AC 2010-1502: FIRST-YEAR ENGINEERING: A COMPREHENSIVE APPROACH

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First-Year Engineering:
A Comprehensive Approach

Introduction

Over the past four years, the College of Engineering at Michigan State University (MSU) has planned, developed, and implemented an integrated first-year engineering program and residential living-learning program. This single initiative of both curricular and co-curricular activities has given us a holistic approach to engaging and connecting with first-year engineering students.

The curricular piece of this integrated program, *Cornerstone Engineering*, consists of two introductory courses. The first provides a set of broad, team-based, hands-on design experiences as well as an introduction to topics common across all engineering disciplines. The second course introduces problem solving and mathematical modeling of engineering problems and systems. Much of the Cornerstone Engineering program has been developed from common themes contained within first-year courses previously offered by our six individual engineering departments and nine engineering degree programs.

These courses were piloted on a small scale during the 2007-08 academic year. They were then offered to all incoming first-year engineering students 2008-09. Following the two years of experience in delivering these courses, we were able to objectively examine course content as compared to course learning objectives and measured outcomes. This resulted in several modifications to both lecture content and delivery as well as to laboratory assignments as is detailed below.

Since 1993 the College of Engineering at MSU was actively involved with the *Residential Option for Science and Engineering Students* (ROSES) initiative. This was a residential living-learning program intended to provide a supportive and collegial environment for new freshmen intending to pursue majors and careers in technical fields. Starting in fall semester 2009, our new program, *Engineering Residential Experience* (ERE), transitioned that small-scale science and engineering residential program with approximately 150 students to a large-scale living-learning community program with a potential to accommodate more than 400 undergraduate engineering students. It also incorporated the Cornerstone Engineering program into a single facility.

We have developed a living and learning environment that assists students in thinking analytically and to succeed in the MSU College of Engineering. This community brings another dimension to our common first-year curriculum and further enhances student knowledge of the engineering profession, cultivates their problem solving skills, connects them with campus and community resources, and enhances their communication skills.

The development of the MSU Engineering Residential Experience includes much more than just the physical housing of first-year engineering students in a single residence hall. It also includes delivery of student service operations, including career services, freshman academic advising and peer-led tutoring sessions. Another aspect of our co-curricular program includes the

development of a faculty speaker series and alumni panels. These activities are intended to compliment the social events offered through residence hall programming.

A comprehensive approach to integrating a first-year academic program with a living-learning community does not come easily. Previous work on the partnering of these two programs has presented the coordinated plan joining the Cornerstone Engineering program and the Engineering Residential Experience, while detailing the challenges encountered by the development and implementation teams.[1] This paper details recent modifications made and the initial results to the academic portion of the program. It also presents the inaugural integration of the residential program and the challenges faced by the implementation team. Among those issues discussed are providing a balance to students regarding the amount of co-curricular activity. Much work has been done to assure we have content and frequency appropriate programs to engage our first-year students such that we do not over-saturate students with co-curricular programming.

Background

Authors of "The Engineer of 2020" urge the engineering profession to recognize what engineers can build for the future through a wide range of leadership roles in industry, government, and academia not just through technical jobs. Engineering schools should attract the best and brightest students and be open to new teaching and training approaches.[2]

There is a realization that engineering education needs to shift to address the demands of the new globally connected workplace.[3] Globalization and outsourcing raise serious questions about the future of engineering jobs in the USA. Jobs that require the mere application of existing knowledge have been, and will continue to be, outsourced. Neither the United States, nor its universities, can afford to lag other countries in supplying engineering graduates trained to be flexible, creative thinkers with a deep understanding of core engineering principles. There is a clear need to rethink and re-conceptualize how engineering education is conducted in this country. Redeveloping superiority in this area will require a significant shift in the priorities of engineering education across the country. An emphasis on innovation, creativity and design is of critical importance.

One of the key strategies in rethinking the engineering curriculum has been the increased attention paid to first-year engineering courses in order to make them representative of the demands placed on engineering graduates in the new world of work. This includes a greater emphasis to be placed on design-based courses, moving engineering away from its traditional composition based on core scientific knowledge (such as that of physics, chemistry and mathematics) towards a more holistic curriculum that is representative of the true nature of engineering design. This concern has also been voiced by industry employers, who want engineers with better skills in teamwork, communication, social awareness, and ethics. This has led to significant changes in accreditation requirements towards a greater importance on outcomes based Engineering Criteria 2000.[3]

The Cornerstone Engineering Initiative

The newly designed Cornerstone Engineering program by the MSU College of Engineering, seeks to address the concerns stated above, by developing curriculum and learning experiences that will allow students to remain agile and adaptive in the ever-changing employment market.

As an integrated first-year engineering experience**,** the Cornerstone Engineering program seeks to provide early engineering students with a broad introduction to engineering design, the engineering profession and its expectations (e.g. working in the global workplace, engineering ethics, etc.), engineering problem-solving skills and teamwork skills. This component, which we refer to as *design engineering*, aligns directly with the recommendations of the recent National Academies report *The Engineer of 2020,* which lays out a vision of engineering education in a rapidly changing global economy.[2] It provides a beginning "bookend" to match our already successful senior capstone courses.

The *design engineering* component realizes a proven expectation in attracting top students to engineering programs and retaining them. We see it as a key factor in maintaining and improving student and program quality.

Faced with similar challenges in student attraction and retention, the MSU College of Engineering introduced the Cornerstone Engineering program in fall 2008. The sequence of courses is an attempt to introduce engineering as a profession early in the career of the students and put them on a path of inquiry. It provides first-year engineering students with a broad introduction to engineering design, the engineering profession and its expectations, engineering problem-solving skills and teamwork skills. It consists of two new first-year courses: EGR 100 (Introduction to Engineering Design) and EGR 102 (Introduction to Engineering Modeling). EGR 100 is an addition to the existing core course requirement for admission to an MSU engineering program and is also a prerequisite to EGR 102. The broad goals of the new initiative are:

1. Attract top students to engineering programs and retaining them;
2. Better prepare graduates to adapt to a quickly and constantly in a changing global engineering workforce by appreciating the importance of teamwork, project management, innovation, hands-on experience, ethics, career preparation and professionalism;
3. Enable students to see engineering as a broad field with many opportunities;
4. Position engineering as a favored choice for prospective students and parents;
5. Affect an appreciable and positive change in the first-year attitude towards engineering.

The Cornerstone Engineering design sequence is aimed at achieving these objectives by raising the sense of community and interaction centered on design projects to reap the benefit of long, strong and integrated technical education, and social and professional development.

Engineering Residential Experience

Zmich and Wolff [4] provided an earlier summary and assessment of the predecessor residential program, ROSES, which was launched in 1993 as a joint effort of the Colleges of Engineering,

Agriculture and Natural Resources, and Natural Sciences. By 2005, the latter two colleges had removed themselves from the joint program, as they both had their own forms of first-year student engagement. Several of the components of ROSES remain in the Engineering Residential Experience such as the scheduling of students into common sections of several first-year classes, in-hall tutoring, and a contingent of peer leaders (typically sophomores who were in the program the previous year). A formerly required success seminar has been discontinued and replaced with co-curricular efforts, partly because of the additional course credits required of the Cornerstone Engineering program and partly because of resource scaling. Some emphasis on writing and oral communication in the previous ROSES seminar course is now resurrected in EGR 100, with content directly tied to engineering design.

Starting fall semester 2009, approximately 350 of the over 750 incoming first-year engineering students were housed in the single residence hall (Wilson Hall) which contains the Cornerstone Engineering lecture auditorium, computer and project labs, and other program facilities. Because students will live in the same residence hall community, it is hoped that an academically supportive peer group will enhance the overall experience.

As part of the ERE, the following initiatives are being planned:

1. The creation of "themed" communities and common areas within the residence hall that are centered around a broad engineering topic, such as transportation, sustainability, or energy. Through the sponsorship of corporate partners students will have access to information, environment, and tools to supplement their educational experience. Students will participate in corporate visits and company-sponsored activities. Engineering students will work together to brainstorm and provide technical solutions to a challenge posed by a specific industry. Students will be "getting their feet wet and their hands dirty, as they apply knowledge to real-life problems. And the benefit to the sponsor company? They will gain the opportunity to engage the innovative thinking of a group of bright young minds. It could also provide a base of students – already immersed in the knowledge of a particular industry or company – from which to recruit for cooperative, internship, or full-time positions.

2. The college is also contemplating the idea of a "professional in residence" program – an opportunity for industry leaders to interact with students. Professionals would spend extended periods of time on campus sharing their strategies and experiences with students. Through lecturing to classes, attending college events, assisting in labs, and providing career advice, industry leaders could assist students with the link of theory to practice. This would provide students and faculty with new ideas on how to serve the business community.

Following the first full semester of the larger scale Engineering Residential Experience, we will be initiating focus groups to better understand the factors outside the classroom that determine students' interests, potential for involvement, and potential for commitment. As might be expected, there can be a high variance in students' engagement, even by the same student in the same semester, depending on many factors.

Our vision for this program includes recruiting several corporate partners to provide financial

and in-kind support for student activities around "grand challenge" type issues. As of this writing, we have recently developed a partnership with Consumer's Energy Company focused on the topic of energy. To maximize the engagement of students, corporate partners, and academic personnel in learning, professional, and service experiences outside the classroom the program offers a series of discussions and focus groups. Feedback loops will ensure that activities will be continuously reviewed as the program evolves.

Activities for the Engineering Residential Experience were created with the following objectives in mind:

1. Create an environment where students are free to express themselves and learn from one another;
2. Enhance the classroom experience by implementing experiential opportunities;
3. Build a lasting connection between students and faculty;
4. Introduce students to engineering majors in the College of Engineering early in their academic tenure;
5. Introduce students to resources on campus and in the college;
6. Create peer mentoring relationships between upper class students and students new to the College of Engineering.

To foster this type of environment, the ERE co-curricular director and engineering peer leaders/mentors have created a speaker series, student success seminars, free tutoring services, peer mentoring, community service opportunities and site visits to engineering companies.

Speaker series in this living and learning environment have provided an opportunity for engineering faculty and other engineering professionals to lead formal and informal discussions in Wilson Hall that centered on their professional research, their profession, admissions requirements, and student success seminars. Faculty members working in broad areas such as transportation, materials, energy, security, and health served as presenters for the residential speaker series. The importance of creating this type of programming is to provide a space for students with various comfort levels to interact with faculty members, engineering professionals, upper level students and staff members, and eliminate the intimidation factor of the formal classroom or office setting.

During the fall 2009 semester, a representative from NASA was invited to present to the living and learning engineering students on how to use their engineering educational experience to secure internships or professional positions in the area of space research or travel. Students who participated in this presentation were given the opportunity to spend time with the chief engineer on the Hubble Space Telescope project and to ask questions regarding the presentation and the role of NASA in future space travel.

Another aspect of the Engineering Residential Experience is the peer support that first-year students receive from upper-level engineering students. Triesman and Gelade noted in their study of cooperative groups that as a result of peer support, students were more confident in their ability to be successful in higher education.[5] Peer support in the ERE living and learning environment comes in the form of peer leaders and peer tutoring. Peer leaders are students who

have been admitted to the College of Engineering (or are eligible to be admitted) who serve as role models for the ERE living and learning program. Peer leaders assist first-year engineering students with time management skills, study skills, social issues, family problems or tensions, and other typical difficulties facing students who are new to the college academic and social environment. A peer leader can also simply be someone for a student to spend casual time with or to learn more from about engineering majors, the curriculum, college research, engineering career fairs, engineering student organizations, college faculty and staff. Peer leaders in this program do not serve in any disciplinary role for the residential participants so the relationships that they establish are mutual.

Peer leaders also work to create an environment in the residence hall that is designed to engage living and learning participants in their academic and social environment. According to Tinto, an expert on student success and the impact of learning communities on student growth and attainment, effective retention is highly contingent upon inclusiveness.[6] Peer leaders work to include students in the development of all aspects of the living and learning environment. During each academic semester the engineering peer leaders and the ERE co-curricular director recruit students to participate in a residential focus group. The main goal of the group is to create programs that directly relate to the needs of the residential students. This focus group is considered the voice of the students.

The engineering living and learning students have access to free tutoring services sponsored by the College of Engineering and located in Wilson Hall. This tutoring in math and science is offered five nights per week on a walk-in basis. Tutoring services are provided by students who have successfully mastered the academic skills needed for math and science comprehension. Tutors are available weekly Sunday through Thursday (6:00pm-10:00pm) to help students work through homework assignments and to assist them with preparing for exams.

Measuring student success and the feeling of inclusiveness is a difficult task in terms of defining what is meant by “student success” and “the feeling of inclusiveness”. During the first year the ERE living and learning program was offered in Wilson Hall, emphasis was placed on development of the living and learning events programs, evaluating student participation, evaluating programmatic outcomes, measuring student persistence in the College as a result of their participation in the engineering living and learning program and the effectiveness of support services and peer support offered through the program. As a result of these goals and objectives, students will also be asked to evaluate the inclusiveness of this engineering living and learning environment. This data will be collected at the end of the current academic year as a tool to evaluate the overall effectiveness of the peer leader role, speaker series, speaker series, and tutoring services.

Advising/Student Services

A critical component to the Engineering Residential Experience is giving students a place within the residence hall where they can seek support. To this end, the student services arm of the College of Engineering has purposefully placed student support assistance in the building. Traditionally, all services available to students (advising, career support, academic assistance)

have been within the confines of the Engineering Building. Beginning in fall 2009, much of this was transitioned to Wilson Hall to be in closer proximity to the first-year population.

Career services began offering workshops and presentations in the hall, sending the message that it is never too early to start a search for an internship or job. This also gave the career services staff the opportunity to get to know the first-year population. Information regarding cover letters, resumes and job searches was disseminated to students through both formal sessions in EGR 100 and informal presentations outside of class.

Student organizations have been an important part of the College of Engineering, with over 30 active groups. In the fall of each year, the student groups host an organization fair (O-Night) to attract new students. This past year, O-Night was held in Wilson Hall in the main center court area. Each organization staffed an informational display with current group members. Several brought visual aids, such as components of the Formula SAE and Baja racing cars, the concrete canoe, and steel bridge. As students passed through the area, they engaged with current upperclassmen and were able to see the types of activities available to them. Several groups reported increased interest by first-year students after O-Night.

Perhaps the largest shift in student services was the placement of academic advising in the residence hall. With specific course and GPA criteria needed for admission to the College of Engineering, early advising is critical to ensure students are on the correct academic path. Traditionally, students have scheduled appointments with their assigned advisor (done by major) and have met with their advisor in the Engineering Building.

In fall 2009, an advising office was constructed in Wilson Hall, adjacent to the Cornerstone Engineering project and computer labs. Advising for first-year engineering students is on a strictly walk-in basis, thus eliminating the need for students to navigate an appointment scheduling system to see an advisor. The advising office is staffed 32 hours per week by a rotating group of 7 advising professionals. All advisors are trained and knowledgeable regarding all engineering majors, curriculum requirements and career options.

Student traffic in the advising office was steady throughout the fall semester, with increased student volume during the first and last weeks of classes, as well as the final day when students could drop a class, which occurred mid-semester. During fall semester 2009, approximately 275 students utilized advising in Wilson Hall, with discussions ranging from 5 to 30 minutes. Average appointment times ran 8 to10 minutes. Topics of concern to students ranged from adding/dropping classes, to financial aid, to career options, to changing majors.

Initial feedback from students was positive. They appreciated the fact that advising was located in the building where they lived and also attended classes. And, the walk-in format allowed for greater flexibility as they could stop by between classes. As we progress, the advising office will experiment with evening advising hours and perhaps some weekend hours, as student need demands.

Academic Program

As was detailed in an earlier publication, the academic portion of this integrated program, Cornerstone Engineering, consists of two introductory courses.[1] The first, EGR 100, Introduction to Engineering Design, provides a set of broad, team-based, hands-on design experiences and an introduction to topics common across all engineering disciplines. This course is required of all incoming engineering majors. The second course, EGR 102, Introduction to Engineering Modeling, introduces problem solving and mathematical modeling of engineering problems and systems. It is required of all majors except computer science and computer engineering.

Modifications implemented for fall 2009, based on 2008-09 student feedback, included mapping of specific course learning objectives to individual lecture and lab materials and assignments. No new lectures or assignments were created. However, the order of delivery and assignment was modified to more closely match the topics discussed in the lecture portion of the course with the student work being assigned in the laboratory sessions. Typical assignments have students practicing technical communications skills in the form of writing of short memos, proposals, and summaries as well as detailed engineering reports and formal presentations in support of their team-based projects.

Another modification involved the inclusion of background and objective statements on all assignments so as to inform students of the rationale for each task based upon professional need and mapping to the stated learning objectives. Much work was done develop an "evergreen" curriculum that may be easily improved based on changing educational needs.

Below is an example of such statements included on an assignment in which students were to write a formal engineering report for their first design project:

> *Background: Most design projects you will perform will consist of a product or process along with proper documentation. As has been discussed, the written engineering report is equally essential to the completion of a design project as is the design itself. Engineering reports are technical documents that convey the ideas and procedures used in order to complete the project. The technical report is very well structured and well written using strict guidelines.*
>
> *Objective: Write a complete, well structured technical report which conveys your ideas and procedures for Project 1.*

Structure of EGR 100 and EGR 102

EGR 100 is a two-credit course taught in a lecture and laboratory format. Lectures are held once each week for 50 minutes throughout a 15 week semester. The laboratory sessions also meet once per week for 110 minutes each. The instructional team is composed of faculty members from each of the nine engineering programs in the College. Each member of the team develops and presents at least one of the lecture sessions during the semester. In addition, graduate student teaching assistants are charged with conducting the laboratory sessions. A group of three

undergraduate mentors per lab section (juniors and seniors in their respective majors) aid the students with homework and projects during the laboratory sessions. Lectures are held in a traditional auditorium, whereas the laboratory sessions are held in a computer facility populated with Windows®-based PCs.

The lectures primarily deal with the various aspects of the engineering profession. Topics include the engineering disciplines, communication, professional resources, engineering calculations, energy, time management, design methods, problem solving, and ethics. Two lecture examinations are given, covering the lecture materials.

The laboratory sessions concentrate on application of the lecture topics with utilization of various computer tools. The sessions have individual and group work portions. Each week, students learn and practice technical writing and presentation skills using Microsoft® Office® products. Excel® calculations and plotting are also taught. The students work on this portion of the laboratories individually. At the end of each lab session, a certain amount of time is allotted to group work.

Throughout the entire semester, students are occupied with team projects, independent of the individual work assigned them during the lab. The projects consist of a two-week, team building project; a four-week topical, multidisciplinary optimization project; and an eight-week open-ended design project. The student teams are randomly selected on the first day of class. The teams of four students each remain the same throughout the course. All of the projects involve the construction of functioning prototypes.

EGR 100 students use the project lab in which to build their projects. They have access to the facility during their laboratory sessions and during specified out-of-class hours. As the majority of first-year students live in the residence halls, this facility is necessary for student teams to complete their projects. The supervisors in the project lab instruct the students on the best and safest ways to operate the machinery. They also provide help and suggestions on the most effective ways to produce the student's designs. The lab includes simple machining equipment and also has some construction materials available to the students.

EGR 102 is also a two-credit course also taught in a lecture and laboratory format. The lectures meet once per week for 50 minutes while the lab sections meet twice per week for 80 minutes each. This course is comprised of lectures introducing numerical methods techniques for solving engineering problems as well as laboratory sessions instructing students on the usage of computer tools, such as Excel and MATLAB, to solve engineering problems using iterative techniques.

As with the EGR 100 course, graduate student teaching assistants are charged with conducting the EGR 102 laboratory sessions. And, as with EGR 100, a group of three undergraduate mentors per lab section again aid the students with homework and projects during the laboratory sessions. Lectures are held in the same auditorium as EGR 100 and the labs in the same computer facility.

Initial Facilities

In July, 2008, two laboratories were constructed in the designated residence hall. The first was a 37-seat computer laboratory equipped with dual monitored personal computers, conference tables for team meetings, and an instructor's station. This laboratory occupies approximately 2400 square feet on the ground floor of the residence hall. Laboratory sessions for both program courses are held in this facility.

The second facility, also constructed in July, 2008, was a project assembly lab equipped with drill presses, band saws, sanders, a horizontal saw, benches and associated hand tools. This facility occupies approximately 1600 square feet also on the ground floor of the residence hall. This laboratory is intended for construction and testing of student projects and prototypes and is staffed for students to utilize Monday through Thursday evenings from 5:00pm to 9:00pm.

A suite of offices has been designated near the computer and project labs for instructional staff, academic advising, support services, graduate teaching assistants and upper-level undergraduate mentors.

Expanded Facilities

In July, 2009, an additional 30-seat computer laboratory was constructed in the designated residence hall. Also, the 37-seat computer laboratory was expanded to 41 seats. This was in response to program changes detailed below. The revised 41-seat facility is scheduled for instruction 8:00am to 9:00pm Monday through Thursday and 8:00am to 3:00pm on Fridays. The 30-seat laboratory is primarily used for drop-in student usage with some daily scheduled instruction. Both of these laboratories are used only by students enrolled in the two Cornerstone Engineering courses.

Course Scheduling and Phase-In

The first course, EGR 100, was piloted during the fall semester 2007, with 39 students distributed across 2 laboratory sessions. It was then piloted again in spring semester 2008, with 44 students again distributed across 2 laboratory sessions. The course was then offered in a large scale during the fall semester 2008, with 465 students distributed over 13 laboratory sections. During spring semester 2009, the course had 195 students divided into 6 laboratory sections. For fall semester 2009, 531 students were distributed over 14 lab sections. Anticipated enrollment for spring 2010 is 358 students divided into 10 laboratory sessions.

The second course, EGR 102, was piloted spring semester 2008, with 30 students distributed over 2 laboratory sections. It was piloted again fall semester 2008 with 46 students, again with 2 laboratory sections. Large-scale offering of the courses began in spring semester 2009 with 312 students divided over 10 laboratory sections. The course was offered summer 2009 with 18 students in a single lab section. In fall 2009, there were 124 students distributed across 5 lab sections. In spring 2010, we anticipate 10 lab sections with a total of 399 students.

Enrollments for the pilot and initial large-scale offerings of both courses are given in Table 1. Our projected estimates for steady state course enrollments are shown in Table 2 below.

Course	Fall 2007	Spring 2008	Fall 2008	Spring 2009	Summer 2009	Fall 2009	Spring 2010*
EGR 100	39	44	456	195	-	531	358
EGR 102	-	30	46	312	18	124	399

Table 1: Pilot and Large-Scale Course Enrollments
* Anticipated enrollments as of publication

Course	Fall	Spring	Summer
EGR 100	550	360	-
EGR 102	240	400	40

Table 2: Steady-State Large-Scale Course Enrollments

The numbers discussed above vary somewhat from previously reported estimates. The MSU College of Engineering saw a marked increase in first-year students entering fall 2009. We had become accustomed to admitting 650 new students each fall. For fall 2009, over 750 students were admitted. Since all incoming first-year engineering students are required to take the two courses, we need to make scheduling and facilities modifications. Thus, we were able to accommodate the increased enrollment with the expansion of the revised 41-seat laboratory and the construction of the new 30-seat facility.

Future Work

Course modifications, such as the mapping of course learning objectives and background statements on assignments, were implemented for fall 2009. Student feedback at this point is purely anecdotal as specific data has not yet been reduced. It is planned to have that data available for examination prior to presentation of this paper.

Our next major undertaking will be to modify the structure of the projects currently offered in EGR 100. Based on instructor and student feedback, we plan to reduce our lab projects from three to two by eliminating the second project. This will allow our students to have a more complete design experience by transitioning our larger project into more of a capstone-like exercise.

With the continued evolution of offerings by the Engineering Residential Experience, we plan to remove some of the softer, non-technical skills currently covered in the lecture portion of the course and transition them to the living and learning program. Prior to having a residential program with informational sessions easily delivered within the residence hall, many of the non-design-related skills required of engineers, such as resume construction and job seeking, had

been delivered in the lecture portion of the course. By moving those topics, we will be able to supplement the course with additional lectures focused on engineering design.

Lecture materials, laboratory assignments, and project composition, as well as order of delivery, will continue to evolve as we continue to grow in this program. The College currently has an assessment team in place examining not only the performance and results of the program but also that of other recruitment, engagement and retention initiatives. Results of their findings will continue to be made available as data is collected and analyzed.

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