Cornerstone Design for Sociotechnical "Grand Challenges"

Dr. Jenn Stroud Rossmann, Lafayette College

Jenn Stroud Rossmann is Professor of Mechanical Engineering at Lafayette College. She earned her BS in mechanical engineering and the PhD in applied physics from the University of California, Berkeley. Prior to joining Lafayette, she was a faculty member at Harvey Mudd College. Her scholarly interests include the fluid dynamics of blood in vessels affected by atherosclerosis and aneurysm, the cultural history of engineering, and the aerodynamics of sports projectiles.

Dr. Hannah Stewart-Gambino, Lafayette College
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Introduction

This Evidence-based Practice paper describes the development and evolution of an interdisciplinary First Year Seminar providing a cornerstone design experience addressing the Grand Challenges. The sociotechnical nature of the Challenges is emphasized, making clear the need to develop sociotechnical skills and practice, and a sense of sociotechnical justice. The authors are an engineer (with expertise in biomedical engineering and design) and a political scientist (with expertise in the politics and gender of development in the Global South) who sought to collaborate in the development and teaching of the course. Building that collaboration required each author to think deeply about her existing expertise, gain new knowledge, and effectively model interdisciplinary curiosity and collaboration for our students. We will describe the development and implementation of these seminars, and their assessment and refinement over four offerings. This cornerstone experience lays a foundation for integrative education and fosters an understanding of the need for interdisciplinary collaboration.

The National Academy of Engineering Grand Challenges (Table 1, [1]) are inherently sociotechnical, multidimensional and context-specific problems whose resolution requires meaningful collaboration among and across multiple disciplines. At Lafayette College, we emphasize this complexity, and require Grand Challenges Scholars to work in interdisciplinary teams. To foster such collaboration and lay a foundation bridging engineering and the liberal arts, we developed a linked pair of first-year-seminars addressing a “grand challenge.” Building on the WPI Great Problems model [2], these two First Year Seminars are team taught by a mechanical engineer and a political scientist, each addressing the problem of global hunger. Students from both sections work together in project teams and participate in discussions of course topics and shared readings. The course includes a community-based learning component as well as the development of a research & development plan for future engagement.

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<tr>
<th>Sustainability</th>
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Table 1. The 14 Grand Challenges issued by the National Academy of Engineering in 2008. The broad, “cross-cutting” [1] categories into which NAE organized them are at left.
The nature of each Challenge is distinct in specific geographic, cultural, and political contexts; so too must its meaningful resolution be a set of nonunique “solutions” that take those contexts into account. (For example: “Engineer better medicine” raises the questions, what is “better,” and for whom? The constraints and objectives for the design space may vary widely with the context.) The pitfalls of imposing externally designed solutions without a deep understanding of local culture, societal norms, and power structure have been well established ([3]-[7]). Relying on technological progress to drive or require the social progress that would make “solutions” widely available has also been shown to be inadequate (e.g. [8-9]). As scholars [10] have written, “Critical analyses and reflections on the design of science and technology are essential if societies are to meet their challenges in ways that create real improvements rather than re-create inequalities.” Meaningfully addressing the Grand Challenges thus requires interdisciplinary collaboration, critical thinking about the potential and the limitations of engineering design methods, and deep understanding of local social context and larger economic and political systems.

Lafayette College began its Grand Challenges Scholars Program (GCSP) in 2010. We reframed the Challenge language to emphasize the sociotechnical complexity of these challenges, as shown in Table 2. Students proposing GC projects to were required to have had an interdisciplinary curricular preparation, a global experience (more than 50% of our College’s students, including those in engineering, study abroad), and an exposure to entrepreneurship. (Full requirements are listed in Ref. [11].) We were able to offer support for student stipends, travel, and materials for several projects per summer. Through information sessions, students were encouraged to collaborate with friends in other majors to address projects of shared interest.

We hoped to inoculate our Grand Challenges program against the they/us “those people have needs, and we have skills to help” paradigm that has been problematic in humanitarian engineering and economic development efforts alike (e.g. [5],[12]). We hoped to make our engineers less likely to see themselves as “problem solvers” offering “solutions,” our non-engineers more likely to see their expertise as critical to the success of such efforts, and all our students more capable of developing empathy for other, “underserved” communities and less likely to define those communities by what they lack [13]. We hoped that our reframing of the challenges would emphasize the **interdependence of the social and technical aspects of the Grand Challenges**, rather than permit them to be considered distinct [6].

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<td>Grand Challenge</td>
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<td>Make Solar Energy Economical</td>
<td>Design renewable energy systems that are viable, socially well-integrated, and/or marketable; study and propose policy that would promote the development or adoption of renewable energy systems or explore why prior public policy efforts have not succeeded; investigate renewable energy solutions for the developing world while respecting diverse cultural conditions; build an artistic representation of, study the use of language or ethics surrounding, or write about solar or renewable energy solutions; and so on.</td>
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<td>Develop Carbon Sequestration Methods</td>
<td>Design scalable implementation plans for biological processes to accomplish sequestration; model the environmental effect of scaling up techniques such as geo-engineering, phytoplankton growth, or peat bog extension; improve the economic feasibility of CO2 capture and transport; evaluate the multiple tradeoffs using reforestation (or anti-deforestation) as a sequestration technique; design communication strategies for industrial clients and the general population; develop policy to encourage wider adoption of methods; determine the direct and indirect impacts of large-scale sequestration efforts; and so on.</td>
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<td>Provide Energy from Fusion</td>
<td>Research and develop ways of harnessing energy from fusion reactions; assess the economic viability and political consequences of building and maintaining fusion power plants; track the environmental advantages and disadvantages of fusion power as an alternative energy source; examine ways to minimize the extent to which the reliance on fusion power from nuclear plants might pose security and health risks; and so on.</td>
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<td>Manage the Nitrogen Cycle</td>
<td>Develop methods for ameliorating human interference with the nitrogen cycle such as improving motor vehicle emissions through the use of alternative fuels and engine technologies and/or redesigning industrial agriculture practices; optimize technologies for both developing and developed nations giving thoughtful attention to the ethics and politics of solving an “industrial” problem before all nations and economies have had the opportunity to industrialize; balance the technical, economic, political, and cultural aspects of new technology dissemination; and so on.</td>
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<td>Provide Access to Clean Water</td>
<td>Develop novel methods for cleaning water and wastewater; explore the practical implementation of a “global water ethic;” explore the controversy over whether water should be considered a common good with its distribution a public policy responsibility, or whether water should be considered an economic resource or private commodity with its distribution governed by market forces; consider the sociopolitical consequences of each of these attitudes in the past and in various cultural contexts; determine the extent to which water is a basic human right and hence fundamentally in the domain of politics and even religion; and so on.</td>
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<td>Engineer Better Medicines</td>
<td>Explore alternative and innovative biomedical options such as personalized medicine which utilizes the individual’s genetic variability in order to develop individualized therapies; address the ethical and political issues surrounding personalized medicine, stem-cell research, and other strategies for research and development; consider the relevance of the burgeoning discipline of the medical humanities to both medical development and patient care, for example, the use of patient’s first-person narratives of illness as supplements to traditional diagnostic reporting; explore the economic, social, and psychological impact of the rise of diagnostic psychiatry and the pharmacological revolution; and so on.</td>
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<td>Advance Health Informatics</td>
<td>Provide models and tutorials for increasing health informatics literacy; develop technological mechanisms to make health informatics easily accessible across cultures and economic environments; promote effective health education for at-risk and low-income families; develop health literacy programs for senior citizens; investigate the political, legal, and cultural opportunities for, and obstacles to improving and implementing health information systems; and so on.</td>
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<td>Secure Cyberspace</td>
<td>Study and develop not only the technology behind cybersecurity, but also the politics of cybersecurity as evidence in recent legislative enactments, including the Cybersecurity Act of 2010, as well as controversial, recently introduced “kill switch bills” which would grant the</td>
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<td><strong>President emergency power over maintaining the internet during emergency times; evaluate the history of representations of cyberspace in fiction and popular culture, including the genre of cyberpunk literature, films and video games which feature virtual reality, digital art that manipulates cybertechnology; devise ways of monitoring computer software that can be used to facilitate cybercrimes and cyber-terrorism; and so on.</strong></td>
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<td><strong>Prevent Nuclear Terror</strong> Develop methods of protecting attacks on nuclear facilities; devise new ways of monitoring the construction of radioactive weapons and fissile material; assess the legal ramifications of nuclear terror including international court rulings, the sharing of information among countries, and the political ramifications of increasing anti-intelligence policies globally; research and develop alternatives to radioactive materials; track the economics of developing and acquiring fissile material, especially practices of smuggling and black-market acquisition of such material; manage the cost of nuclear threat reduction; determine the cost of maintaining a secure infrastructure and emergency preparedness; evaluate restrictions on human rights in relation to national security threats; determine the economic and intangible costs of fostering national security; etc.</td>
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<td><strong>Restore and Improve Urban Infrastructure</strong> Develop technological designs and management systems to revitalize urban infrastructures particularly in areas damaged by floods, storms, earthquakes and other natural and induced disasters; facilitate the architectural planning and design of improved infrastructural elements; contribute to the understanding of economics and politics of disaster management and relief; revise local and national public policies regarding housing development and poverty relief; explore questions of property rights raised by urban renewal, as well as policy challenges in building infrastructures in developing countries; evaluate the intersection of infrastructure and culture; and so on.</td>
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<td><strong>Advance Personal Learning</strong> In addition to conceptualizing and developing communications software that would facilitate adaptive learning, assess the impact of personalized pedagogy at the individual and collective level. For example, design experiments to test the benefit and variability of individualized learning for different groups; examine the psychological benefits and drawbacks of distance learning; investigate which tools are needed to assess properly the results of personalized learning; evaluate whether advances in individualized learning narrow or widen already existing gaps in the availability of education.</td>
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<td><strong>Reverse-Engineer the Brain</strong> In addition to studying and developing “neural prostheses” and new models of Artificial Intelligence (AI) in order to understand and manipulate the brain, evaluate the philosophical, theological and ethical issues that accompany such neuroscientific developments. This might include the impact of findings in neuroscience on the nature of consciousness and mind-body relations; the manner in which individuals process verbal and visual material such as metaphor and digital imagery; and the impact of the cognitive revolution on religious belief and practice.</td>
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<td><strong>Enhance Virtual Reality</strong> Study and develop techniques for improving virtual reality, and assess the larger sociopolitical implications of such an enhancement. To what extent will advances in virtual reality impact intersubjective communication, as well as cognition generally? Will enhanced virtual reality displace the development of actual communities? What are the political and economic ramifications of an increased immersion in virtual reality? Does virtual reality reinstate class distinctions based on access and knowledge? Can virtual reality foster deception &amp; similar vices?</td>
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<td><strong>Engineer the Tools of Scientific Discovery</strong> Develop and implement advanced technologies such as lasers, cameras, and computer software to aid in the investigative fields of, for example, oceanography, astronomy, medicine, for example. Explore the history of scientific development and the impact of technology on cultural values and ideologies, i.e., the impact of the scientific revolution on early modern religious belief; and assess the ethical and political implications of using technology to, in some cases, exploit the natural environment.</td>
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But despite the thoughtful design of Lafayette’s Scholars Program, it soon became clear that we needed a pipeline. In particular, we sought to recruit non-engineering majors to roll up their sleeves and address these vexing, complex Grand Challenges. While non-engineering students are just as inclined to want to “make a difference in the world,” their academic scaffolds and curricula are more typically constructed to encourage research and community-based work in their own fields and with their own faculty. They may not see themselves in the Grand Challenges opportunities perhaps in part because they do not believe that they have the technical skills – but also because other opportunities are emphasized within their own majors and minors. They did not as readily envision themselves – for example – spending eight weeks in Haiti to design and implement a water filtration system, no matter how much our publicity materials and information sessions emphasized the critical contributions of the non-engineering members (International Affairs/French, and Economics majors) of that 2013 GCSP team from our College. We also lacked a mechanism to develop the humility of engineering majors so that they might pause before rushing toward technical “solutions.” With our seminar, we aimed to address both of these needs.

Class Context and Content

Central to our course is the goal of illuminating the sociotechnical design pipeline for both engineering and non-engineering students. To create a cornerstone for our Grand Challenge and other project experiences that would encourage all students to appreciate the importance of interdisciplinary collaboration, we designed a First Year Seminar class on the challenge of global hunger. We chose to focus on a global issue that was not directly aligned with a Grand Challenge, but whose sociotechnical complexity would adequately prepare students for GCSP work, and whose urgency would be patent regardless of the students’ disciplinary inclinations.

Lafayette College is an undergraduate-only liberal arts college with approximately 2600 students, of which roughly a quarter pursue one of four ABET-accredited BS engineering programs or our AB in Engineering Studies. This distinguishes Lafayette’s student body from that of WPI, whose Great Problems Seminar [2] was a key inspiration for our course; it meant we could not take for granted a project-based, engineering mindset in all our students. We hoped the class would appeal to a broad group of students, so that for some students we might be introducing engineering design, while for others we might provide a first encounter with the methods of anthropology, sociology, and political science.

All Lafayette College students, regardless of intended major, must complete a set of core curricular requirements known as the Common Course of Study. These include a First Year Seminar; courses that fulfill learning outcomes in humanities, social science, values, quantitative reasoning, and global/multicultural understanding; elementary proficiency in a foreign language; and additional breadth requirements beyond their major. By designing our Grand Challenges cornerstone to fulfill curricular requirements, we would be ensured of student enrollments. We elected to design and teach two distinct First Year Seminar sections that would be linked through shared reading, discussions, and a cornerstone design project.
All of our students take a First Year Seminar (FYS) in the first semester of their first year. (Transfer students are permitted to waive this requirement or substitute a similar class taken elsewhere.) In the summer before their first semester, students rank their preferences from among a menu of available FYS courses. The FYS classes are designed and taught by faculty from all departments, with themes chosen by the teaching faculty, and each class must fulfill learning outcomes in written communication and information literacy. The College notes that the FYS “is designed to introduce students to intellectual inquiry” (http://catalog.lafayette.edu/current/Catalog/Majors/First-Year-Seminar); each class is limited to approximately 16 students, allowing for active discussion and giving faculty the opportunity to provide meaningful feedback on students’ writing process. Each section is supported by the College Writing Program which provides a student Writing Associate to provide additional guidance to students, and by the College Library which assigns a research librarian to work with each section to develop research skills.

The FYS was a promising context for our foundational interdisciplinary project-based learning experience for the same reasons such seminars are effective pedagogically and “high-impact” [14]. They engage students with faculty and with their peers in formal and informal conversations “about substantive matters, typically over an extended period of time” [15].

To our College’s standard FYS learning outcomes related to writing and information literacy, we added three additional learning outcomes: that after completing this class, students will:

- Appreciate the multidimensional nature of the sociotechnical problem of world hunger;
- Develop strategies for effective collaboration with problem solving teams; and
- Understand and apply engineering design thinking.

The current course topic schedule and reading list is shown in Table 3. Writing assignments include personal essays, responses to reading, analyses of food distribution processes, site visit/interview write-ups, and several progressive assignments related to the team-based design project. Examples of these assignments are included in Appendix A.

In four iterations of this course, we have made changes including to the textbooks and reading list, and to the timing of the project introduction. We now assign project teams and begin project work in the fifth week. Note in the schedule in Table 3 that weeks 5-12 all include significant class time devoted to project “design studio,” in which both faculty members interact with project teams as they research and brainstorm.

**Table 3.** Topic and reading schedule for cornerstone Grand Challenges seminar.

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<th>Week</th>
<th>Topics and/or Activities</th>
<th>Reading</th>
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<td>1</td>
<td>World Hunger: Problems &amp; Progress&lt;br&gt;• Our Multidisciplinary Approach</td>
<td><em>Stuffed &amp; Starved</em>, Raj Patel, Ch 1</td>
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<tr>
<td>2</td>
<td>Defining Hunger: Food and Nutrition Insecurity</td>
<td>Biology and Neuroscience of Hunger</td>
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<tr>
<td>3</td>
<td>Economic and Political “Solutions”&lt;br&gt;• Green Revolution, Soylent, &amp; Beyond</td>
<td><em>Stuffed &amp; Starved</em>, Ch 2-4&lt;br&gt;<em>No-Nonsense Guide to World Hunger</em>, Ch 1-3</td>
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<tr>
<td>4</td>
<td>Technological “Solutions”&lt;br&gt;• Green Revolution, Soylent, &amp; Beyond</td>
<td>Norman Borlaug background&lt;br&gt;“Design Thinking for Social Entrepreneurship”</td>
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A key theme of our seminars is the moral responsibility of those involved in “development” or “humanitarian engineering” interventions to deeply and resourcefully anticipate “unintended consequences” of their work. Like others (e.g. [6]), we were concerned by the NAE Report’s silence regarding such consequences. We wanted our students to be aware of how frequently well-intended projects were undone by “unintended consequences” which could and should have been anticipated, and that a failure to anticipate them constituted a failure of imagination. We thus built a reading list that was rich in both historical case studies and in the methodologies of social sciences’ engaged research: we wanted them to identify pitfalls and appreciate that strategies and expertise were available to help them mitigate the risks. We invoke Dori Tunstall’s advocacy for “relationships of accountability” in order to “decolonize design” [16] and development. Over the semester, and sometimes several times within a class meeting, our seminar oscillated between empowering students with an optimistic, sleeve-rolling-up enthusiasm to address the challenges and tempering that enthusiasm with a more pessimistic understanding of the geopolitical and cultural complexities that would complicate implementation and accessibility, making sociotechnical justice difficult to achieve and sustain.

During the semester, students in our linked cornerstone seminars develop both socio- and technical competencies. Early on these are developed in parallel, but by the end of the semester they intersect in the collaborative research & development project performed by student teams. We pointedly refer to their project as designing an “intervention,” not a “solution,” and their final deliverable includes a proposed process of further development, including specific stakeholders with whom they will speak, and specific questions they have, as well as proposed assessment measures and possible “offramps.”

The “design thinking” framework popularized by the Stanford d.school is our language for the engineering design process in this class. Our adaptation of this framework is shown in Figure 1.
That design thinking is founded on developing **empathy** is critical: empathy requires a full understanding of the societal context in which all stakeholders operate; empathy is distinct from “sympathy” which could yield the problematic “need my help” framing; and empathy has been shown to be enhanced through the humanities and social sciences [17]. Design projects in the first year have been shown to develop empathy and to help students develop an emotional understanding of stakeholders’ interests [18]. In our view, empathy requires and dictates an **ethical approach** to design, as the potential risks and rewards for all conceivable stakeholders must be considered. During a class period early in the semester, we involve students in a 75-minute design thinking “bootcamp” exercise in which they work through this process to identify and address a food-related need for a classmate partner. Figure 2 shows students participating in this exercise, as well as the prototyping supplies provided. We return to this language and framework for the design process throughout the course.

**Figure 1.** Design Thinking process taught and practiced, after Stanford d.school.

**Figure 2.** Early design thinking experience and supplies.
Project teams form and perform initial research, then each student prepares an individual Literature Review on some aspect of the specific location on which their team is focusing. We encourage, but do not require, teams to choose a geographic location outside the continental United States. The four members of a team may choose to write their literature reviews on, for example: (1) local politics; (2) local geography and environmental issues; (3) local demography and cultural practices including religion, education, and taboos; and (4) local infrastructure and existing practices relevant to the project – which may include farming, cooking, or food distribution. Each team member is encouraged to view the individual literature review as something that will support the team: this provides an audience and a motivation for their research and writing.

In their teams, students participate in hands-on activities at a field trip to our College’s organic farm, then visit assigned community partners who they interview about their work and the challenges they have faced in trying to address local hunger problems. These experiences provide additional context and information, and also help the teams develop their collaborative skills and senses of team identity.

The final deliverables for the project are (a) an individual report from each student (specifically addressing how the team’s proposed intervention is informed by the research that student performed in the literature review), as well as (b) a group-prepared poster and presentation to the combined class. Non-presenting students are designated as potential “investors” for each project, therefore accountable for posing questions about the proposed research and development (R&D) – from schedule and budget to underlying assumptions to questions about cultural sensitivity and implementation. In Figure 3, representative student project posters are highlighted.
Assessment and Evaluation

Over the four offerings of this cornerstone seminar, we have made adjustments to the course schedule, reading list and assignments, class activities, and project pace. We now highlight some of those features of the course’s evolution, as well as course assessment.

This is a cornerstone, not a capstone, experience: there are no prerequisites, no expectations of a priori knowledge, and no assumptions made regarding students’ anticipated fields of study after this first-semester seminar. The course is designed for students from all backgrounds, with the paired goals of empowerment and humility about the extent and importance, and limitations, of their expertise. The seminar’s primary goals are: an understanding of the engineering design process, appreciation of social context, and preparation for sociotechnical work. The class also has secondary goals of developing students’ team collaboration skills, research skills, communication effectiveness with a range of audiences, and creative confidence. We chose to focus the quantitative assessment efforts described here on the primary goals of the course.

We identified four dimensions that are consistent with both our course’s primary student learning outcomes and best practices in humanitarian engineering, the achievement of which would effectively prepare students to participate meaningfully in future Grand Challenges-style design projects: understanding the design process; using empathy to appreciate what level of intervention was appropriate in a given context; demonstrating intercultural competence and sensitivity; and using an ethical framework to guide decision-making.
In keeping with best practices in student assessment, we used student work to measure student’s understanding and appreciation of the kind of interdisciplinary work that our Grand Challenges initiative envisions. Because the course is designated as a writing intensive course\(^1\), each student writes multiple, individualized writing assignments in addition to the final team poster and poster presentation. All student writing is evaluated and graded on a variety of dimensions. In addition to that evaluation, we sought to measure how well students had met the cornerstone’s primary goals. We used the final individual writing assignment, a 12-15 page project proposal for [imaginary] funding from each team member that includes a general introduction to the specific location (e.g., country, region, town, even neighborhood) and hunger-related issue (e.g., water filtration, food storage, agricultural production or storage, or information dissemination), literature review specific to the member’s role on the team, description of the proposed solution, and an examination of the proposed solution’s “practical considerations” (unknowns, ethical choices, budgets, safety, etc.). The assignment prompt for this proposal is included in Appendix A.

Consistent with our goal of constructing a first college semester cornerstone course that exposes engineering and non-engineering students to skills and approaches necessary for taking advantage of the college’s Grand Challenges program (or similar multidisciplinary, “real world” project-based opportunities at Lafayette), we coded student final proposals for four variables:

1. Understanding of the **design process** (defined as a description an iterative process regardless of correctly identifying the individual steps in the design process)
2. Ability to choose **appropriate technology** (defined as a description of the team’s rationale for choosing a particular solution regardless of the level of technicality).
3. **Intercultural awareness** (defined as a description of cultural differences that influenced the team’s choices, approach, and/or practical considerations)
4. **Ethical awareness** (defined as a description of the group’s approach to weighing ethical choices, regardless of correctly identifying Kantian, utilitarian, religious, or other ethical frameworks)

The frequency with which these variables were addressed in students’ final project proposal papers is shown in Figure 4. We coded 28 papers from the Fall 2017 seminars, and 29 papers from Fall 2018. Illustrative examples of student work demonstrating each of these variables are shown in Appendix B.

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\(^1\) Courses designated as writing (W) courses require students to write at least 20 pages or 5,000 words across the semester, receive feedback on their work, learn to revise in response to that feedback, and acquire strategies for composing, revising, editing, and proofreading.
The relatively high percentages of students each year whose final proposals include reference to each of the four variables encourages us that our course design provides students with the material and guidance necessary to demonstrate awareness of the value of a breadth of approaches for addressing “real world” problems. We were pleased that there was no statistical variation between the frequency values of students in the two sections (one taught by a mechanical engineer, one by a political scientist).

For non-engineers, the ability to discuss the value of the design process and the importance of technical considerations for designing solutions to problems such as world hunger suggests that they may be open to participating in future opportunities that appear to be “engineering” ones. And for engineers, the ability to discuss the importance of devoting resources to cultural understanding (often described as a way of developing empathy) and recognizing that design choices are framed by ethical considerations (often described in Kantian or utilitarian terms) suggests that they may be able to articulate the importance of non-engineering expertise in constructing effective solutions. We recognize, however, that the relatively small size of each year’s cohort can appear to amplify small differences in student performance from one year, or one section, to the next.

In addition to this quantitative assessment of the primary course goals, we have an anecdotal sense of how well the course achieves its secondary goals, and have made some refinements to improve these, as described below.

*Section identity formation:* In the course’s first iteration, we had the two sections meet together once a week, and separately once a week, until about the 7th week when project work began and the sections met together for each class session. This had a negative impact
on our ability to achieve one of the goals of the First Year Seminar: an intimate discussion among 16 students of the course readings and issues. In subsequent iterations, we worked to develop a sense of camaraderie and trust among the distinct sections before bringing the sections together, and reduced the number of shared meetings in the first two weeks of the semester. We also added individual meetings between the relevant faculty member and each student in her section, developing that connection early in the semester.

**Team cohesion and community engagement:** In our first three offerings of the course, we hosted an on-campus event at which students were paired with community partners (food bank organizers, church and community leaders, nutrition educators, farmers’ market organizers, and others). Over dinner, students interviewed these community members about their work addressing local hunger issues; we hoped they would make connections to their eventual project work. We found those connections were strengthened by two changes we made in the fourth iteration: (1) we introduced the project and formed project teams earlier in the semester, and (2) we sent the project teams to specified community partners in their place of operation, so that they could observe the work being done in its community context. This change resulted in a dramatic increase in the number of students who specifically cited the community partners’ experience and information they provided when discussing their own proposed interventions elsewhere. Our informal assessment of the course includes students’ self-evaluations and team evaluations about their teammates and the degree to which their team collaborated effectively, and these changes to the course have had a marked positive effect on both faculty members’ and students’ sense of the team dynamics and effectiveness.

Over four offerings of the seminar, we have observed an increase in number of student teams who emphasize working with local experts, demonstrating their appreciation of the limitations of their own expertise and the value of others’ – exactly what we would hope they would have taken from our repeated discussions of the failures of exclusively economic, exclusively political, or exclusively technical approaches to complex problems. This is anecdotal evidence of their appreciation of the importance of multidisciplinary collaboration. We hope to measure this attribute of their project presentations and posters in future assessments, perhaps using instruments developed by researchers investigating the development of empathy in design [18].

We note that students perceive themselves as having a disciplinary inclination and identity even in their first semesters, before they have pursued much disciplinary instruction. Although students at Lafayette College do not formally declare majors until their second year of study, engineering students and many others have intended areas of study in their first semester. We observed them aligning themselves accordingly with the sections of our seminar taught by either a political scientist or an engineer, sometimes requesting to transfer to the other section, or defining themselves within their project teams according to these identities. We have declined those requests, desiring both sections to be comprised of students from a broad range of majors.

A strength of this course is the true partnership between engineering and non-engineering faculty in its development, instruction, and assessment. Each faculty member receives a full course load. Neither of us had previously been expert in all aspects of the course content, and each had to learn new content, context, and skills in order to teach the course effectively. Building a meaningful collaboration meant that each of us thought more deeply, performed
research, and effectively modeled interdisciplinary curiosity and collaboration for our students. We introduced ourselves to our students in the way we hoped they would introduce themselves to their project teammates: here’s what I bring to the table, and here’s the kind of questions that interest me.

Another measure of the effectiveness of the course in achieving its goals is the number of students who go on to pursue interdisciplinary project opportunities at our College (and beyond). In addition to the Grand Challenges Scholars Program, these include the Technology Clinic, Community-Based projects facilitated by our Center for Community Engagement, and the opportunity for non-engineers to participate in a range of engineering capstone projects. After four consecutive fall semester offerings of this class, we do not yet know the long term impact on this measure, nor can we be certain that the seminar was responsible for students’ subsequent choices – our FYS may self-select students inclined to be involved in such projects. Still, approximately a third of the students who have completed our Grand Challenge cornerstone have built on that experience with these additional interdisciplinary projects. This is much higher than the rate of participation of our College’s general student population.

Additional assessment faces several research design and practical constraints. We do not expect to expand the course beyond two sections, limiting the population to no more than 32 students each semester. Because the college FYS program courses are designed to attract a wide diversity of students (diverse in terms of demographics, high school preparation, intended majors and minors, etc.), a well-designed study to measure the effect of our course on future academic and co-curricular participation in programs like Grand Challenges Scholars faces a challenge. For example, the literature shows that first year student performance on a number of dimensions can be affected by differences in student gender, socio-economic status, high school background, writing or English writing ability, time management skills, first generation status, etc.

We are gratified by the student engagement about, within, and beyond this course. In our College’s course evaluations, students rate their perception that they “learned a great deal in the course” as a 4.25 on a 5-point scale where 5 is the highest. Students’ written comments suggest the course is achieving its goals: “I learned that engineering is not enough to solve big problems;” “Even I can think like an engineer and help people;” and “Everyone should take this course.”

Future collection of data will offer an increasingly robust picture of student outcomes at the course level, but a longitudinal assessment – whether our students are more likely to choose to participate in Grand Challenges or similar opportunities over their college careers – also faces challenges in our campus’ current Banner informational management system. Although the academic data is robust (majors, minors, study abroad and other credit-bearing enrollment), other participation in other activities such as community-based research or real-world team- or project-based internships are either not coded or are coded in separate information systems tailored for other College divisions such as Student Life, Career Services, or Alumni Affairs.
Conclusions

A linked pair of first-year seminars addressing the problem of global hunger was designed to serve as a cornerstone experience in defining and designing responses to multidimensional sociotechnical problems. The course culminates in projects completed by multidisciplinary student teams. Building on the WPI Great Problems model, these two First Year Seminars are team taught by a mechanical engineer and a political scientist, each addressing the problem of global hunger. Students from both sections combine in project teams and for interdisciplinary discussions of course topics. The course includes a community-based learning component as well as the development of a research & development plan for future engagement. Introducing students to the multidisciplinary complexity of such “Grand Challenges” as global hunger lays a foundation for integrative education and a felt need for interdisciplinary learning and collaboration. The course has evolved over four offerings to improve its achievement of its goals. Assessment of student work indicates that students are developing the desired perspectives and skills. Further study faces data collection challenges, but may highlight the effectiveness of this cornerstone experience as a “pipeline” for students’ later pursuits.

Acknowledgments

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References

Appendix A: Cornerstone Design Project Assignments

Final Project: Proposal for Research & Development

For your final project, you will work with your team to define and address a “design problem” in the context of world hunger. As a group, you will prepare a poster and presentation of your problem, your proposed intervention or “solution,” and what you have learned about it, as well as your practical considerations/questions. As an individual, you will be responsible for researching a specific aspect of the project (for example, you might be the political, infrastructure, agricultural, economic, cultural, or logistics expert on the team). You will be responsible for bringing relevant research from your area to the team in order to contribute to the project’s success. This research will take the form of a literature review. You will work with your team to integrate all of your research, informed by the course readings and discussions, and collaborate on the final team project.

Key dates:  

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| Sept. 26 | Presentations of potential project topics  
Your goal is to offer & receive feedback |
| Oct. 5   | Project topic due: 1 paragraph per group. Specify:  
• Where you will be focused  
• What’s going on there to contribute to hunger  
(3 sentences or less)  
• What general issue your team anticipates focusing on (supply, access, transport, storage, cooking, ...), and why.  
• How you’ve responded to any feedback from classmates & professors so far |
| Oct. 12  | List of 8 sources for your lit review due |
| Oct. 21  | Literature Review draft due |
| Nov. 9   | Literature Review final version due |
| Nov. 21  | Poster files due |
| Nov. 26  | Poster Presentations start |
| Dec. 7   | Final Report due |
Individual Literature Review, due Oct. 21 (draft) with final version due Nov. 9.

In order to describe your group project and how it might contribute to solving issues related to hunger, you need to understand what scholars already think they know so that you can identify what questions you need to answer on the ground. Put your role in your group project in context: what are the major conversations (literatures) that relate to your group project? For example, is your project related to the scholarship regarding food markets and infrastructure, availability and cost of technology, economic policy, international trade or aid policy, culture, state capacity or corruption, etc.? Next, what are the major conversations that relate to your assignment in your group project? Are you taking the lead on economic issues, political issues, technical issues, cultural issues, etc.? Identify and analyze at least 8 scholarly, peer reviewed articles related to your assignment in your project. You may use information from the media or other non-peer review materials to help you search for relevant articles, but the literature review should be based on your review of what academic scholarship tells us.

Your 8-10 page Literature Review should thus include:

1. **Introduction to the Problem** (typically 1-3 paragraphs; this is where media or other sources can be helpful)
   a. Who has the problem
   b. Where the problem exists (describe the context, including a brief history and current social, cultural, and environmental landscapes).
   c. Detailed description of the problem itself: what are the major conversations that relate to this topic? (For example, is your project related to the scholarship regarding food markets and infrastructure, availability and cost of technology, economic policy, international trade or aid policy, culture, state capacity or corruption, etc.)
   d. Why is it a problem? What are the significance and consequences of inaction?

2. **Summary of the Conversation** about your particular, individual angle on the group’s topic (Are you taking the lead on economic issues, political issues, technical issues, cultural issues, etc.?): this is the bulk of the literature review
   a. What do scholars think are the major issues and concerns?
   b. What’s the “state of the art” of thinking on the subject?
   c. In addition to scholarship focused particularly on your group’s chosen region and situation, is there other work that may be relevant?
   d. How much do we already know about this, and what questions remain?

3. **Bibliography** of scholarly sources (included within the page count)
Your Final Report (due Dec. 7, presented Nov. 26-Dec. 5), approx. 10-15 pages, should include:

1. Problem Statement

2. Background. Clearly describe the problem and its underlying causes. This section must be fully referenced: every statement of fact should have a citation associated with it, and/or be supported by a concrete, cited quote. This can be a revision/compression of your literature review, integrating what you’ve learned from your teammates as well.

3. How might we...? What approach will you take? How will you evaluate your “solution”? Did you consider possible solutions that your team decided against? This should include possible methodologies, data collection, and analyses. What are you going to evaluate? This may include academic literature, attitudes, empirical facts, ethical claims, ...

4. Practical Considerations.
   a. What types of data will you, or could you, collect in order to try to ensure that your project is, in fact, helpful?
   b. Description of “stakeholders” in your problem. Who is affected?
   c. What are the social, political, or economic issues connected with your problem/project?
   d. Ethical Considerations. Briefly address: In considering your problem and its context, what ethical principles guided your decisions? Will your solution(s) benefit some people more than others? Were there potential negative consequences that you sought to avoid?
   e. If your team was given a $50,000 grant to pursue your proposal, how would you spend it? Who would you meet with, and what questions would you ask? Note that your team may delegate this work, so that each team member may have a different list of people and questions associated with each member’s particular “lens” on the problem. List possible contacts (titles/societal roles, not specific names) for interviews or inquiries, and provide an explanation of why you would want to talk with these people and what questions you have, what you already know about their role, and how they could help you define the design problem and evaluate possible solutions. If possible, estimate the costs of your work.

5. Conclusion.

6. References (included within the page count)
### Appendix B: Examples of student writing consistent with coded variables

| Design Process / Iteration: | While we are confident that we have done enough research for our plan to succeed, there is no better teacher than experience. As such, our first steps must be to travel to Madagascar ourselves and learn from the people what their needs are. We would contact the local government and work with them to try and have the people respond to a survey detailing their experiences with food insecurity, droughts, and what they feel would help them to develop better food security. Based on their responses, we plan on tailoring our plan to better meet their specific needs.  

Our solution is called the biodegradable shock dampener, and it utilizes excess corn husks that are woven together using pre-existing cultural practices to construct a durable suspension system. This system surrounds a crate, most likely containing produce or goods, on the bottom and top suspending it, and ultimately reducing the damage of items during transport... After going through R&D in the U.S. we shall travel to Guatemala and introduce ourselves and our goals to rural Mayan villages outside of Los Encuentros. To do this we would most likely need to meet with a local who knows the geography of the area and could guide us. We would use the translator to communicate with villagers and develop an understanding of their specific needs and desires. From there we would most likely have to adapt our intervention to better meet the people’s needs and educate them about the methods behind each step of the intervention.  

In order to better understand the current water delivery and storage systems, we are planning...to survey a random sample of 100 families in the city. This survey would, hopefully, also enable us to gain useful feedback on our proposed clay water collection, storage, and filtration system. Based on feedback from the survey, we would be able to improve the design for our rainwater harvesting system to better meet the needs of the inhabitants of Ciudad Dario...From our literature review, we found that the key to implementing a sustainable water supply project is the community participation in the entire project cycle. Closely related to this is the issue of gender roles in rural areas of Nicaragua. As a way of highlighting the principle of gender equality as it relates to hunger, we would emphasize the importance of participation of both men and women in all stages of the project implementation. We believe that this would improve the sustainability of our project through the application of gender approach, community participation and community strengthening in management, operation and maintenance of water systems. |
| Appropriate Technology | We experimented with a few interventions before my group decided upon one that we felt was both reasonable and effective. One action we considered was to establish an early warning system in the event of a cyclone approaching...One of the reasons that cyclones, especially in the south, can have devastating impacts is that there is very little information being broadcast to the people...The people of the south also rely on radios as their main source of information and communication with the rest of the country; very few, if any, of the people can afford phones or televisions which makes accessing vital information, such as the severity and timing of incoming cyclones, extremely difficult. We had proposed establishing a radio station which could broadcast information to the farmers of the region, letting them know in advance of sustained droughts, cyclones, or other weather patterns. The glaring problems with this plan, however, were many. The budget that it would take to establish and run a radio station is far more than the allotted $50,000 that we were working with...There are already other radio stations in Madagascar as well, which |
would decrease the effectiveness of our intervention.

There are many possible solutions that we considered to address the problem of malnutrition, but we decided on growing a garden as our ultimate solution. Initially, we considered creating a food education program at a primary school to teach students about the importance of a well-balanced diet with nutritious, vitamin-packed foods. However, this solution addressed more of what could be done without actually doing anything physical. We could teach the students that they must eat fruits and vegetables but they would have no way of acquiring these foods. We also considered implementing agricultural technology to improve crop diversity, which would allow foods to grow in the high-elevation areas that originally would be unable to. However, it would have been difficult finding a specific technology that would work in the Peruvian climate at such high altitudes. We would also need to bring our supplies up the mountains, and there would be a large margin for error or malfunction. One last idea that we considered was building a ski lift-like system that could bring food up to the high elevations from lower elevations or villages. This system would be extremely expensive to build though, would not be sustainable, and would be very invasive to the Andean land.

Our design is to install a gutter system that would collect rain from the rooftops of houses...This was not our first idea, but it was the best. One of our other ideas was to drill wells but after we determined the groundwater was polluted it seemed like a useless effort and it was expensive. The well would require a drilling crew and a filter that wouldn’t cost less than about $100,000. This was too much and not a system that was sustainable...Another one of our ideas was to install a pump that would pump water to the city. Though this solution was cost effective it required too much upkeep to seem as a viable solution. The last thing we want is to leave an area worse off than when we got there.

Cultural Awareness

When we first arrive in Peru, I will meet with some Quechua families who live in high elevations close to Callarrayan to discuss the geographic and topographic impact on their lives. Some questions include: Is it difficult to access food markets? What does your diet consist of? Do you eat nutritious foods? Would you eat more nutritious foods if you had access to them? These questions will identify the problem of malnutrition and express their interest in consuming healthy foods.

The last step of the preliminary stage is learning about the culture and modifying our intervention based on the new information we obtain. Research on the culture in Madagascar has given us a good amount of information on the overall culture, but we won’t be sure all of this applies to Ambondro until we stay there for a bit. Truly understanding the culture and making sure that our proposed intervention does not significantly disrupt important Malagasy traditions or values is vital for the success of the operation.

The foods we plan to implement in the garden will combat the anemia, vitamin A deficiency, and malnutrition found in the students by diversifying their diet. Key nutrients to defend against these issues are iron and vitamin A. Vegetables that are rich in these nutrients that we are considering for the garden are leafy greens such as lettuce, spinach, chard, and cabbage; carrots; beets; and legumes, such as black-eyed beans and fava beans. To ensure that we will not be offending the culture of the people in any way with our food choices, we will first discuss potential crops with the people at the Kusi Kawsay school, then with the faculty and students and their families at the school in Callarrayan. The goal of our project is to provide a solution...
that will help the people, rather than offend them or their culture in any way. This is another reason we will be splitting our first month between Kusi Kawsay and the school at which we are constructing the garden. This way, we will develop relations to the faculty and students at the school, and get a better understanding of the ways they live.

**Ethical Awareness**

Ethically, we guided our decisions based on Immanuel Kant’s principles. He argues that humans are not a means to an end, including that every human has intrinsic value. As volunteers and researchers, we are there not just to build a garden and observe its impact on a school, but for the Quechua children. We want to teach them the importance of agriculture at a young age and introduce new foods into their diet which will give them more energy. However, despite the children benefitting, we will not be focusing on the Quechua adults who also struggle with malnutrition. Our solution will only benefit younger Quechua children who attend school. To avoid any negative consequences from our solution, we will only grow culturally appropriate food. We will also ensure that our solution is sustainable by teaching the staff and students how to properly and effectively run the garden after we leave. Lastly, we will avoid imposing our solution on the community and instead work together toward a final project that will achieve our and their goals.

When entering a foreign country, it is crucial to study how the people live in order to be the least invasive as possible. It is unethical to demand a group of people to do something that they will not accept...This idea aligns with John Stuart Mill’s consequentialism ethics because especially in projects involving other people, it is necessary to think about the consequence of our decisions and actions. When further considering about the impact of our project, it makes sense to focus on consequences because there have been projects in the past whose intents were to help people...Depending on the specifics of a project, failures can ruin people’s lives and if that were to happen, our project would most definitely be viewed as unethical.

We discussed many ethical considerations before deciding on a solution, as we wanted to ensure that our proposal would be realistic and noninvasive to the society living in Guayabo. In choosing a solution, we wanted to ensure that all citizens would be treated in an equal manner. This led us to realize that an educational based solution would not satisfy our goal, because in Lima women are often deprived of education. We focused on engineering a solution that would be accepted by the citizens and would not contradict any cultural practices or traditions. After extensively researching fog catchers, we realized that this was the ideal solution, not only because they have been installed in comparable towns, proving that they are accepted by the culture, but also because they have the ability to provide an abundance of clean water. We also prioritized finding a location where our solution would provide adequate water for all its inhabitants, which led us to choose Guayabo, a small town located near Lima.