Madison Initiative for Undergraduates Proposal

Campus-Wide Engagement of Undergraduates in Society’s Engineering Grand Challenges

Submitted by the College of Engineering:

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Abstract: The objective of this project is to introduce two synergistic undergraduate opportunities to better prepare our students to help solve the grand challenges facing our global society in the 21st century, such as sustaining sources of clean water, food, and energy, slowing global warming, developing new medicines and improving health care, countering terrorism and the destructiveness of natural disasters, and restoring aging urban infrastructure. This is a broad objective that we believe can be addressed through the offering of two undergraduate “Grand Challenge” experiences designed to enhance student outcomes on this campus: 1) a first-year interdisciplinary and cross-disciplinary course that builds on the preliminary success of InterEgr 102: Introduction to Society’s Engineering Grand Challenges while doubling its capacity to 300 students/year to permit broader campus-wide participation; and 2) second-year undergraduate research opportunities tied to engineering grand challenges, offered through the Undergraduate Research Scholars Program (URS) in a coordinated manner that will increase by more than five-fold the number of engineering-related URS projects. These Grand Challenge experiences address several MIU goals and areas of need by making use of best practices in and increasing student access to a faculty-taught inter-/cross-disciplinary gateway course for first-year students, expanding and coordinating undergraduate research opportunities for second-year students, and giving students more options for satisfying degree requirements. These experiences will provide a more holistic undergraduate educational experience for both engineering and non-engineering students alike.
Introduction

In 2009, President Obama announced his “Strategy for American Innovation” which includes the goal of harnessing science and engineering to address the “grand challenges” of the 21st century. As a global community, we are indeed facing significant grand challenges to meet human needs on this planet of finite resources. A host of complex societal issues, including sustaining sources of clean water, food, and energy, slowing global warming, developing new medicines and improving health care, countering terrorism and the destructiveness of natural disasters, and restoring aging urban infrastructure, have recently been named by the National Academy of Engineering (NAE) as “Grand Challenges for Engineering” for the next several decades. This Grand Challenges list serves as a call to action and a tangible motivation for young people who want to make a difference in the world. Effective solutions to these challenges require a systems approach that is both interdisciplinary and cross-disciplinary – that is, one that involves not only the integration of multiple engineering disciplines but also partnerships with the physical and biological sciences, the social sciences, and the humanities. This requires preparing engineering students to work across eroding disciplinary boundaries and with diverse teams that will shape public policy and commercialize innovative technologies. This also requires better informing students outside of engineering (and the physical and biological sciences) about how engineering shapes our world. In fact, we argue that technology literacy is an integral part of a holistic “liberal arts” education in the 21st century.

The objective of the proposed project is to introduce two synergistic undergraduate opportunities on the UW-Madison campus to better prepare our students to solve many of the grand challenges facing our global society. This is a broad objective that we believe can be addressed through the offering of two undergraduate “Grand Challenge” experiences designed to enhance student outcomes on this campus:

1) A first-year interdisciplinary and cross-disciplinary course that builds on the preliminary success of InterEgr 102: Introduction to Society’s Engineering Grand Challenges while increasing its capacity for campus-wide participation;

2) Second-year undergraduate research opportunities tied to engineering grand challenges, offered through the Undergraduate Research Scholars Program.

These Grand Challenge experiences represent a unique and timely opportunity for the UW-Madison to transform the educational experience for undergraduate students. As explained further below, this proposed project addresses several MIU goals and areas of need by i) making use of best practices in and increasing student access to a cross-disciplinary introductory/gateway course for first-year students, taught by faculty, ii) expanding and coordinating undergraduate research opportunities for second-year students, and iii) giving students more options for satisfying degree requirements.

Overview of InterEgr 102: Introduction to Society’s Engineering Grand Challenges

Inspired by the NAE Grand Challenges project, we designed and offered for the first time in Spring 2008 an introductory course that engages first-year students in learning about the interdisciplinary roles of engineering in tackling society’s grand challenges. This course has been offered as Interdisciplinary Engineering (InterEgr) 102 every fall semester since 2008. InterEgr 102 incorporates two best-practice enhancements recommended by the NAE’s Committee on

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1 http://www.engineeringchallenges.org/
Engineering Education,\textsuperscript{2} namely that engineering schools should introduce interdisciplinary learning in the undergraduate environment, and engineering educators should make appropriate use of a case-studies approach in undergraduate curricula.

\textbf{Existing Course Structure and Content:} InterEgr 102 begins with a few introductory team-taught lectures in a large-class setting, followed by two theme-based modules of the student’s choosing, selected from the following societal themes, ordered by scale, that tie together several engineering grand challenges: 1) Engineering challenges that impact our lives on a personal scale, 2) Engineering the Wisconsin Idea, 3) Engineering challenges in developing communities around the world, 3) Engineering the megacity, 4) Global engineering challenges, and 5) Engineering challenges beyond Planet Earth. These theme-based sections are taught in smaller groups of approximately 25 students. Each faculty instructor leads one of the theme-based sections during Module 2, and then repeats that instruction with a different group of students during Module 3. Brief descriptions of each theme are provided below.

- \textbf{Engineering challenges that impact our lives on a personal scale:} As the population of the world grows and ages, we face a host of challenges – disabilities, diseases, and accidents – that directly impact our physical well being. We also face challenges in safeguarding our identity and personal data from security threats. This theme focuses on overcoming these challenges through the development of engineering solutions such as improved diagnostics, implantable medical devices, personalized healthcare, prostheses, artificially grown tissue and organs, and biometrics. Sample cases studies include devices to overcome hearing disabilities, face recognition technology, and wearable health monitoring systems.

- \textbf{Engineering the Wisconsin Idea:} Engineering challenges abound in all types of communities around the world, including communities in our own backyard. Weather extremes, changing population dynamics, energy needs, and environmental concerns all combine to create a unique set of problems here in Wisconsin that requires important engineering contributions. As an embodiment of the Wisconsin Idea, this theme focuses on the development of engineering solutions to the problems facing communities like those in Wisconsin, or other similar regions of the United States and the world. Sample case studies include high-speed rail, infrastructure restoration (such as bridges), and detection of nuclear material at ports.

- \textbf{Engineering challenges in developing communities around the world:} Over the next four decades, the earth's population is expected to grow by more than 2 billion people.\textsuperscript{3} This growth will be almost entirely in less developed regions of the world, creating unprecedented demands for water, food, shelter, health care, energy, infrastructure, transportation, etc. This theme focuses on the development of sustainable and appropriate engineering solutions to address these basic needs and advance the United Nations Millennium Development Goals. Sample case studies include low-cost solid-state lighting technology, affordable field-portable diagnostic tools for medical care, and drinking water distribution systems.

- \textbf{Engineering the megacity:} According to United Nations estimates, there will be 29 cities worldwide with populations exceeding 10 million by 2025.\textsuperscript{4} The high population densities


and explosive growth of these megacities puts severe strains on supply and distribution systems for energy, water, and other utilities as well as transportation. The vulnerability of megacities to natural disasters, pollution, disease outbreaks, and crime also poses significant engineering challenges. Sample case studies include eco-friendly mass-transportation technologies, an early earthquake detection system to mitigate damage and loss of life, and improved crime fighting through a centralized electronic database of criminal records.

- **Global engineering challenges:** Many of the greatest unsolved challenges are of global proportion. These challenges include energy (e.g., finding sustainable energy sources as the supply of fossil fuels becomes limited), the environment (e.g., developing engineering solutions to global warming through carbon dioxide sequestration and management), health (e.g., thwarting pandemics), security (e.g., developing strategies for protecting borders), and water resources (e.g., finding methods of supplying purified water to the ever increasing global population). An example of a case study considered under this theme is the development of liquid fuels from renewable resources.

- **Engineering challenges beyond Planet Earth:** Our world is increasingly reliant on space for everything from communication to early warnings of approaching weather. A colossal expense is still required to transport new satellites to space even to maintain existing technology, and many more possibilities exist. Manned space flight was one of the most significant achievements of the previous century, and space may hold the key to providing food, energy and safety for our planet in the coming centuries. This theme focuses on the challenges and opportunities associated with engineering for space and presents case studies including terraforming Mars and helping astronauts to maintain bone density while in space.

Course activities are designed to achieve specific learning objectives. Upon completion of this course, students are able to articulate an understanding of several engineering grand challenges that our society faces in the 21st century, research an aspect or case study of an engineering grand challenge in society, create materials for technical presentations (both platform and poster formats), identify the role of specific engineering fields in multi-disciplinary engineering projects, and articulate an understanding of social and multicultural issues encountered in engineering as well as an appreciation of how political, economic, ethical, and social issues influence or constrain engineering solutions.

In-class activities and out-of-class assignments introduce students to the basic principles, potential, and limitations of engineering solutions and technologies. In-class activities are interactive, discussion-oriented, and based heavily on case studies. Introductory engineering design and analysis techniques and concepts are woven into those case studies. For example, a case study on Tokyo's engineering grand challenge of developing an earthquake early warning system includes an introduction to a simple signal processing technique for identifying a wave source location from signals received at three different locations – a technique relevant to predicting the epicenter of a quake. Reference materials are selected from diverse sources, such as position papers and magazine articles published by engineering professional societies, reports from government laboratories and non-governmental organizations (NGO’s), newspaper articles, and journal papers. Many of the out-of-class assignments are writing-oriented. We have made a concerted effort to overcome the compartmentalization of communication skills by integrating the “writing across the curriculum” concept into this course, to give students the benefit of a sustained approach to communication instruction. In addition to individualized assignments, students work on two team projects during the semester that culminate in oral presentations in
each section at the end of Module 1 and poster presentations across all sections at the end of Module 2 (illustrated in Figure 1). The contextual background of important societal applications of engineering provided by this first-year course helps students get the most out of their subsequent in-depth theoretical and applied courses in their chosen fields of study.

**Course Demographics:** This course has proven attractive to a significant number of non-engineering students. During the past three offerings of the course to date, 20-30% of the students did not have pre-engineering standing; they were either affiliated with other colleges/schools on campus or were undecided. It is also worth noting that female enrollment in since fall 2008 has been consistently around 30% -- the highest of any introductory engineering course over the past seven years. This is a very significant trend; while the percentage of women enrolled as undergraduates in the biological sciences nationally now exceeds 50%, the corresponding figure for engineering is only about 20%. The Women’s Experiences in College Engineering project sponsored by NSF and the Alfred P. Sloan Foundation identified factors that contribute to women continuing their engineering studies.

The report emphasizes the importance of illustrating early on for women students how engineering can solve societal problems. It is our conviction that a first-year course on society’s engineering grand challenges, with its emphasis on humanitarian applications, will help to increase gender diversity in engineering, which is of critical importance to technological innovation.

**Course Staffing:** One of the key features of this course is the opportunity for first-year students to interact closely with faculty instructors. To date, a dozen faculty members representing six departments from across the College of Engineering have served as instructors for InterEgr 102. Many of these instructors are recipients of departmental, college, and university teaching awards and recognitions.

**Course Visibility and Offshoots:** Our Grand Challenges course has been highly visible at the national level. It has received coverage in several professional society publications and has garnered interest from several other universities. Most recently, on August 11, 2010, the National Science Foundation’s “Science 360” website featured a video piece about the course. We note that this course has also served as the inspiration for a spin-off project in K-12 instruction and outreach funded by the National Science Foundation, involving two of the team members on this MIU project proposal (Profs. Wendt and Hagness).

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Proposed Cross-College Expansion of InterEgr 102

We propose to increase the capacity in InterEgr 102 from 150 students per year to 300 students per year, maintaining a ratio of approximately 70:30 between pre-engineering students and students outside of engineering. This expansion will help to accommodate the increasing number of pre-engineering students in the College of Engineering. This expansion will also enable us to accommodate a much larger number of students outside of engineering. During the past three years, we have had to place a cap on the number of spots in InterEgr 102 available for non-engineering and undecided students, in order to save enough seats for pre-engineering students. The demand during SOAR from students outside of engineering has exceeded the capacity cap. Our goal is to eliminate the need for a cap and provide enrollment opportunities to all students who want to participate. The broader campus-wide participation of students in InterEgr 102 will foster cross-departmental and cross-college community.

We believe it is important to the overall quality of the educational experience to preserve the small discussion-section environment of the course as it currently stands. Thus the expansion will be carried out without increasing the size of any of the theme-based sections. We will maintain a course enrollment of 150 students distributed across six sections during Modules 1 and 2, and increase the annual capacity, instead, by offering InterEgr 102 in both the Fall and Spring semesters of each year (instead of Fall only). In any given semester, we will staff the course with six faculty instructors, as we are currently doing.

The cross-disciplinary and holistic nature of the course is reflected in the manner in which it will fulfill various curricular requirements for different students. For engineering students, InterEgr 102 counts towards the liberal studies requirement (“S” designation) for degrees granted in the College of Engineering; it also satisfies the General College Requirement for an introductory engineering course. For students outside of engineering, it is our intention that InterEgr 102 will count as a “P” course towards the L&S and CALS breadth requirement; we are currently pursuing university approval for this designation.

We will establish an advisory committee comprised of several key faculty primarily from outside of engineering. We envision several important roles for the advisory committee members. They will serve as liaisons to help us position the course as a campus resource for participation in a cross-disciplinary discussion about the Grand Challenges, and to tie the course into broader opportunities and initiatives on campus that draw together interdisciplinary teams. We also see meaningful opportunities for several advisory committee members to participate as guest lecturers in the course. The following faculty members have already agreed to serve:

- Anne Miner, Professor of Management and Human Resources (School of Business), Executive Director of the Initiative for Studies in Technology Entrepreneurship, and Director of the G. Steven Burrill Technology Business Plan Competition
- John Rudolph, Professor of Curriculum and Instruction (School of Education) and Program Area Head for Science Education
- Andrew Sheinis, Assistant Professor of Astronomy (College of Letters and Sciences), and Faculty Affiliate of the Materials Science Program and Mechanical Engineering Department (College of Engineering)
- Jeremi Suri, Professor of History (College of Letters and Sciences), Director of the Grand Strategy Program, and Co-Director of the Global Health Initiative
This preliminary roster illustrates the types of cross-campus connections that are natural fits for InterEgr 102. The course will be advertised through channels identified by our advisory committee, as well as through the Cross-College Advising Service.

**Proposed Cross-College Partnership with the Undergraduate Research Scholars Program**

We propose to offer on an annual basis approximately 20 research opportunities related to engineering grand challenges to “graduates” of InterEgr 102, through a formal partnership with the Undergraduate Research Scholars Program (URS). (See the letter of support from the URS director, Svetlana Karpe.) The “Grand Challenge” Undergraduate Research Scholars will participate in a year-long research experience during their second year, after having completed InterEgr 102 during the Fall or Spring semester of their first year. We envision that many of these students will continue their research activities beyond their second year after establishing formal relationships with faculty research advisors through the URS.

Countless junior and senior undergraduates participate in research projects within the College of Engineering by taking independent study credits, pursuing honors theses, and working as undergraduate research assistants within specific departments. However, historically, the opportunities for first- and second-year students have been more limited as those students do not have seamless access to typical department mechanisms for supporting undergraduate research until they are admitted to a department within the College of Engineering. The URS offers a well established mechanism for connecting faculty advisors with first- and second-year students. Our proposed partnership with the URS and our intentional and organized offering of grand-challenge research opportunities through that program will have a significant impact on the overall number of engineering-related research opportunities available for our younger scholars on campus. Over a 10-year period between 1998 and 2008, approximately 1000 research opportunities have been offered through the URS; only ~40 of those came from faculty and staff in the College of Engineering. Our coordinated and committed effort to offer ~20 opportunities each year (between two and three projects per department, on average) represents a five-fold increase over the current annual average of ~4 opportunities.

To illustrate the feasibility of meeting our target of 20 Grand Challenge URS opportunities each year, we offer the following data points. Our MIU proposal team of 11 professors – a small subset of the entire College of Engineering faculty – has worked with more than 100 undergraduate students on research projects over the past five years – an average of more than 20 per year, albeit not through the URS. The Department of Electrical and Computer Engineering, as another representative subset of the College of Engineering, has a Fall 2010 semester enrollment of 49 students in independent study credits. The majority of these projects are directly relevant to engineering grand challenges. Thus there is clearly sufficient capacity for offering ~20 opportunities per year, at a level that is appropriately challenging for second-year students, through the URS.

Our proposed partnership with the URS furthers our university’s commitment to the Wisconsin Experience – “the idea that, together, we create and apply learning inside and outside the classroom to make the world a better place.”

It also addresses a specific goal within the URS to increase not only the number of engineering projects available, but also the number of women participants from science and engineering.

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9 [http://www.learning.wisc.edu/](http://www.learning.wisc.edu/)
Assessment and Dissemination

The assessment component of our project will leverage the expertise of the UW-Madison’s Delta Program\(^{10}\) and our past experience in evaluating the pilot offerings of InterEgr 102. Our assessment of InterEgr 102 will continue to make use of survey-based assessment tools implemented at the beginning and end of each semester, along with the Student Assessment of Learning Gains (SALG)\(^{11}\) instrument administered at the end of the semester. We will recruit a Delta Program graduate-student intern who will work as an integral member of the project team to refine and augment our existing assessment tools, implement them, and analyze the data. Our assessment plan for the pilot offering of InterEgr 102 was reviewed by the Education Research Institutional Review Board (IRB) and granted an exemption as a study of educational practices. We will submit an updated protocol for IRB review prior to implementing any of the changes required for assessing the MIU project.

Several measures of success specific to our course can be reasonably well assessed using the survey tools and SALG instrument. Examples include increased understanding of current societal engineering grand challenges; increased appreciation of the interdisciplinary and cross-disciplinary nature of grand challenge solutions, including increased awareness of how engineering solutions are influenced by ethical, political, social/cultural, economic, legal, and environmental considerations; and competency gains in technical writing, team-work, and presentation skills. We will continue to track the numbers of pre-engineering and non-engineering students, as well as the gender ratio in the class. We also will survey course alumni to assess the impact of the course on their choices of major, electives, and extra-curricular activities in their later undergraduate years.

We will track the number of engineering research projects offered through the URS on an annual basis and compare with those numbers prior to the partnership. We will also track the number of InterEgr 102 course alumni in the URS program (InterL&S 250). This data will be obtained using Integrated Student Information System (ISIS) queries. We will also track retention and graduation rates in science and engineering disciplines among the Grand Challenge URS participants.

While we do not have plans to formally assess the impact of this course on the faculty who have been involved, it is worth noting that this project is undeniably enriching the professional lives of all faculty involved. The opportunity to work with first- and second-year students is extremely rewarding. The opportunity to meet weekly with faculty from other departments who are at different stages in their careers under the auspices of a team-taught course is invaluable in fostering cross-departmental community.

Dissemination plans include reporting our outcomes and experiences at the national level. We will continue to make a conscious effort to engage other faculty across campus in discussions about this course. Sharing our excitement with our colleagues is critical to moving the conversation and ideas forward.

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\(^{10}\) [http://www.delta.wisc.edu/](http://www.delta.wisc.edu/)

\(^{11}\) [http://www.salgsite.org/](http://www.salgsite.org/)
Budget

Annual recurring costs:
- 12 faculty instructors for InterEgr 102 (salary only) $155,555
- 12 student assistants for InterEgr 102 (salary only) $9,000
Total: $164,555

Budget Narrative

The requested budget for faculty instructors is needed to ensure the financial sustainability of offering InterEgr 102 to a total of 300 students from across campus each year. Departments within the College of Engineering will be called upon to staff this interdisciplinary course. Redirecting the instructional efforts of 12 faculty members from department-specific courses to this interdisciplinary course leaves those departments with instructional staffing gaps. Our proposed budget addresses those gaps by providing each of the instructors’ departments with compensation that is equivalent to one month of a nominal nine-month $100k faculty salary. In any given semester, one of the six InterEgr 102 instructors will also serve as the course coordinator. An additional month of salary compensation is requested for that lead instructor to cover the extra effort required in coordinating the instructional team and managing the administrative tasks. Thus, we are requesting the equivalent of 7.0 months of salary per semester (two months for lead instructor and one month each for the other five instructors). The department compensation amount of one month of the nominal faculty salary is approximately equal to the costs incurred in hiring an appropriate lecturer for the departmental course that would otherwise be taught by the faculty member.

We are also requesting funds to support 12 undergraduate student assistants (SAs) each year. The SAs play an important role in InterEgr 102. They assist with course-wide administrative tasks such as managing survey data and assigning students to the different theme-based sections for Modules 1 and 2. They also provide assistance to student teams during in-class project work periods within specific sections. More generally, they serve as role models to the first-year students. The total request of $9,000 is calculated based on an assumed hourly rate of $10.00 and an average of 5 hours per week per SA over a 15-week semester.

We note that none of the engineering-bound students in InterEgr 102 pay the engineering differential tuition because as first-year students, they have not yet been admitted to a department.

There are no extra costs associated with the Grand Challenge Undergraduate Research Scholars component of the proposed project; we are leveraging existing URS program infrastructure and the in-kind support of faculty advisors/mentors.
MEMORANDUM

Date: November 29, 2010

To: Paul DeLuca, Provost

From: Paul Peercy, Dean

Subject: Madison Initiative for Undergraduates Phase 3 Proposals

The College of Engineering is pleased to forward for consideration the following seven proposals, in ranked order, for Phase 3 MIU funds.

1. Wisconsin Collaboratory for Enhanced Learning (WisCEL)
2. Campus-Wide Engagement of Undergraduates in Society’s Engineering Grand Challenges
3. Expansion of the Biomedical Engineering Undergraduate Program at UW-Madison
4. Literacy in Sustainability: A Core Competency for All Students
5. Nanotechnology Undergraduate Education: Bridging Technology and Society
6. An Alliance for Engineering and Science Career Services
7. Reinventing Manufacturing Education

Our ranking reflects our assessment of the effect of the proposed work on teaching and learning in the College of Engineering (CoE) and more broadly across campus, and the degree to which the proposals articulate a high impact plan of action. We find significant merit in all seven proposals and believe they are worthy of consideration for MIU funding.

Proposal 1 concerning WisCEL has the potential to dramatically enrich teaching and learning on campus and in the CoE. For this approach to achieve its potential, it must be supported in its formative stages. In addition, it repurposes obsolete spaces to student-focused uses. The WisCEL concept with full implementation could be a “game changer” in CoE and across campus. Faculty are prepared to offer their courses as soon as the facilities are available.

Proposal 2 also has broad impact for both the campus and the college. The project will challenge our students to think about the opportunities and difficulties our world faces and how their generation will need to advance interactive social and technical systems.
to find solutions to those challenges. The project provides technical literacy for non-technical students and provides social context for technical students.

Proposal 3 is a resubmission of a request to increase capacity in the high-demand major of Biomedical Engineering and emphasizes the cross-linkages of this area of study with students in other bio and medical fields on campus. This proposal is very important to the College of Engineering, which has made significant investments in expanding the major, and other biological and health programs on campus.

Proposal 4 is a College of Engineering perspective on campus needs related to sustainability. There is no question about the importance of sustainability in the CoE and the broader campus. The key question is how to best synergistically interface the proposed faculty cluster with activities and proposed degrees in CALS, the Nelson Institute and other areas of campus. This proposal addresses that interface.

Proposal 5 addresses the important educational need of bridging society and technology with a focus on nanotechnology. It is a strong proposal that concentrates on one aspect of technology and technological literacy.

Proposal 6 focuses on the obvious need to better align and coordinate career services across campus. It will make UW-Madison more user friendly for employers and enhance employment opportunities for students.

Proposal 7 addresses the important state and national need to re-invent and re-energize manufacturing. UW-Madison could strengthen its visibility as a focal point of economic development in the state by moving forward with such an investment.

Thank you for considering these proposals.

Enclosures

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