitment of more than $400M, which made it possible for Olin to offer free tuition to classes who entered before fall 2010, whereas the U.A. Whitaker School of Engineering has received ~$24M in public and private funding for a 70,000 gsf building and $2.2M in recurring funding from the state to support the costs associated with teaching engineering and pre-engineering courses.

Background

FGCU began its engineering programs from a blank slate by hiring the Founding Director (February 2005), an academic advisor, and an office manager and with a commitment to build a state-of-the-art facility for engineering education and hire 13 additional faculty members, including several in leadership positions.[3] Lessons learned from The Engineer of 2020, The World is Flat by Thomas Friedman,[4] the NSF-sponsored Babson-Olin Symposium on Engineering Entrepreneurship Education,[5] the Student-Centered Active Learning Environment for Undergraduate Programs (SCALE-UP) Project at North Carolina State University,[6] and a 2006 Project Kaleidoscope workshop on designing undergraduate science and mathematics facilities[7] all contributed to the development of engineering at FGCU and to the design of its new building (Holmes Hall), which opened for classes in January 2009. During the U.A. Whitaker School of Engineering's initial 5-year period, its vision and mission evolved based on input from faculty and external advisors and in response to the addition of computer science to become:

Vision	Mission
The U.A. Whitaker School of Engineering at Florida Gulf Coast University will be internationally recognized for excellence in interdisciplinary engineering and computing education.	*The mission of the U.A. Whitaker School of Engineering is to produce graduates and community leaders in selected engineering and computing disciplines with superior technical competence and business skills to meet the engineering and computing challenges of Southwest Florida and beyond. This is accomplished in an entrepreneurial and innovative educational environment that values diversity, service, integrity, leadership, and collaborations.*

Olin used Invention 2000 to develop the entire institution from a blank slate.[8, 9]

> *"INVENTION 2000 is a blueprint for developing all academic and operational aspects of the Franklin W. Olin College of Engineering from a clean slate. The plan outlines an intense two-year project intended to produce innovative educational processes for preparing the next generation of leaders in a technological society and institutional policies which will establish a commitment to continuous improvement and innovation. Intense efforts will be focused on (1) a comprehensive re-examination of engineering curricula and educational processes, (2) student life and social development, (3) institutional culture of innovation and continuous improvement, (4) college operating procedures, (5) college marketing, external relations and development, and (6) college governance. The project will be funded by generous support from the F.W. Olin Foundation in New York. As a result, the faculty and staff will be able to devote two full years of effort to this project without the distraction of simultaneous teaching responsibilities. Staffing for the project will be provided by the founding faculty, staff, and Board of Trustees, as well as selected students, consultants, and corporate partners who will work primarily in residence on the Olin College campus in Needham, MA."*

Since the U.A. Whitaker School of Engineering was formed within an existing institution with all of the appropriate institutional infrastructure (except for a dedicated building) already in place, its engineering programs were expected to develop faster than those at Olin, i.e. with four years until the first students graduated instead of six. Like the WSOE, Olin's vision has also evolved over a multi-year period and now encompasses the following:[10]

Aspiration	Mission
Olin College seeks to redefine engineering as a profession of innovation encompassing 1) the consideration of human and societal needs; 2) the creative design of engineering systems; and 3) the creation of value through entrepreneurial effort and philanthropy. The College is dedicated to the discovery and development of the most effective educational approaches and aspires to serve as a model for others.	*Olin College prepares students to become exemplary engineering innovators who recognize needs, design solutions, and engage in creative enterprises for the good of the world.*

One difference between Olin and the WSOE is that engineering enrollment is capped at the former, but not at the latter, which has open enrollment for pre-engineering. At FGCU, pre-engineering students must achieve a grade of C or higher in Calc I, Calc II, Comp I, Comp II, Chem I, and Physics I and have an overall GPA of 2.5 in the four non-composition courses before they can declare an engineering major. As of 2009, Olin had 334 freshmen, sophomores, juniors, and seniors[10] whereas the WSOE currently has 418 engineering students in all four classes plus 116 computer science students out of a total enrollment of around 11,000 at FGCU. The WSOE has 17 faculty including the Founding Director and Olin has 19 faculty whose disciplines include engineering and/or computer science,[11] giving engineering student-to-faculty ratios of 32.1 and 17.6, respectively.

The Class of 2009 at Olin had 76 students (47 men and 29 women, 38%) whose average high school GPA was 4.2/4.0 and whose middle 50% of SAT scores ranged from 1450 to 1550.[12] The

WSOE graduated 21 engineering students in 2009. Of these, nine were women (43%). All of the freshmen who entered FGCU in the fall of 2005 had an average high school GPA of 3.37/4.0 and an average SAT of 1039. Although the averages for the students at the WSOE are much lower than the averages at Olin, the top engineering students at FGCU are also exceptional with three from the first class currently attending graduate school, one from each of the engineering majors.

Before the 2010-2011 academic year, students who were admitted to Olin paid no tuition. Beginning in that academic year, students will automatically receive a 50% tuition credit ($18,200) with additional assistance available. Even with the tuition credit, the estimated net cost for students to attend Olin in 2010-2011 is ~$31.5k with no meal plan. The comparable net cost for students at FGCU is less than $10k. In fall 2008, 24% of the undergraduate students at FGCU were part-time, mostly due to having to work to support themselves while in college. This is also true for the students in the WSOE, some of whom work 20 or more hours per week.

Olin has three Program Educational Objectives (PEOs) that cover all three of its majors:[13]

- **Objective I**: Our graduates will be able to make a positive difference within their profession and their community.
- **Objective II**: Our graduates will demonstrate technical competence and creative problem-solving skills that foster success in a variety of postgraduate environments, including professional practice and graduate school.
- **Objective III**: Our graduates will be prepared for and capable of appropriate response to social, technical and global changes during their careers.

The PEOs for the three programs at FGCU are very similar to those at Olin.

Bioengineering	Civil Engineering	Environmental Engineering
The Department of Bioengineering in the U.A. Whitaker School of Engineering at Florida Gulf Coast University will produce graduates who: • are technically competent bioengineers, enabled to be leaders and/or valued contributors in their professions and communities, • make use of the necessary attributes, learning skills, and entrepreneurial/business outlook to successfully adapt to and remain competitive in a changing global society and technological world, • are accomplished at communicating and working collaboratively as professionals in a diverse, interdisciplinary environment, and • successfully enter chosen careers in the medical device, health care, or biotechnology fields, and/or graduate studies or professional training.	The Civil Engineering Program of the Department of Environmental and Civil Engineering in the U.A. Whitaker School of Engineering at Florida Gulf Coast University will produce graduates who: • are technically competent and are leaders and valued contributors in their professions and communities, • successfully adapt to and remain competitive in a changing global society and technological world, • work collaboratively as professionals in a diverse, interdisciplinary environment, • successfully enter careers in civil engineering, serve society, and pursue further studies in their profession, and • attain professional licensure.	The Environmental Engineering Program of the Department of Environmental and Civil Engineering in the U.A. Whitaker School of Engineering at Florida Gulf Coast University will produce graduates who: • are technically competent environmental engineers who are leaders and valued contributors in their professions and communities, • successfully adapt to and remain competitive in a changing global society and technological world, • work collaboratively as professionals in a diverse, interdisciplinary environment, • pursue further studies in their profession to remain technically competent and advance their technical competencies, and • attain professional licensure.

Learning Environments

Olin College has five buildings that comprise 377,000 sf of academic, residential and administrative space on a 70-acre site adjacent to Babson College.[14] FGCU is much larger since it is a comprehensive regional university that offers 52 undergraduate majors, 30 Masters degrees, and two terminal degrees (Ed.S. and D.P.T.). FGCU has 760 acres, almost half of which is protected wetlands, and currently has 62 buildings comprising over one million sf.[15]

The U.A. Whitaker School of Engineering moved into Holmes Hall, a 70,000 sf new building, in December 2008, and the faculty began teaching classes there in January 2009. A vision for Holmes Hall was developed by a team of FGCU faculty and architects who attended Project Kaleidoscope's 2006 Planning Facilities for Undergraduate Science & Mathematics[7] and was used as a guide for planning the building.

Holmes Hall was designed to:

- Provide a learner-centered environment that engages students and faculty in innovative, integrated, interactive, and interdisciplinary engineering education;
- Promote interdisciplinary collaborations among students, staff, and faculty as well as members of the greater community;
- Be connected to the natural environment through views to the sky and landscape and the incorporation of sustainability principles;
- Have flexible and adaptable space to meet current and future needs for engineering education and research;
- Be a beautiful building that puts engineering on display and draws people in to experience the problem-solving world of engineering.

Every aspect of this vision was achieved in Holmes Hall, which contains the spaces shown in Table I and described below. The spaces "belong" to the WSOE first and are available to other units at FGCU if not being used by the WSOE. For example, WSOE courses have priority for scheduling in the classrooms, and the WSOE has priority for scheduling the two conference rooms that are also available to everyone through the University's scheduling system. Some classrooms are not available for scheduling by anyone other than the WSOE because of safety issues with regard to the equipment that is in those rooms.

Offices

Holmes Hall contains 36 faculty, staff, and administrative offices and 4 reception areas with space for support staff. The WSOE currently uses 22 offices and 3 reception areas, and the Office of Research and Sponsored Programs has 5 offices, one reception area, and the room that will eventually provide space for graduate students when a Masters degree is approved.

Studio Classrooms and Teaching Laboratories

Each of the four studio classrooms contains 8 tables that seat 6 students (total of 48). The rooms were designed to provide a learner-centered environment where faculty can integrate lecture, discussions, and hands-on activities. Each studio classroom has white marker boards on three walls and dual projection and was modeled after the SCALE-UP approach to teaching that was

initiated at North Carolina State University (NC State) "to establish a highly collaborative, hands-on, computer-rich, interactive learning environment for large-enrollment courses."[6] One difference is that the SCALE-UP classroom in which physics is taught at NC State seats 99 students whereas the Holmes Hall studio classrooms were limited to 48 because of safety concerns since this approach has never been used before across multiple engineering disciplines. The ZEP Construction Studio Classroom is on the ground floor and is used for courses such as soil mechanics, geotechnical engineering, civil engineering materials and reinforced concrete design. The "wet" studio classroom is on the second floor and is used for courses such as engineering fluid mechanics, hydrology, hydraulics, and water resources engineering.

Table I. HOLMES Hall Spaces

Type of Space	Number	Square footage	Seats
1. Offices			
Graduate student office	1	619	10
Faculty/advisor/support staff offices	28	~120	1@
Department chair/director offices (one temporarily used as a conference room)	7	187-232	1@
Director's office	1	310	1
Reception areas	4	N/A	1@
2. Studio Classrooms and Teaching Laboratories			
Studio classrooms	4	2050, 2073, 2052, 2073	48
Teaching labs	3	1273, 1285, 1288	24
Computer classrooms	2	1191, 1203	46
Student computer labs	2	742, 744	32
Computer hardware classroom	1	630	16
Hole Montes Lecture Hall	1	1698	84
Classroom	1	1472	54
Design studios	2	1465, 1792	48
3. Research Spaces			
Prep/storage	4	612, 554, 610, 614	N/A
Electrical/mechanical workshop	1	532	N/A
Environmental research	1	654	N/A
Johnson- Prewitt & Associates High bay	1	772	N/A
Analytical research	3	749	N/A
Cell and tissue engineering	1	733	N/A
Arthrex Biomechatronic Lab	1	856	N/A
Robotics/software engineering lab	1	692	N/A
4. Community and Student Areas			
Johnson Engineering Lobby	1	631, ~300	N/A
Owen-Ames-Kimball Student Lounge	1	1083	N/A
Student club offices	5	96, 96, 96, 93.5, 101.5	N/A
Student studies	5	176	12
Faculty lounge	1	866	N/A
Conference rooms	2	388, 312	20, 12
Atrium lobby	1	2030	N/A


Holmes Hall in Fall 2008 (left) and "Wet" Teaching Studio (right)

The "biomechatronic" studio classroom is on the third floor and contains specialized instrumentation for bioengineering courses. The fourth studio classroom is used for teaching chemistry-based courses, e.g. environmental chemistry for engineers, fundamentals of environmental engineering, water and wastewater treatment, solid and hazardous waste management, and atmospheric pollution. Three of the studio classrooms have access to 24-seat teaching laboratories where smaller groups of students can be taken to do hands-on activities that require more supervision or more expensive equipment that cannot be duplicated to serve 48 students at a time.

Holmes Hall has two computer classrooms for 46 students. Computers in one room are loaded with engineering-specific software whereas the other has computer science-specific software. Both have white marker boards and dual projection. Each computer classroom is adjacent to a student computer lab, which can hold up to 24 desktop computers with access to engineering and computer science software. There is also a 16-seat computer hardware classroom that is primarily used for computer science courses.


Computer Classroom (left) and Student Computer Lab (right)

General instructional space in Holmes Hall includes the 84-seat Hole Montes Lecture Hall and a 54-seat classroom. The Hole Montes Lecture Hall has white marker boards that can be hidden when the room is used for seminars or symposia and a 12' motorized screen and is used by the WSOE for joint meetings of the senior design sections as well as other multidisciplinary events.

The 54-seat classroom is used for EGN 1006L Intro to the Engineering Prof and has movable tables, dual projection, and cabinets with sinks for design projects that require water.


Hole Montes Lecture Hall (left) and general classroom (right)

There are two design studios in Holmes Hall. One (shown in the picture below) is reserved for use by juniors taking the two-course sequence of EGN 3383C Engineering Service Learning (fall) and EGN 3641C Engineering Entrepreneurship (spring). The other is reserved for seniors in EGN 4410L Engineering Senior Design I (fall) and EGN 4411C Engineering Senior Design II (spring). Juniors and seniors can access the appropriate design studio with their student id cards any time Holmes Hall is open so that they can work on their projects. The spaces were planned with movable tables and white boards so that it is easy to rearrange the furniture to meet the needs of the design teams. Each design studio has lockable mobile carts for each team. Both design studios also have built-in cabinets with sinks and snorkels.


Junior Design Studio (left) and Environmental Research Lab (right)

Research Spaces

Holmes Hall has six laboratory spaces totaling ~4500 sf that are available for interdisciplinary research. Faculty share space rather than owning it, although some spaces are very specialized in nature, e.g. the cell and tissue engineering laboratory, so these spaces may have less interdisciplinary use than others.

The civil engineering faculty make primary use of the Johnson-Prewitt Engineering High Bay and the Environmental Research Lab. There is a prep/storage room available on each floor, which provides additional space for supporting both teaching and research activities. There is also an Electrical/Mechanical Workshop that contains equipment that can be used for research or teaching.

Johnson-Prewitt Engineering High Bay (left) and Electrical/Mechanical Workshop (right)

Community and Student Areas

Holmes Hall is the first building on campus to provide students with their own lounge (Owen-Ames-Kimball Student Lounge) plus five student club offices with built-in desks and storage. The lounge was designed to provide spaces for groups or individuals to work and study and to be a gathering place for engineering and computer science students. There are also five small student study areas at the ends of the building on the second, third, and fourth floors. Each has chairs, round tables, and a white marker board.

Owen-Ames-Kimball Student Lounge (left) and Student Study Area (right)

Holmes Hall is also the only building on campus to include a faculty lounge with a small kitchenette nearby and a large balcony on the north side of the room. There are two conference rooms in the building, which can be reserved by anyone on campus through the University's scheduling system. In addition, one of the larger offices in the Director's Suite has been furnished with a conference table and chairs and is only available for use by the faculty and staff of the WSOE.

The spaces in Holmes Hall are very similar to ones that were viewed and used at Olin College during the 2005 Babson-Olin SyE[5] workshop, including the design studio shown below.

Multidisciplinary Courses

During initial planning, the curricula for the WSOE's three engineering programs included eight multidisciplinary core courses, one each semester: introduction to engineering (1 credit), computer methods (3), engineering mechanics (4), solid mechanics (3), engineering entrepreneurship (3), service learning in engineering (2), and two semesters of senior design (2) for a total of 18 credit hours. Over the past four years, the curricula have evolved through a process of assessment and continuous improvement and now contain 15 common credit hours: introduction to engineering (1 credit), computer methods (2), engineering mechanics (4), mechanics of materials (3), engineering entrepreneurship (3), and engineering service learning (2). The WSOE is committed to maintaining the multidisciplinary nature of the remaining courses. Even though the senior design sequence (4 credits total) is no longer taught as a multidisciplinary course, all sections have one common meeting time that allows them to meet together in the Hole Montes Lecture Hall to hear guest speakers.

During the first few years that the WSOE was in existence, it was possible to have faculty from at least two different disciplines co-teach multidisciplinary courses so that examples from the different engineering majors were included. As the number of scheduled offerings expanded to meet the needs of the first class as they went from sophomores to juniors to seniors and as enrollment increased so that multiple sections of both multidisciplinary and discipline-specific courses were needed each semester, it was no longer possible to assign co-teachers to sections other than some sections of engineering mechanics, the only 4-credit course in the three programs. However, the multidisciplinary nature of the courses has been maintained because of

the availability of examples that were developed during early offerings when courses were co-taught.

The junior-level sequence of courses on engineering service learning and engineering entrepreneurship is multidisciplinary and evolved after FGCU faculty participated in the Babson-Olin SyE^3 during two summers and are loosely based on Olin's course, Foundations of Business and Entrepreneurship. Their descriptions and learning outcomes are given in Table II.

Table II. Engineering Service Learning and Engineering Entrepreneurship

	Engineering Service Learning	Engineering Entrepreneurship
Description	Team-based community service activity that incorporates engineering and responds to a community need. Topics emphasize the societal context of engineering, the use of the design methods and engineering analysis, team skills, project management, communications, engineering standards and liability, and components of critical thinking and self discovery.	Introduces students to engineering entrepreneurship through case studies and the process of defining an engineering service learning project.
Student Learning Outcomes	After completing this course, students will have: • acquired the skills necessary for public problem solving; • developed an appreciation for social responsibility; • developed the skills necessary for interdisciplinary work including team work and conflict resolution; • developed basic leadership skills; • demonstrated effective communication skills; • an understanding of the value and impact of engineering solutions in a societal context and the ability to interview potential clients to determine their needs; • an understanding of the value of lifelong learning; and • the ability to design a project to meet specific criteria and to carry the project through to completion and delivery to the client.	After completing this course, students will be able to: • Identify and evaluate a business opportunity • Use quantitative and qualitative methods to compare different investments or projects • Explain standard accounting statements and describe how they are used • Discuss how entrepreneurs raise money to start a new venture • Describe how entrepreneurs understand their customers and define and segment markets • Discuss how intellectual property is protected • Discuss characteristics of and effective team • Define entrepreneurship in terms of individuals in both for-profit and not-for-profit businesses • Analyze business case studies • Discuss ethical and legal aspects of business decisions • Communicate effectively in a short oral presentation • Interview potential clients to determine their needs • Work successfully in a multidisciplinary team to write a business plan based in client needs.

Both courses have been offered twice and have undergone major changes following assessment by WSOE faculty during twice a year academic retreats. Two major changes have occurred. The first was that the sequence was switched so that Engineering Service Learning is now a prerequisite for Engineering Entrepreneurship. The second change is that both courses are no longer taught as combined lecture-lab courses since much of the work that students do is outside of normal course hours.

Summary

Schools like the Franklin W. Olin College of Engineering and the U.A. Whitaker School of Engineering at Florida Gulf Coast University had the unusual opportunity to start from a blank slate in terms of curricula, faculty, and facilities. In both cases, new and different ways of educating engineers, which were based on published pedagogy and forward-thinking reports, were explored as engineering programs were developed, resulting in many similarities in spite of the obvious differences in terms of public and private funding. Both Olin and the WSOE emphasize hands-on learning and provide facilities that support this approach. Both foster cultures of assessment, feedback, and continuous improvement and provide opportunities for students to learn about entrepreneurship and pursue entrepreneurial activities. This is made possible at Olin through its partnership with Babson College,[14] a business school that is accredited by the Association to Advance Collegiate Schools of Business (AACSB International) and at the WSOE by its initial incubation in the Lutgert College of Business,[16] which is accredited by the same organization. Finally, both Olin and the WSOE clearly value multidisciplinary learning as demonstrated through their curricula and course offerings, and both expect their graduates to contribute to both their profession and their communities.

Acknowledgement

The authors would like to acknowledge the contributions of Dr. Michael Moody, who died on January 21, 2010, to the development of the U.A. Whitaker School of Engineering. Dr. Moody was part of a select group of engineers and academics who provided the original vision for the WSOE and was also a member of the WSOE Advisory Board from its inception. He brought the ideas that were implemented at Olin and generously shared them with FGCU. A paragraph in his obituary speaks to his contributions, “Dr. Moody, a resident of Needham, was a key force in creating Olin College’s groundbreaking curriculum, designed to develop well-rounded engineers who can work well in interdisciplinary teams, key skills in the real world. Though he was a mathematician, Dr. Moody believed that engineers needed to take classes in the arts, humanities, business and social sciences.”[17] The legacy of his guidance and vision live on at both institutions.

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