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Great Problems Seminars: A New First-Year Foundation at WPI

Arthur Heinricher
Worcester Polytechnic Institute, heinrich@wpi.edu

Brian Savilonis
Worcester Polytechnic Institute, bjs@wpi.edu

David Spanagel
Worcester Polytechnic Institute, spanagel@wpi.edu

Robert Traver
Worcester Polytechnic Institute, rtraver@wpi.edu

Kristin Wobbe
Worcester Polytechnic Institute, kwobbe@wpi.edu

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**Arthur Heinricher[1], Brian Savilonis[2], David Spanagel[3],
Robert Traver[4], Kristin Wobbe[5]**

Abstract

The *Great Problems Seminars* are a new program designed to engage Worcester Polytechnic Institute's first-year students with current events, societal problems, and human needs. Each seminar starts with an important global problem and helps students to find a place where they can make real progress, no matter how small, in solving the problem.

Four WPI faculty representing Chemistry, Mechanical Engineering, and Humanities developed and delivered two Great Problems Seminars in 2007. *Feed the World* explored the chemical, ethical, physiological and economic dimensions of a (simple) question: Why do we eat what we eat? The students completed projects on subjects ranging from hunger in Worcester to controlling fertilizer runoff. *Power the World* focused on the physics, history, and the environmental and economic impact of energy technologies. The students completed projects ranging from an energy cost analysis of green roofs and photovoltaic systems for WPI to air pollution in China.

This paper will describe the final student projects as well as the smaller projects and activities designed to help students develop the intellectual skills needed for research and professional work, including clear, succinct writing, oral presentation, pair and small group discussion, and the ability to take and understand multiple-perspectives. Perhaps the most important "finding" is that first-year students can do much more than we (or they) expect.

I. Introduction

A group of four first-year students were working on their poster for project presentation day in December, 2007. Their RA, a junior, stopped by to look at what they were doing and said

"*Hold on. You're not supposed to be able to do that yet.*"

The RA remembered his first-year classes and this group of first-year students was doing something that certainly had not been part of his first-year experience. The first-year students were enrolled in the *Great Problems Seminars* at Worcester Polytechnic Institute.

The Great Problems Seminars are new first-year offerings defined by problems not disciplines. They do not start with a list of topics to cover. They are interdisciplinary, not multidisciplinary. They are not designed to provide a survey of fundamental engineering concepts or an overview of how science and engineering disciplines could address real problems. They start with great problems and the students learn that there is no single solution, that no one discipline could

[1] Associate Dean for First-year Programs, heinrich@wpi.edu
[2] Mechanical Engineering Department, bjs@wpi.edu
[3] Humanities and Arts Department, spanagel@wpi.edu
[4] Massachusetts Academy of Math and Science at WPI, rtraver@wpi.edu
[5] Chemistry and Biochemistry Department, WPI, kwobbe@wpi.edu

provide a solution, and that great problems will be solved only through the efforts of many small solutions coming from many disparate directions.

There is a national trend toward more active, project-based learning in engineering education that has been (slowly) gaining momentum for more than 40 years. (See Felder, 2004.) A recent, and widely publicized, illustration of the trend was the creation in 1997 of the Olin College of Engineering. The Olin Foundation made a $300 million investment to establish a new college of engineering that would integrate project work in all four years of the new curriculum. (Somerville, *et al*, 2005).

For almost 20 years, there has been significant investment by the National Science Foundation intended to increase student interest and retention in science and engineering studies. An example is the Foundation Coalition based at Texas A&M University, where one focus is on *curriculum integration*: help students link ideas across disciplines. Many schools have developed courses which focus specifically on engineering fundamentals in the first year and continue to look for elements that improve these courses (Hagenberger, *et al*, 2006).

A new program at Wright State University in Engineering Mathematics challenges first-year students to work with mathematical models that they will meet in more advanced engineering courses *before* they study all of the mathematics behind the models (Klingbeil, *et al*, 2005), The WSU course starts with the engineering applications and uses these to motivate the mathematics. This approach is similar, in a very important sense, to the approach taken in the Great Problems Seminars at WPI: the students are challenged to dig into a problem before they have all of the usual background.

It is important to note that a focus on the importance of the first year is not limited to engineering education. The Center for the First-Year Experience and Students in Transition recently organized its 20th international conference on the first year. Many colleges have developed new first-year programs designed to smooth the transition from high school to college. Some focus on study skills and transition issues, others use learning communities to build a network of social support for the academic mission, and others build first-year seminars connecting students with faculty research interests. (See Upcraft, *et al*, 2006.)

WPI made project-based learning the core of its academic program in the early 1970's when it defined graduation requirements that included two major projects (Grogan, 1988). One is in the major and is usually completed in the senior year. The second project is usually completed in the junior year and challenges students to work on a problem at the interface of science, technology, and societal needs.

Today, about half of WPI's students (about 400 students each year) complete their junior-year project at one of 23 project centers around the world. For example, a team of three students (one chemical engineer, one civil engineer and one biomedical engineer) recently lived and worked in Windhoek, Namibia for seven weeks and developed a plan for erosion and flood control in the informal settlements there. (See Vaz, 2000 and the WPI Global Perspectives web site.) This kind of project work has not been available to first-year students. Perhaps just as important, traditional courses in the first year have not always prepared students for project work in the junior and senior years.

When do students have enough background to start working on something interesting and important? Tryggvason and Apelian (2006) have argued that the engineer of the 21st century "knows everything" in the very real sense that advances in information technology have made all

information available to everyone everywhere with almost infinite speed and ease. First year students have access to the same information and are ready to begin work on important problems. The shift from delivering content to challenging students to work on real problems, where they will have to find the knowledge that they need when they need it, is an important part of the Great Problems Seminars.

II. Building the Great Problems Seminars

The faculty who developed the seminars focused on three key principles. They decided that the seminars must

- engage first-year students with current events, societal problems, and human needs;
- require critical thinking, information literacy, and evidence-based writing;
- develop effective teamwork, time management, organization, and personal responsibility.

The first point, the focus on engagement as the primary goal for the Great Problems Seminars, is the key. The courses were defined by the problems, not the disciplines. The plan was to get students involved in project work during their first semester of their first year and trick them into becoming more proficient at writing, thinking, presenting while they are distracted by a topic that fully engages their interest.

Feed the World: This Great Problems Seminar started with questions related to hunger. They began with readings and writing assignments studying both the biochemistry and the physiology of nutrition and hunger. The students studied the science of nitrogen fixation and the policy and economics of food production and delivery. Projects and assignments asked how science informs policy decisions and how policy decisions guide scientific research.

The faculty developing *Feed the World* built a sequence of readings, writing assignments, mini-projects, and "adventure assignments" tied to food. The readings included fairly technical articles on nutrition and agriculture (*The World Food Problem*, articles from Scientific American) as well as recent popular writing (Michael Pollan's *The Omnivore's Dilemma* and Barbara Kingsolver's *Animal, Vegetable, Miracle*). In one small project, students were given a budget of $80 and assigned to visit one of the local ethnic markets. There job was to feed a family of four for the week and analyze the nutritional content of their proposed menu. In another small project, the students spent two full days collecting (and weighing) all of the food wasted in one of WPI's main dining halls. They then wrote letters to different offices on campus with recommendations for reducing waste.

Power the World: This Great Problems Seminar started with questions about energy. Early assignments developed the thermodynamics of power production as well as the history of energy technologies. Readings and assignments focused on the physics of new (future) energy sources and the economics and environmental and social costs of these possibilities. Students learned how engineering informs policy decisions and how social and political constraints guide engineering solutions.

The readings for Power the World included a basic physics text (Aubrecht, 2005) and a scholarly (but very readable) survey of the history of energy technologies and how they have changed human culture and the world (Crosby (2006)). The author, Alfred W. Crosby, presented an opening lecture and met the following day with small groups of students for open discussions. The students visited a local co-generation plant and attended a panel discussion by professional

experts in alternative and traditional energy production. To help with group dynamics, a Professor from the Management Department gave a workshop on teamwork.

Some Details: The Schedule and the Students

In a first-year class of about 800 students, more than 100 chose to enroll in the Great Problems Seminars. The Seminars extended over the first two terms (14 weeks in total) and were equal to two full courses. Students in the first offering received elective credit in science (chemistry for Feed the World and physics for Power the World) and humanities.

Power the World:

- 63 students.
- One large lecture (2 hours) and two small group meetings each week.
- The goal at the end of the first 7-week term was a project proposal.
- The focus of the second 7-week term was project work. The students still met once a week in the large group. The other meetings were reserved for project team meetings with the faculty advisors.

Feed the World:

- 38 students.
- One large group meeting (2.67 hours) and one small group meeting each week.
- Sequence of "small" team projects through both terms.
- Large team project at the end of the second term.

Each of the great problems attracted a different population of students. For example, there was a (statistically significant) difference in the gender distribution for the two seminars. Feed the World had about 45% female and 55% male enrollment (drawn from a first-year class that was about 26% female) while Power the World enrolled about 24% female and 76% male students.

	Feed the World	***Power the World***	***First Year Class***
Male	55%	76%	74%
Female	45%	24%	26%

Table 1: Student gender in Great Problems Seminars

The students enrolled in the seminars represented 21 different majors. For Power the World, about 40% could be categorized as "traditional engineering" (Aerospace Engineering, Chemical Engineering, Civil Engineering, Electrical and Computer Engineering, Mechanical Engineering). For Feed the World, only about 13% came from these majors. On the other hand, about 40% of the students in Feed the World had declared a major in the Life Sciences (Biology, Biomedical Engineering, and Chemistry) while only about 3% of the Power the World students had declared one of these majors.

The largest number for a single major in the Feed the World seminar was Biology. The largest number for a single major in the Power the World seminar was Engineering-Undecided.

	Feed the World	*Power the World*	*First Year Class*
Engineering	13%	40%	36%
Life Science	40%	3%	17%
Other	21%	28%	30%
Undecided	26%	29%	17%

Table 2: Student majors in Great Problems Seminars

Some of the difference in majors can be explained by scheduling. Feed the World was scheduled to avoid conflicts with introductory chemistry and biology courses. Power the World was scheduled to avoid conflicts with the introductory physics courses. (This did not work completely. Many students interested in Feed the World could not enroll because it conflicted with the only available section of Calculus for Business and Life Sciences. Many students interested in Power the World were not able to enroll in the seminar because it conflicted with the only introductory Physics lecture with available seats.)

III. The Final Projects

Each project team had three to five members and was guided by one faculty member. Each team completed a written report on their work and made an oral presentation to their advisors and fellow students. In addition, students for Feed the World were required to produce "promotional materials" designed to sell their solution to a defined target group.

The main event for the Great Problems Seminars was the Project Presentation Day. This was a two-hour poster session held in the Campus Center and advertised to the entire WPI community. Eighteen faculty, staff, and students served as project reviewers, interviewing the student teams and filling out written evaluation forms. More than 200 faculty, staff and students attended the poster session and most teams were busy discussing their project with a visitor or reviewer for the full two hours.

Projects for Feed the World
All projects were advised by Professors Kristin Wobbe and Robert Traver. The students chose their projects. In some cases, the project grew out of work done earlier in the course; the students spent the day on one of Heifer International's farms and what they learned there led them to a project connecting the work of the organization with WPI's project center in Namibia.

Project #1: *Corn with Less*
This group had not worked together before initiating this project, but proved once again, to themselves and us, that the whole can be greater than the sum of its parts. They ended up with a great mix of artistic talent (poster development), organization, skepticism, writing ability and social glue. They started with the knowledge that fertilizer runoff is a major problem for many waterways worldwide, and were looking for ways to reduce the amounts of fertilizer required, particularly for corn which is a very fertilizer intensive crop. As they researched the topic, they discovered a patent for capturing runoff water and recycling both the water and the dissolved fertilizer, essentially a solution to the original problem and to a water use problem. Their project then became about promoting that system to farmers and devising ways to reduce the initial cost for the system.

Project #2: *Preventing Elderly Malnutrition in Worcester: Expanding the Meals on Wheels Program*

Elderly malnutrition is a greater problem in the U.S. than the growing obesity epidemic, but much less well publicized. The group struggled for a bit, trying to find an effective potential solution to the problem. With some advice, they began calling organizations that worked with the elderly to see what suggestions might be provided by those in the trenches. This digging resulted in the final project idea. In spite of the forgivable diplomatic error in defining people in the 50—60 age group as "elderly," this group did a good, practical analysis of the costs and benefits of expanding an existing, successful program to a new area of need.

Project #3: *Heifer in Namibia*
This project grew out of the students' excitement and engagement. These students had not heard of Heifer International until this course; the day spent at the Heifer farm seemed to galvanize their interest. They saw an opportunity to connect WPI's existing Global Perspectives Program and its Project Center in Namibia with Heifer International. They discovered that vitamin A deficiencies reduce the effectiveness of AIDS treatments; thus poor nutrition can be a double hazard. Providing animals that can increase income and nutritional status has a very broad positive effect on the area. They are likely to have raised the $10,000 necessary to start a Heifer site in Namibia before they are eligible to go for their junior year project.

Project #4: *Food Security in the Inner City*
This was a group of very bright, hard working students who worried about food issues in the inner city. They struggled with but were not overwhelmed by the incredible complexity of this problem. The most impressive part of their final report was their clear, organized analysis of the components of the problem and how interconnected the different components are. They still tried to give "the answer" at the end of the report and did not appreciate the value of the work they had done to just understand the complex structure of the problem.

Additional Projects for Feed the World:

Project #5: *Obesity: A GROWING Concern*
Project #6: *Aspartame: Not Always a Healthy Alternative to Sugar*
Project #7: *Fish Stock Depletion: Mainland Tanzania*
Project #8: *Keeping Kids Healthy: The Harmful Effects of Food Additives*
Project #9: *Method for Preserving Fishery Yield in Chesapeake Bay*
Project #10: *Hyperactivity from Food Additives?*
Project #11: *Saving Thanksgiving*

Projects for Power the World
In Power the World, students worked on project proposals during the final week and a half of the first term (week 5 of the fall semester). The students presented their project ideas in a small discussion section meeting, with everyone's ideas listed on the blackboard in brainstorm fashion. The goal was to help students build teams with compatible interests.

Most of the second seven weeks of the semester was devoted to project team meetings. Students gave formal oral presentations during the last two weeks of the semester. They also produced a poster and presented their work on Project Presentation Day. All projects were advised by Brian Savilonis, David Spanagel, James Demetry (Electrical and Computer Engineering Professor), and Svetlana Nikitina (Humanities Professor).

Project #1*: Green Homes*
One group of four students came to that brainstorming/recruiting session prepared to be a team with a relatively well-formulated project idea. This group calculated payback periods for the various construction and refurbishing options that are currently available to Massachusetts

homeowners. Their original proposal in late September had been to research and write about how "green" building standards have been developed and implemented. Gentle guidance and consistent challenges to do serious work led to a remarkably robust and useful final product.

***Project #2**: The Cost of Green Roofs versus Conventional Roofs*
This was the first of two "green roof groups." This group focused on four urban environments around the U.S. They were disconcerted by the direct economic payoff periods of the "technology" but they rightfully praised the indirect benefits of green urban spaces with reduction of heat islands and improved stormwater drainage. This group was actually patched together from two first-term groups; it had little leadership and faltered but, with prodding, produced some very concrete findings.

***Project #3:** Energy Cost Analysis of a Green Roof and Photovoltaics System for the WPI Sports and Recreation Center*
This was the second of two "green roof group completed a cost-benefit analysis of two technologies: green roof and/or photovoltaic system for the proposed WPI Sports and Recreation Center. This group was partially formed in the first term but added a student to complete the project. The added student was perhaps the best technically skilled student in the class and he migrated to this group because he felt that they were taking their work seriously.

This group worked 10-15 hours per week per person outside of class on a regular basis. In the last two weeks, they reported working over 20 hours per week to meet deadlines. They chose a rather concrete problem, but the Center is still in the early design phase so they needed to make many assumptions about construction. They used many Web-based design tools (heat loss/gain) and gave much thought to pursuing grants or tax credits (as if WPI were not non-profit). They presented a white paper to WPI's Vice-President for Facilities Management to see what could/would actually be considered by WPI. This project was very close in scope and analysis to a junior level project. The students lacked some technical skills (had never thought about heat loss or cost-benefit analysis) but they progressed well on a need-to know basis.

***Project #4**: Air Pollution in China: Is the United States Responsible?*
This project explored a difficult social aspect of energy policy. The students took the U.S. to task, arguing that by outsourcing manufacturing, the U.S. has shifted some of its local environmental concerns to a foreign country. By demanding cheap goods, we as consumers are complicit with China in furthering global warming, mercury emissions, etc. The students were quick to see the global issues at hand – That air quality does not have boundaries. They went beyond global warming and looked at the migration of pollutants to other countries as well as the West Coast of the U.S. from China. They offered sparse solutions, but the international environmental issues and global connections of the economy were openly explored. This project dealt with atmospheric chemistry, quantities of emissions and energy usage and fuels consumed, along with both local and global medical impacts (from drinking water to fish contamination to warming). It was very ambitious but managed to stay on track. The link to the U.S. gave it some grounding, helping to focus both the analysis and discussion.

***Project #5:** Power the World: Global Fusion Initiative*
This group of students did not produce a great project, but their experience was perhaps the most illustrative of what the Great Problems Seminars were intended to achieve. The four students were only weakly connected by an interest in the most visionary (impractical), long-term approaches to energy generation. One wished to study "Dyson spheres" (Dyson, 1960), another was an aficionado of Nicola Tesla's dream of wireless power transmission, and a third simply

wanted to know why controlled nuclear fusion is always projected to be "50 years away," no matter when the prediction is made. The group was able to focus their attention (eventually) on a single body of technical research having to do with the International Thermonuclear Experimental Reactor (ITER). With some patient coaching (which was necessarily intermittent, since none of the weekly progress meetings included all four team members) the team managed to produce a project report, poster, and oral presentation promoting the idea of an "X-prize" style global competition to build a practical and sustainable nuclear fusion reactor.

The team's advisor was convinced that these four students had a high probability of leaving WPI within their first year because they had such trouble negotiating the disciplinary demands of regular coursework. All four are exceedingly bright (= intelligent) and yet intensely individualistic in their outlook; students you could picture becoming brilliant, unorthodox inventors. Through the Great Problems Seminar, they each began to learn how to work with fellow students in a responsible and fruitful way. We were able to create a first-year experience sufficiently different from traditional classes to capture their interest and engage them in their education.

Additional Projects for Power the World:

Project #6: *Bio-Fuels, How do you get turned on?*
Project #7: *U.S. Ethanol Policy*
Project #8: *Hydrogen Cars*
Project #9: *Wind Template and Bylaw*
Project #10: *U.S. Tidal Power*
Project #11: *Combating Misconceptions about Nuclear Power*
Project #12: *Solar Desalination: A Comparative Analysis*
Project #13: *Feasibility Study of Photovoltaic Systems at WPI*

IV. Discussion

Engagement was the goal and engagement, especially in the final project work, was achieved for the majority of the students. In almost every case, the first-year students completed work well beyond what faculty had believed possible.

Assessment has included pre-surveys for the entire first-year class focusing on attitudes and expectations connected to project work. An external consultant has interviewed focus groups as well as the faculty. Post-surveys will be administered near the end of the academic year, once again to the entire first-year class. The most important component of assessment will study the long-term impact of the seminars; do the students from the Great Problems Seminars have a better project experience in their junior and senior years?

Early observations from interviews include:

- Project work, especially the chance to choose a project that they really care about, is the most valuable (and enjoyable) aspect of the student experience;
- Lack of traditional structure, especially in the early weeks of the program, is challenging (and frustrating) for students;
- The seminars are more work than traditional courses. Some student in Feed the World said that it was more work than their other courses combined. (The same students also reported spending 9-12 hours per week on the seminar, which is *less time* than WPI faculty recommend for any single course.)

Faculty in Power the World identified developing an awareness and appreciation for complexity as one of the most important and challenging components of the project experience. It is more difficult to learn how to ask a *fruitful question* than it is to find the answers well-defined problems.

The faculty who presented the Great Problems Seminars in 2007 will be offering the same problems again in 2008. There will be changes in the structure and assignments derived from lessons learned this year. The most important changes will be in ways that we involve the students and projects from 2007 in next year's program. We will be able to give students examples of what is possible, defined by work done by this year's students.

Faculty at WPI plan to offer two additional Great Problems Seminars in 2008. One new seminar will focus on the biology epidemics and the management of healthcare policies; how does disease spread and how can it be controlled? The other new seminar will focus on material science and the ways that new materials are making sustainable development possible.

For Feed the World, some students complained that they were disappointed because they thought that the course was going to teach them how to really Feed the World. They expected to learn the answer to the great problems. They did not expect to be told that it was *their* responsibility to build the solutions.

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