Building the Whole Engineer: An Integrated Academic and Co-Curricular First-Year Experience

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Timothy J. Hinds is the Academic Director of the Michigan State University College of Engineering CoRe (Cornerstone & Residential) Experience program and a Senior Academic Specialist in the Departments of Mechanical Engineering and Engineering Undergraduate Studies. His current responsibilities include teaching and administering first-year courses in engineering design and modeling. He has also taught courses in machine design, manufacturing processes, mechanics, computational tools and international product design as well as graduate-level courses in engineering innovation and technology management. He has 30 years of combined academic and industrial management experience. He received his BSME and MSME degrees from Michigan Technological University.

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student leaders through the creation of innovative learning opportunities. She created the first ever Living and Learning Summit for Michigan Colleges and Universities in an effort to create a platform for shared best practices for student affairs practitioners. She was recently elected as a university representative for the Academic Specialist Advisory Committee. As the Co-Curricular Director she is responsible for the recruitment and retention of student participants. She earned a Masters of Education degree in Higher, Adult, and Lifelong Education from Michigan State University.

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Building the Whole Engineer: An Integrated Academic and Co-Curricular First-Year Experience

Introduction

Engineers in the 21st Century need the ability to innovate, communicate, and perform at the highest levels in an increasingly global and demanding world. Educating graduates that meet these standards is critical to retaining America’s worldwide technical leadership. The Michigan State University College of Engineering has responded to this need through a large-scale initiative, the CoRe Experience, that integrates the first-year engineering academic program and an engineering living-learning community to support the academic, personal, and professional growth of early engineering students during this important transition year. Instructors, peers, advisors, staff, and faculty all play a role in “building the whole engineer.” The CoRe Experience name captures the two primary program components, the Cornerstone Engineering courses (academic program) and the Residential Experience (co-curricular program), and their purposeful alliance in educating a well-rounded, well-prepared engineer for the future. In Spring, 2012, we undertook the first large-scale assessment of CoRe Experience activities. We surveyed all students who were enrolled in engineering majors (> 3000), and 831 responded. The data presented throughout this paper are the first results to arise from this survey.

History and Administration of the CoRe Experience

The roots of the CoRe Experience residential/co-curricular activities can be traced to 1993 with the initiation of the Residential Option for Science and Engineering Students (ROSES) program. In parallel to the evolution of the ROSES program into the Engineering Residential Experience, the College was exploring how better to integrate first-year students into engineering-specific coursework and shorten the gap between matriculation and the students’ first experience with engineering. In 2006, we began development of two new courses based on themes essential to students across engineering: design, engineering modeling, oral and written technical communication, teamwork, creativity, and ethics and professionalism, all of which are also outcomes designated by ABET Engineering Criteria. We have described the development and large-scale implementation of these courses previously, dubbing them our Cornerstone Engineering courses. In rechristening the Cornerstone Engineering and Engineering Residential Experience programs as the CoRe Experience, we hope to make explicit our goal of integrating academic and co-curricular activities to the benefit of early engineering students.

The administration of the CoRe Experience is overseen by the Associate Dean for Undergraduate Studies in the College of Engineering. The CoRe Experience is led by a faculty director, whose principal responsibilities include providing a vision for the program and interfacing with internal and external constituencies such as corporate partners, an advisory board, the faculty, College and University administrators, and students and their families. With the director’s input, management of CoRe activities is directed by two individuals whose responsibilities are broadly divided into academic and co-curricular activities. By design, the group collaborates closely to ensure that timelines of academic and co-curricular activities are aligned and reinforce and complement each other.
The academic director has the following principal responsibilities:

- develops the curriculum for the academic program
- coordinates instruction for the academic courses
- manages the teaching assistants and undergraduate mentors required to operate the courses
- establishes interdisciplinary connections and initiatives that provide broad opportunities for course projects
- maintains the quality and safety of the academic spaces (e.g., project and computer laboratories)
- serves as the first point of contact for inquiries regarding the academic program

The co-curricular director:

- coordinates with the housing department to secure residential space for participants
- plans and implements co-curricular programming
- manages a staff of tutors and resident mentors (termed Peer Leaders)
- serves as the first point of contact for inquiries regarding the residential program and co-curricular activities

Four additional staff members provide advising, instructional, and programmatic support on a full-time or part-time basis. In support of the professional staff, a number of graduate students serve as teaching assistants (TAs) for the courses, and a number of undergraduate engineering students (~50) provide support as mentors/leaders in the courses (described below with the academic course descriptions) and the co-curricular programs. For our co-curricular activities, these student leaders, called Peer Leaders, assist CoRe residents with time management and study skills and facilitate connections with engineering faculty, staff, and CoRe corporate partners. Peer Leaders also spend casual time with students, providing an informal means to learn more about engineering majors, the curricula, undergraduate research, career opportunities, engineering student organizations, and study abroad opportunities. It is well-established that this type of peer support makes students more confident in their ability to succeed in higher education. An unanticipated benefit of this relationship is the professional and personal development of the Peer Leaders themselves. The CoRe Experience also has peer-to-peer tutoring specifically for the introductory mathematics, chemistry, and physics courses taken by first-year engineering students. Student tutors are trained by CoRe staff to use examples situated in an engineering context to maximize the relevance of the material for the students. Tutors seek to identify each student’s strengths and weaknesses in the subject matter, which are often based on their unique prior experiences and opportunities. Ninety-five percent of student respondents had a positive or very positive attitude toward our tutoring program.

Part of the mission of the CoRe Experience is to demonstrate to students the importance of engineering and the positive impact that engineers make on society and the world around them. One way we accomplish this is to collaborate with corporate partners to bring real-world expertise and challenges into the classroom and the living-learning environment, reinforcing the relevance of studies in engineering to solving global challenges. The unique involvement of industrial partners has been described in greater detail previously.
Facets of the “Whole Engineer”

To “build the whole engineer”, we must recognize that 21st century engineers must possess a broader and, in some dimensions, deeper skill set than those of their predecessors. The whole engineer can operate in multicultural, multidisciplinary teams and can do so while simultaneously addressing the economic, global, social, and environmental impacts of their work. Following a three year period of integration and evolution, adding and refining curricular and co-curricular components, the CoRe Experience now provides a comprehensive set of program components that connect across the domains of personal development, professional development, and academic success. In this way, we intentionally and specifically support students’ development of a set of skills encompassing those that will be required in their future endeavors. Though these are generally grouped under the categories of academic, professional, and personal skills, we recognize the considerable overlap that exists among these categories. Indeed, we intend for students to recognize that these skills are heavily intertwined.

Academic skills are those that are traditionally ascribed to an undergraduate engineering education. This primarily means applying fundamental mathematics, chemistry, and physics to the solution of engineering problems. To ensure that students develop the best fundamental abilities, however, requires that they understand the relevance and importance of the skills being taught with respect to engineering. Thus, we need to emphasize them in engineering-specific coursework. Nonetheless, academic performance alone, as assessed by high GPA, is not a good predictor of persistence in engineering, hence our intentional focus on the simultaneous development of students’ other dimensions.

Professional skills are those that are essential to gain entry into, and function in, a modern engineering career. These include those skills necessary to get a job, such as resume preparation, interviewing skills, and participating in experiential and industry exposure activities. Once in the professional environment, modern engineers require effective teaming skills, clear communication, an appreciation for the importance of diversity, and a strong basis of ethical decision-making. These skills are typically not emphasized in early technical coursework.

Personal skills are those that are often least considered by the faculty and staff of universities but are critical to students and their persistence/success. These are the connections that students make to their peer cohort as well as to the advisors, staff, and faculty in their disciplines. Without these strong connections, many of these students would not persist through the rigorous curriculum, regardless of their academic aptitude. We ensure that students recognize, despite the size of our student population, that students are part of the College of Engineering team, a small community within the larger university community. Moreover, by placing them in academic and social groups from their first days on campus, they become part of still smaller groups within the larger engineering community. These group associations reinforce their connections to each other, to their chosen disciplines, and to the College of Engineering as a whole. This connectivity is especially critical for maximizing retention of members of traditionally underrepresented groups.
**Descriptions of Activities and Events**

The mission of the CoRe Experience is to:

- Provide early engineering students with unmatched learning opportunities within a supportive community that encourages academic, personal, and professional achievement
- Foster life-enriching connections between students and their peers, faculty members, advisors, and corporate representatives
- Cultivate students' skills that encourage lifelong learning
- Demonstrate to the students the critical roles of engineers in contributing to society

Our activities and events are organized around the principles of our mission. In this paper, we will highlight some of the specific activities we undertake in our academic and co-curricular programs that encourage development across the student skill sets we have defined (summarized in Figure 1). The activities are described to assist others who may have interest in adapting these activities for their own programs.

**Co-Curricular Program Activities**

**College Colloquium**

First-year students are introduced to the College and the CoRe Experience through our College Colloquium, which occurs the day before classes begin in the Fall Semester. Faculty members and corporate partners attend this event with the mission of welcoming students to the campus community, the College of Engineering, and the engineering profession. Students first attend a welcome session where faculty members and corporate partners provide strategies for success as engineering students and professional engineers. After the welcome session, students attend a resource fair, visiting booths hosted by the support service departments from the College and University. The resource fair is an informal event where students also have the opportunity to
Colloquium is designed to address all three of the principal skill dimensions without being overwhelming. The academic director of the CoRe Experience introduces himself to the students at this event and describes the first-year courses and what students need to do to be successful in them. Corporate partners provide advice from the “real world” on what skills students should foster during their undergraduate careers to maximize their chances of achieving their professional goals (described in additional detail in Wolff, et al6). The environment of the resource fair, in particular, with music and prize giveaways, encourages students to interact with each other and seeks to dispel the often-held notion that engineering is not a welcoming environment. Students reflect the success of this approach in that fully 99.3% of survey respondents indicated that the Colloquium had at least “some value,” with 45% rating the event as having "considerable value", and 14.2% giving a rating of "excellent".

The Colloquium program also makes clear to the students the connection between the CoRe Experience and the Center for Spartan Engineering. Through this collaboration, we encourage first-year students to begin thinking about how to gain experiential education, whether through internships and co-ops or through undergraduate research. As part of this collaboration, the CoRe Experience staff, both through announcements in the academic courses and through Peer Leader-led groups, facilitates students attending career-oriented activities such as our fall “Career Gallery” and spring “Engineering Expo”. Through direct interaction with the Center, we further encourage students’ professional development and success.

First-Year Advising

A critical component of the CoRe Experience is ensuring the availability of advising for students seeking academic, professional, or personal support. To this end, the CoRe Experience provides walk-in, first-year academic advising co-located in the residence hall with the majority of our co-curricular and academic activities10. Through this office, students can also access support services by professional staff from the Diversity Programs Office, the Center, the Women in Engineering program, and the Peer Assisted Learning (PAL) program. It should be noted that co-localization of these facilities with the majority of the first-year residential and academic program facilities makes them easily accessible for all students, whether or not they have elected to take part in the residential program. Eighty-five percent of survey respondents had a positive or very positive attitude about first-year advising activities.

Industry Expos and other Corporate Interactions

Recognizing that first-year students (and even more senior students) often are ill-informed about what engineers do and in what fields they
work, we have held industry expos in the residential community. For these events, engineers from industry, government, and academic entities staff booths to meet with students in an informal setting to detail how their work relates to a particular theme from the NAE Grand Challenges (e.g., security or health). Because these events are focused on a theme rather than a discipline, it provides students from all majors an opportunity to identify how they could apply their chosen discipline across a wide variety of professional settings. Conversely, it allows students who have a thematic interest but who have not settled on a given discipline to ascertain which discipline might be best for them to choose. These expos are organized and operated by our Peer Leaders, thus giving the Peer Leaders the opportunity for professional development and contact with potential employers.

**Evening presentations** provide opportunities to interact with engineering faculty and other engineering professionals who lead formal and informal discussions that center on their research or profession, College admissions requirements (students are first admitted to the University with a major preference and then must satisfy a number of course and GPA requirements prior to admission to the College of Engineering), or resources for academic assistance. Faculty members working in broad areas such as transportation, energy, security, and health serve as presenters throughout the academic year for the CoRe Experience. The evening presentations allow students to interact with engineering professionals and faculty members outside of the classroom environment and to recognize the value of these interactions to their educational success. These programs appear to have had their intended result given that 92% of the students surveyed at all class levels (first-year through senior) responded that the evening programs had either a very positive or positive influence on their attitudes towards engineering studies and engineering as a career.

**Academic Program Activities**

**Academic Courses**

The development of and objectives for our first-year academic program have been described previously, with the chronology of development and implementation activities summarized below (Table 1). The two course sequence includes **EGR 100: Introduction to Engineering Design** and **EGR 102: Introduction to Engineering Modeling**. In EGR 100, the academic and professional skills being principally targeted are engineering design, teamwork, oral and written communication, ethics and professionalism, and creativity. In a survey of all engineering students who had taken EGR 100, over 85% strongly agreed or agreed that they felt that the course had improved their team skills, and about 70%
indicated strong agreement or agreement with improvement in understanding the scope of
engineering (applications, careers), development of problem-solving skills, and positive gains in
verbal and written communication skills.

Table 1: Evolution of the CoRe Experience Academic Program

<table>
<thead>
<tr>
<th>Academic Year</th>
<th>Numbers of Students - EGR 100</th>
<th>Numbers of Students - EGR 102</th>
<th>Major Changes and Updates to Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 2007-2008</td>
<td>Development</td>
<td>Development</td>
<td>N/A</td>
</tr>
<tr>
<td>2007-2008</td>
<td>48</td>
<td>24</td>
<td>● First pilot-scale offerings</td>
</tr>
<tr>
<td>2008-2009</td>
<td>642</td>
<td>369*</td>
<td>● First large-scale offerings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>*large scale only 1 semester</td>
<td></td>
</tr>
<tr>
<td>2009-2010</td>
<td>878</td>
<td>527</td>
<td>● Reorganized EGR 100 lectures to align with project activities</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Created new projects</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Replaced discipline-specific lectures with industrial alumni panel discussions</td>
</tr>
<tr>
<td>2010-2011</td>
<td>947</td>
<td>650</td>
<td>● Introduced NXT Mindstorms robotics programming, team design exercises, and NAE Grand Challenges</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Went from 3 projects to 2</td>
</tr>
<tr>
<td>2011-2012</td>
<td>1112</td>
<td>767</td>
<td>● Went from multiple lecturers to single lead lecturer</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• Decreased average project team sizes from 5 to 4 students</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• Updated course text</td>
</tr>
<tr>
<td>2012-2013</td>
<td>1333*</td>
<td>910*</td>
<td>● Implemented major project revisions as well as new team design exercises</td>
</tr>
<tr>
<td></td>
<td>*estimated</td>
<td>*estimated</td>
<td>• Introduced new text and online homework component</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Adopted small/large group nomenclature</td>
</tr>
</tbody>
</table>
In EGR 102, we focus on systematic approaches to solving engineering problems using advanced spreadsheet functions and MATLAB®. In addition, teamwork and oral and written communication are emphasized. Survey results for EGR 102 students show even stronger positive agreement with student perceptions of the success of their learning objectives. Almost 88% of students strongly agreed or agreed that EGR 102 improved their problem-solving skills. This was further reflected in the students’ response to questions regarding their abilities to write programs for solving problems and modeling systems: almost 90% either strongly agreed or agreed that their skills in this area had been enriched. Regarding the focus on developing MATLAB® skills, 96% of students provided positive responses for their improvement in the ability to use this computing tool. Students did not feel as strongly about the improvement in their communication skills. These data indicate this as an area for further development going forward.

Though the courses are explicitly an opportunity for students to enhance their technical engineering (academic) and professional skills, personal development is also encouraged through the course structure and activities. Academic skill development focuses on the application of mathematics and physics to the solution of design (physical) and theoretical (computational) problems. Through interactions with professional engineers, assessment and feedback on oral and written communication, explicit instruction on professional ethics and conflicts of interest, project work with diverse team members, and collaboration with the Center, students improve their professional skills. Team-based project work and interactions with the course TAs and mentors also provide peer connections that improve student engagement and support personal development.

*Design Day*

For over 20 years, the College of Engineering has showcased student project work at an end-of-semester event known as *Design Day*. Historically, Design Day participants were upper-level student teams working on advanced or capstone projects, often with industrial sponsors. Since the implementation of EGR 100, selected first-year student teams (the number of first-year teams precludes us from having all of the teams participate) have also displayed their projects at Design Day. Participation in Design Day is an opportunity for CoRe Experience students to demonstrate their academic success in a setting that provides an opportunity to interact with industry professionals and members of the faculty. Preparing for this event is another opportunity for students to practice their oral and written technical communication. In some cases, the projects displayed at Design Day are the results of a service learning project. In these cases, students get to share the results of their work directly with a client, a still more realistic professional activity.

*College-wide Activities Facilitated by or with Participation of the CoRe Experience*

The development and evolution of the CoRe Experience has also coincided with the awarding to the College of Engineering of an NSF STEP grant for development of effective retention programs for early engineering students\(^\text{12}\). The CoRe Experience has provided the NSF project with an ideal “laboratory” for implementation of the proposed retention strategies. The NSF project has been described extensively\(^\text{12, 13}\) and has clearly benefited the CoRe Experience directly in two major areas: the Connector Faculty (CF) program\(^\text{13}\), which links EGR 100
students to faculty mentors, and the PAL program\textsuperscript{14}, wherein tutors are linked directly to courses that present the most significant obstacles for students’ admission to the College of Engineering.

When the discipline exploration content was removed from EGR 100 (Table 1, 2009-2010), student access to this information was replaced by the \textbf{Engineering Connect} events. Since Fall 2010, Engineering Connect has linked an EGR 100 assignment to evening presentations sponsored by each engineering program. Each presentation was conducted by program faculty and included a general overview of the particular engineering discipline, discussion of how the discipline supported the NAE Grand Challenges, and laboratory and facility tours, if appropriate. Academic advisors were also available for student questions. The evenings concluded with informal question and answer sessions, with many students staying long after the allotted time had ended.

The Engineering Connect sessions also served to advertise to students their opportunity to opt into the \textbf{Connector Faculty (CF) program}\textsuperscript{13,15}. First implemented as a program to counteract the attrition of qualified students from the College, the CF program has become institutionalized as an informal mentoring program to students in EGR 100. The goals of the program are to lower the barriers between first year students and college faculty and to have students see engineering as a “friendly” career path. Studies have repeatedly shown that one important factor in promoting early student engagement in coursework is the degree to which the students perceive that their instructors want the students to succeed and genuinely care about their academic progression\textsuperscript{16-18}, which we convey in part through the CF program.

Students are assigned to CF mentors by preferred discipline and interact with faculty member either individually or in groups. Meetings are informal, held during office hours, over meals or coffee, during trips to the Dairy Store (MSU’s homemade ice cream shop) or whatever setting is most comfortable for faculty and students. During the most recent CF cycle, over 70 faculty members volunteered to interact with about 350 EGR 100 students who had opted into the program. Based on past cycles of this program, which has been in existence since Spring, 2009, 85% of survey respondents indicated a very positive or positive attitude toward engineering studies and engineering as a future career based on their experiences in the CF program. Archival data also demonstrate that students who participated in the CF program were admitted to the College of Engineering at a higher rate than those who did not participate; 65% of the students who participated at all in CF were admitted to the CoE, compared to 57% of those who did not participate.

**Challenges Faced**

In the development and implementation of the CoRe Experience, we have faced some expected and some unexpected challenges. Foremost among our expected challenges was diversity of our student population. While we have students spanning a broad degree of preparation for engineering, our numbers of female and underrepresented students are lower than we would prefer. This can make forming academic teams challenging (i.e., avoiding single female or underrepresented students on a team) and results in a significant gender imbalance in the residence hall. We are continuing discussions with our recruiting, Diversity Programs, and Women in Engineering offices to ascertain how best we can support their efforts to achieve greater diversity in our student population. However, it is encouraging to note that, of the
students who participated in the residential program, female students returned to the residence hall for a second year at a markedly higher rate than their male counterparts. These preliminary data suggest that the residential experience may serve as an effective tool in recruiting and retaining larger numbers of female students in engineering. In contrast, our population of international students has increased dramatically in the last three years. This presents new challenges of English readiness and a slower rate of integration of these students into the broader student body (as they can form sizable social and academic communities of their own).

All of these demographic concerns are parts of a broader issue, the near doubling of our undergraduate engineering population in the last five years. Unlike computational design projects, hands-on design, build, test projects do not scale easily to over 300 teams per academic year. The ability to provide sufficient guidance, assessment, and feedback to each student on their work is a significant resource concern. From the co-curricular perspective, it is known that living-learning communities are most successful when they are small (< 100 students)\(^9\), thus making it still more critical that we design our efforts to maximize the value of the experience for our over 600 living-learning students.

Finally, we are starting to get more feedback that students greatly appreciate our efforts on their behalf during their first year (60% agreeing that it made the student more committed to studying engineering), but that these students still need additional support during their second year, when they are just beginning to form communities within their majors. We have initiated discussions with our housing office about how best to keep second-year students located in the same area of campus as our first-year activities, thus allowing us to continue to serve them through our professional and personal development programming. As students move off-campus, which is the norm for our third-year and older students, we hope that they will continue to seek out, as necessary, the resources available to them through our activities.

**Lessons Learned**

Among the most critical lessons to be taken from implementing the CoRe Experience is the importance of buy-in at all levels of the University administration. Departments must agree to the additional credits associated with the required courses and supply content expertise that informs the material covered. College and university-level support ensures the availability of space and funding for personnel to achieve the academic and co-curricular goals for the program. This has been particularly critical as the residential program has expanded from 25% of the population of the residence hall to over 60%.

We have found preliminarily that fashioning CoRe students into a residential cohort is an important part of ensuring their academic success and personal growth, with 82% of respondents stating that the residential program was the best living situation for them and 70% saying that it helped them feel more a part of the College of Engineering than if they would have lived in another residence hall. Additionally, students participating in the residential program were considerably more likely to leverage the resources available to them than students living elsewhere (Figure 2). This fact may be particularly important to consider for institutions with large fractions of their students living off campus. For these institutions, on-campus resources can be co-localized, but it may be difficult for students to build the personal connections and
Figure 2: Impact of Co-Localization of Support Resources with Residential Program. For students who remained in engineering, they responded whether they did (A, C, E) or did not (B, D, F) live in the residential program and how frequently they attended tutoring (A, B), academic advising (C, D), or evening presentations (E, F). In all three cases, the attendance frequency for residents was significantly higher. Attendance at least once per semester: tutoring - 50% for residents vs. 20% for non-residents; academic advising – 75% for residents vs. 40% for non-residents, evening presentations – 55% for residents vs. 30% for non-residents. Categories (left to right): At least once a week, About twice a month, About once a month, Two to three times a semester, Never, Didn't know this existed, Didn't exist when I was a first-year student (except C).
cohort identity that are important to long-term success and persistence. It may be necessary to build cohorts, larger than project teams, through the coursework, since these cannot develop organically in the residential environment.

A comprehensive first-year program can be a valuable recruiting tool, as evidenced by our data (the CoRe Experience was a factor in their choice of university for 37% of respondents). Students and their families are often ill-informed about the rigor of engineering and the difficulties associated with the transition from high school to the university environment. Thus, it is our responsibility to anticipate, to the degree possible, what a student will need in terms of support and to provide it in an accessible manner. During visits with prospective students, we attempt to convey this message, so as to reassure them that we are invested in their success in the first year and in all of the academic and professional years beyond.

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