AC 2008-1707: EVOLUTION OF AN INTERDISCIPLINARY SOPHOMORE DESIGN COURSE AT THE UNIVERSITY OF HARTFORD

David Pines, University of Hartford

David Pines is an Associate Professor and Chair of the Civil, Environmental, and Biomedical Engineering Department at the University of Hartford. He completed his Ph.D. studies in the Department of Civil and Environmental Engineering at the University of Massachusetts, Amherst in 2000. He is actively involved with student community projects sponsored by environmental engineering firms, municipalities, and water utilities, and international projects as faculty advisor of the students EWB chapter.

Hisham Alnajjar, University of Hartford

Dr. Hisham Alnajjar is an Associate Professor of Electrical and Computer Engineering at the University of Hartford, Connecticut (USA), where he is also the Associate Dean of the College of Engineering, Technology, and Architecture (CETA). Ph.D. from Vanderbilt University, M.S. from Ohio University. His research interests include sensor array processing, digital signal processing,and power systems.

Evolution of an Interdisciplinary Sophomore Design Course at the University of Hartford

Abstract

The University of Hartford engineering curriculum went through a major curriculum change in 2001 that included adding an interdisciplinary sophomore and junior design course to the existing freshman and senior design capstone courses. The new courses were added as part of a NSF grant entitled "Integrating Engineering Design with the Humanities, Social Sciences, Sciences and Mathematics." The interdisciplinary sophomore design course has undergone several iterations since its inception. Initially, the sophomore course paralleled our senior capstone design course with each project team of 3 to 6 students working on industrial sponsored project with a practicing engineer as the technical mentor. This approach has worked extremely well for our senor design course because of the effort put forth by the faculty to solicit projects and our dedicated engineering mentors who volunteer their time. However, it became overly time consuming for faculty to duplicate this effort for sophomore student teams where it was more difficult to find technically appropriate design projects for students who have taken only one or two engineering courses. Also, the time constraints of a 3-credit course made it difficult to include a hands-on component to a semester long industrially sponsored project where the course curriculum already included lectures on problem solving skills and design concepts.

Faculty assessment of the course has led to several changes to how the design project was integrated into the class. The progression of design projects has included an industrially sponsored project for the entire section of 20 students where students were divided into smaller groups to work on different project tasks or the smaller groups developed alternative designs for solving the same problem; reverse engineering of common consumer products; and instructor developed "paper" design projects. We have now adopted an approach where students work on a project related to the instructor's design interests, which also supports the core applied research areas of the college. The projects have a hands-on component and uses "just in time learning" teaching method to provide the students the technical background needed for their designs. Another change was to provide students with a description of each of the projects so that they can select the project that best meets their engineering interest. To date, all students have been given either their first or second choice.

Introduction

The University of Hartford has a relatively small engineering program that offers ABET accredited degrees in civil engineering (students can select an environmental concentration), mechanical engineering, electrical engineering, computer engineering, and biomedical engineering. The college also has a very strong program in acoustical engineering where students can earn both an engineering degree and a music degree from the University of Hartford's Hartt School. This is a unique program which attracts students from around the country while most of the other engineering students come from the Mid Atlantic and New England region.

In 1998, the awarding of an NSF Grant entitled "Integrating Engineering Design with the Humanities, Social Sciences, Sciences, and Mathematics" was the initiative for a major revision of the curriculum of all of the engineering programs[1,2]. The emphasis of this grant was to integrate design throughout the curriculum. This was accomplished by (i) Redesign of the freshman engineering course by incorporating Integrative Learning Blocks by involvement of faculty from engineering, mathematics, physics, humanities and social sciences; (ii) Creation of a new engineering sophomore design course that is integrated with a course on Ethics in the Profession; (iii) Creation of a new junior year design course integrated with courses in biomedical, civil, computer, electrical, and mechanical engineering; and (iv) Partnership with industry in the creation of real-life engineering projects for senior capstone design course.

This paper presents how the sophomore design course has evolved and the changes that were brought about based on faculty and informal student feedback.

Design Throughout the Engineering Curriculum

Consistent with most engineering programs, the curriculum at the University of Hartford includes a freshman engineering and senior capstone design course. Because of the relatively small size of the engineering program with about 100 incoming freshman students, a common freshman engineering course (*Engineering and Design*) is taken by all engineering students instead of program specific courses. The primary course outcomes are to understand the engineering process, apply design methodology to solve an engineering problem on a group basis, and to communicate technical information in written, graphical, and oral form. This last outcome is a shared outcome with their writing course (Rhetoric, Language and Culture) where the same 20 freshman engineering students take both courses concurrently. Furthermore, creativity and team work is stressed to energize the students about their decision to go into the engineering profession.

All of the engineering programs have either a one-semester or two-semester senior design project where a team of two to four students work on an industry, institutional, or government sponsored design project under the guidance of a practicing engineer or they develop their own design project with a faculty member as their technical mentor. Having each team of students working on a unique project has been very successful and feedback from both practicing engineer mentors and students has shown that this approach is an excellent way for students to transition between their academic and professional careers.

To bridge the gap between the freshman and senior design courses, sophomore and junior year design courses were added to all of the engineering program curriculums. The junior year design course, *Engineering Practice*, is a one-credit course that introduces engineering students to factors such as impact on society, political concerns, and cultural concerns that affect their designs. The course is structured around a large overarching engineering project that involve all engineering disciplines. The students are assigned to multidisciplinary teams of 4-6 students to perform a semester long design project. The course is taught concurrently with a discipline specific, design-oriented junior level course offered by Acoustic, Biomedical, Civil, Computer, Electrical, and Mechanical Engineering programs[2].

The inclusion of how the design courses in each of the engineering programs can be found at http://uhaweb.hartford.edu/ceta/pgminfo/pgminfo.html.

Sophomore Design Course

The sophomore design course is entitled "*Engineering by Design*." The course provides an in-depth study of the design process that includes problem solving methodologies, evaluation of alternate solutions, economic analysis, ethical constraints, group dynamics, and presentation techniques. Each section of the course has about 15 students who undertake design projects that meet these objectives with formal written report and oral presentation required at the end of the semester. Also, the course consists of common lectures where topics such as quality function deployment, statistical process control, failure mode and effects analysis, fault tree analysis, total quality management, commercialization, legal-intellectual property, and project management are covered.

Both the freshman and sophomore design courses use the same textbook to demonstrate to the students the connection between the two design courses. The textbook is Creative Problem Solving and Engineering Design by Lumsdaine, Lumsdaine, and Shelnutt[4]. The first two parts of the book are covered in the freshman design course (Part 1 - Foundational Skills and Mental Models; and Part 2 - The Creative Problem Solving Process). In the sophomore design course, the creative problem solving techniques are then applied to the engineering design process. This is part 3 of the textbook entitled "Application in Engineering Design."

The course is also linked to a sociology course, Ethics in Professions, as part of an integrated learning block. The goal of an integrated learning block is for two courses to share some of the same topics, but approach the material from different perspectives. In this case, the students are assessing the ethical considerations in the context of their specific design project, while studying related topics in the Ethics and Professions course[3].

The following sections discuss how the course projects have evolved from industrial sponsored projects similar to the senior capstone design course to projects that emphasize reverse engineering product design to design projects that support the core applied research mission of the college.

Industrial Sponsored Design Courses

Initially, the sophomore course paralleled our senior capstone design course with each project team of 3 to 6 students working on industrial sponsored project with a practicing engineering as the technical mentor. Examples of the sophomore design projects were Detection of Mercury Emissions from Coal Fired Power Plants, Design of a Generic Monitoring Testing System for Elevators, and Design of Space Shuttle Orbiter Replacement Vehicle. This approach has worked extremely well for our senor design course because of the effort put forth by the faculty to solicit appropriate projects and the involvement of our volunteer technical mentors, and it appeared to also be successful for the sophomore design course as indicated in Table 1 by the student responses to a student survey that was developed by a faculty member from the Business School at our university. In the survey, students were asked to respond to each question by selecting "1" for Strongly Disagree, “2” for Disagree Somewhat, “3” for Neither Agree or Disagree, “4” for Agree Somewhat, and “5” for Agree based on their experience during the semester.

Table 1. Summary of Student Survey Results of Industrial Sponsored Design Projects

Relative Strengths (>4.0)	Relative Weaknesses (3.5 to 4.0)	Most Valuable Aspects from Student Comments
• I feel comfortable using the skills I have learned in engineering to solve problems • I feel comfortable working as a member of a team to solve engineering problems • I have a greater understanding of the ethical issues relating to engineering problems and problem solving in society • I have developed the skills to prepare a written report describing my engineering problem solution • I have developed the skills to prepare and deliver an oral presentation describing my engineering problem solutions • I enjoyed the experience of working on a “real-world” problem this semester • By working on a “real-world” problem, I learned things about the field of engineering and engineering problem solving that I could not have learned from classroom study alone	• I feel comfortable worked as the leader of a team to solve engineering problems • I feel comfortable using computer presentation hardware and software to help me prepare oral and written reports of my engineering problem solutions • The opportunity to work on a “real-world” problem increased by understanding of the field of engineering and engineering problem solving • The opportunity to work with a professional mentor increased my understanding of the field of engineering and engineering problem solving • By working with a professional mentor, I learned things about the field of engineering and engineering problem solving that I could not have learned from classroom study alone	• Interaction with mentor • Gained experience in leadership and delegation • Learned about the process of a project • Having a deadline; time management • Working with the finite element program Marc • Learning the non-design aspects of engineering • Reports and presentations (mentioned by several groups) • Seeing how engineers work in the field (mentioned by several) • Working with real world problems • Spreading out the work over a semester • Experience with team work

However, as faculty examined the achievements and started to prepare for the next offering, it was apparent that these types of projects were not sustainable for several reasons. First, it was hard to find projects that match the students' ability and training. Second, it is difficult to recruit faculty to supervise a semester long project that might not be in their area of expertise or interest. Finally, the Outreach Committee which was comprised of practicing design engineers and faculty members concluded that the top-level design approach was not appropriate for sophomore level students. As can be seen from the tile of the projects, they were conceptual design projects with limited or no detail design required. This conclusion was also supported by the students not feeling that the project had given them a better understanding of engineering.

The recommendation from the Outreach Committee was to move to a different type of project. The committee suggested that Reverse Engineering Product Design is a more suitable approach for a sophomore level interdisciplinary design course. Furthermore, the integration of this course with the Ethics in the Profession course did not work as expected. The link between the courses was very passive rather than an active integration that had been expected. Therefore, we had to re-tool our effort and introduce ethics in the profession in the weekly common lecture.

Reverse Engineering Product Design Project

The OC continued to be involved in the direction of the sophomore course by helping to selected the reverse engineering product design projects. Some of the projects were the re-design of a space heater, re-design of a toaster oven, and evaluation and re-design of the HVAC system in the engineering building. A hands-on requirement was added in addition to the emphases on the importance of each team implementing their final design and critically evaluating its performance.

The primary challenge that arose was keeping both faculty and students interested and enthusiastic about these projects that did not inspire them to be very creative. Student feedback did show that the hands-on requirement of having to build their final design was successful in demonstrating the importance of design details in gong from a paper design into manufacturing of a prototype product. Faculty participation also became a problem because the course projects were not related to faculty interest or research.

Design Project that Supports Core Applied Research Emphasis of the College

The latest change to the sophomore design course is to have projects that have greater appeal to the students. To get more faculty members excited about teaching the course, the projects are related to the instructor's design interests. Furthermore, the projects should focus on applied research areas that support the mission of the college. In making the transition from a project that emphasized reverse engineering product design, it was important not to lose the hands-on aspect of the project. It was also recognized that most of the projects will require a "just in time learning" component so that students have the technical background for developing their designs. The "just in time learning" approach was considered a "positive" since it will provide students an opportunity to actively experience the application of the material that they will learn in greater detail in their upper level technical courses. Furthermore, it is hoped that this will provide a more motivated student in the upper level courses.

Except for an evening section of the sophomore design course for part-time students, the four day sections are offered at the same time on Friday morning and do not conflict with any of the other required courses. In this way, the students can select the project that best meets their interests. Prior to the spring semester, students are given a description of the projects that will be offered. The students are then requested to return the survey form listing their project preferences from most desirable to least desirable. By having a broad range of "interesting" projects, most students have received their top with the remainder getting their second choice. There have not been any problems with one project being perceived by the students as being considerably better than the others. The projects for spring 2007 are listed below and descriptions of the projects are in the Appendix.

- Engineers Without Borders (EWB)[5] – Development Of A Dependable Water Supply For Abheypur, India
- Design and Performance of Solar Cells
- Development of A System to Automatically Detect and Stop an Apnea Event
- Design Acoustical Treatments for the Great Hall at the Hartford Train Station

For spring 2008, the project themes have remained the same (Design for Developing Communities – An EWB Project, Clean Energy, Health, and Acoustics). However, the projects have evolved to match either the instructor's design interests, the needs of the sponsor, or the requirements of the community the project is supporting. The projects for spring 2008 are listed below and descriptions of the projects are in the Appendix.

- Engineers Without Borders (EWB) – Development Of A Dependable Water Supply For Abheypur, India (Follow-on project based on assessment made during implementation trip in January 2008)
- Solar Heating
- Digital Health – Wireless Sensor Diagnostics
- Design Acoustical Treatments For The Hartford Seminary

Analysis of Student Interest

For the spring 2007 semester, 42 of the 53 full-time students (79%) submitted the survey form by the due date. For those students who did not fill out the form, they were assigned projects to even out the number of students working on each project and to provide a breadth of majors working on each project. The results of the students' top selection are shown in Figure 1. Because of the low number of students in many of the majors that submitted the survey, the level of interest in each project may vary significantly from year to year. Also, the relatively high percentage of students interested in a focused field such as acoustical engineering may not make these results representative of other engineering programs. However, the results do provide some preliminary insight into the level of interest for these types of projects by our students.

The most popular project was the design of acoustical treatments for the Hartford train station with about 40% of the students selecting this project. This project was selected by all the acoustic & music majors and all but one of the mechanical engineer majors with acoustics concentration. Because many of these students are very motivated to learn about a relatively focused area of engineering compared to the much broader majors such as civil, mechanical, and electrical engineering, it is not unexpected that they would want to get involved in an acoustics project during their sophomore year. As for civil engineering students, the acoustics project was likely very attractive because of its architectural aspect.

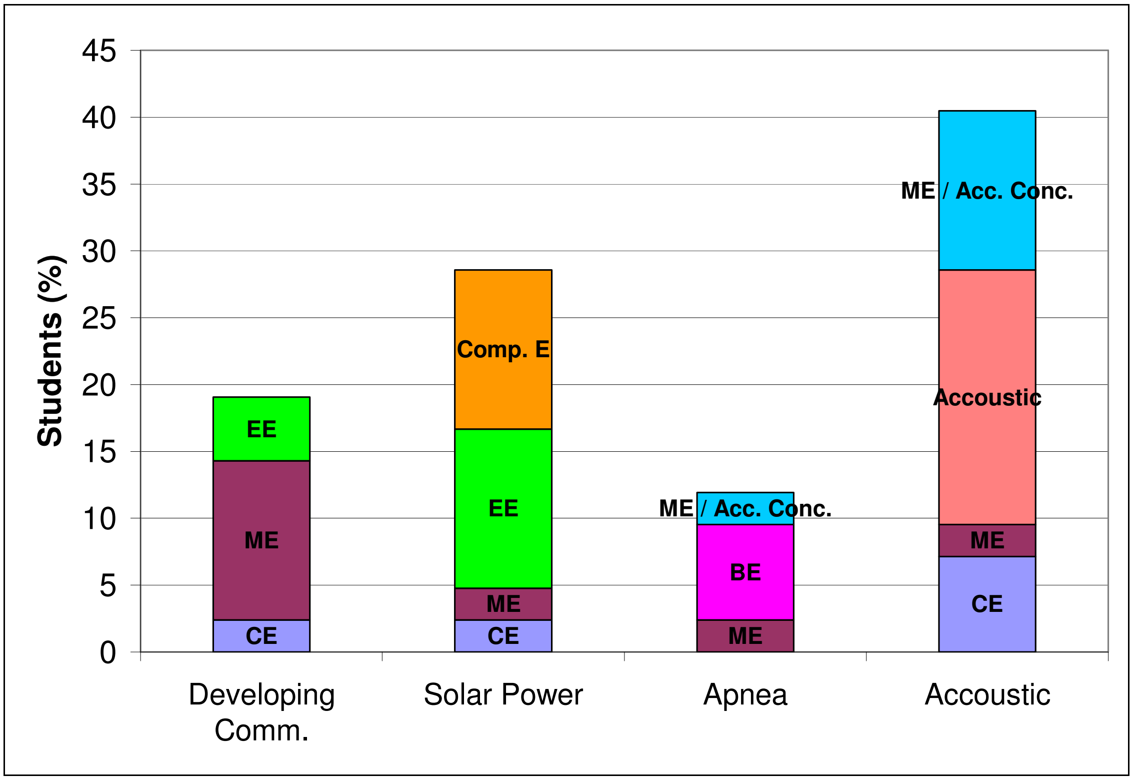

Figure 1. Sophomore Student Interest in Design Projects – Spring 2007

In spring 2008, 50 out 59 full-time students (85%) submitted the survey form by the due date. The distribution of the student's first choice by major is shown in Figure 2. As in the previous year, the acoustics project was the most popular project with all of the Acoustic and Music students and Mechanical Engineering with Acoustics Concentration students selecting this project. Also, there was interest from the computer and electrical engineering students because some of these students are also enrolled in the audio engineering technology program. There was a more even distribution of students between the Design for Developing Communities and Solar Heat project than the previous year. However, it was primarily civil engineering students interested in the more civil engineering oriented Design for Developing Communities project and mechanical engineering students interested in the Solar Heat project. This provides an interesting situation where it appears that the students have selected the project that is most aligned with their engineering program, but that the split of the students too much along engineering program lines reduces the interdisciplinary nature that the course is trying to achieve. The impact on student performance and project outcomes needs to be assessed to determine if this needs to be corrected. Except for the acoustics project, we currently have used the students who did not submit a survey form as a way to provide interdisciplinary mix to the projects.

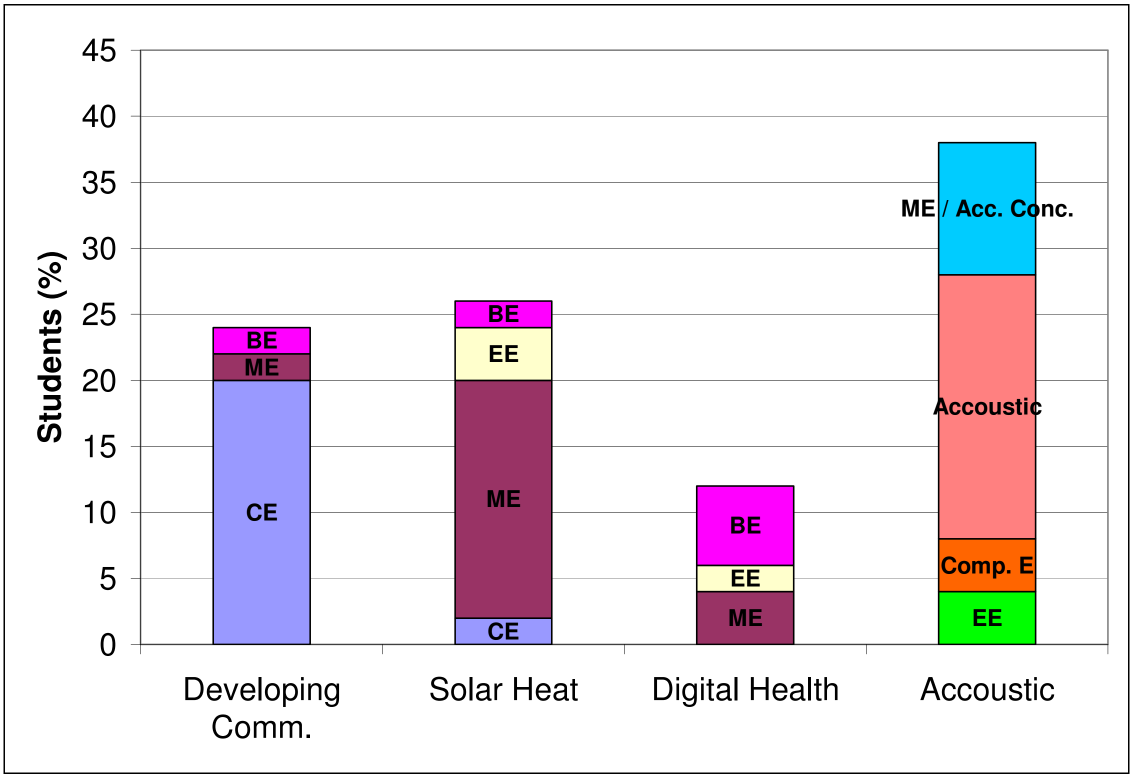

Figure 2. Sophomore Student Interest in Design Projects – Spring 2008

Assessment of Sophomore Course and Design Sequence

In the past, we have relied on faculty assessment of the sophomore design course, student surveys, and student anecdotal evidence for making changes to the course content. As we move forward with our assessment plan, an increase emphasis will be placed on how the sequence of design courses meet each of the programs expected outcomes related to student mastery of design. In addition to continuing the instructor's self assessment of the sophomore design course, we will be surveying the capstone senior design project technical mentors on the students' preparation on applying the design methodology at the beginning of their capstone project. (Technical mentors are either practicing engineers or faculty members depending upon the engineering program.) This feedback will then be incorporated into the continuous improvement of the sophomore design course and its role in the entire freshman through senior design sequence. In situations where individual students are deficient in applying the design methodology, the technical mentor and/or instruct will supplement their capstone design project with appropriate instructional materials.

To accomplish the above task of assessment across the design sequence, instructors of the design sequence courses (freshmen through senior design) are working on the development of a rubric to measure and document the progress and achievements of the expectations across the entire design sequence. The rubric will be one page with sections designated to each year. For each subsequent design course, the expectations will be raised. Data from each year will be collected, progress will be tracked, and action taken when needed for individual students, sections or an entire class. The rubric will focus on collaboration, communication, documentations, critical thinking and innovation. For example, collaboration and communication are emphasized in the freshmen year with much less emphasis on documentation and critical thinking. By their senior design course, critical thinking and innovation are the core expectations where it is expected that they have mastered collaboration, communication and documentation.

Conclusion

Assessment of the sophomore design course over the last eight years has led to changes in the format of the semester long design project. While the overall outcome of having the students more competent in the design methodology, program management, communication skills, and understanding the ethical considerations of their design have been met, it is important that the students are excited about selecting engineering as their professional career. The design course sequence provides this opportunity if the courses are planned and implemented in a way to harness the students creativity and passion.

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Appendix

Spring 2007 Project Descriptions

PROJECT 1: ENGINEERS WITHOUT BORDERS – DEVELOPMENT OF A DEPENDABLE WATER SUPPLY FOR ABHEYPUR, INDIA

This project, sponsored by the Engineers Without Borders[5] (www.ewb-usa.org) is concerned with providing safe, economic drinking water to some villagers in India. Spring 2006's section of ES242 completed a preliminary design for this project. The design includes photovoltaic (PV) panels to generate electricity, an electric pump to pump the water from a borewell. A borewell will be dug as part of this project. The design also includes a storage tank and the infrastructure required to support the tank and the PV structurally. An EWB team will be visiting India in January 2007 to conduct a comprehensive survey of the village that would provide inputs to detailed design.

A scale model of the proposed design will be constructed and tested to verify the concept and predict the output for field conditions. We will interact with Indian companies to obtain detailed cost estimates and pull together an implementation team. It is expected that some students and a faculty member will travel to India in January 2008 for implementing the project. For this to take place, students will be required to submit a report summarizing the assessment trip findings and present their design to EWB's Technical Advisory Board (TAB) for approval. Approval by EWB's TAB is required before an implementation trip can take place. While in India, we will identify other possible projects such as water purification systems, water harvesting systems, education, and other power generation technologies that might be appropriate for the village. These potential projects will be the basis for a spring 2008 ES 242 project.

PROJECT 2: DESIGN AND PERFORMANCE OF SOLAR CELLS

So called "solar cells" use the photovoltaic effect to convert sunlight into electrical current. The simplicity of this direct conversion has, in part, been responsible for a six fold increase in the use of solar cells (now referred to as photovoltaic cells) over the last ten years. However, one drawback of current, silicon based, photovoltaic cells, is that less than 25% of the incident sunlight is converted to electrical current. Thus, a large numbers of cells are required and, without government subsidy, cost about 10 times per kilowatt-hour of electrical energy, as fossil fuel generated energy. However, they produce zero greenhouse gases.

The University of Hartford has installed a 17 kilowatt array composed of 63 individual cells, mounted on three arrays, on the roof of Lincoln Theater. In the six months of operation the arrays have generated about 10 MW-hr of energy. This energy represents about 10% of the energy used by ABC Theater.

This project will be centered on use of the conversion data base from operation of these arrays. The project will include inspection of the ABC Theater arrays, construction of desk-top photovoltaic operated fans and or lamps, review of the theory and performance of photovoltaic cells, sizing and design of solar arrays, comparison of array performance with predictions, improvements in photovoltaic cell manufacture and design, and a possible visit to Spire, Inc. (a manufacturer of silicon for solar cells and computer chips).

PROJECT 3: DEVELOPMENT OF A SYSTEM TO AUTOMATICALLY DETECT AND STOP AN APNEA EVENT

Apnea, the cessation of breathing, continues as a major health problem for infants, especially those who are prematurely born. Most premature babies who are in newborn intensive care units have apnea. Furthermore for sick newborns or for newborns at risk for sudden infant death syndrome (SIDS), apnea is a life-threatening event. Currently apnea may be treated with medications or in the newborn intensive care unit with respirators. For milder conditions a caretaker such as a nurse responds to a cardio-respiratory monitor alarm and physically shakes or stimulates a child's body or extremity. All of these treatments have risks. Medication risks are side effects, raising heart rates, prohibiting sleep and causing gastrointestinal symptoms. Ventilators may cause respiratory infections and lung injuries. A nurse often responds to an alarm in a delayed fashion and, if she had been caring for another patient, in an unsanitary manner. Neonatologist, Leonard Eisenfeld M.D., ABC's Medical Center has developed a mechanical vibrotactile stimulator. The University of Hartford group is working under his supervision to bring this innovation closer to production.

The above project and a second project to listen to the Bowel Sounds of infants after feeding via a feeding tube will be pursued in this class. Both paper designs and hands-on prototypes will be developed.

PROJECT 4: DESIGN ACOUSTICAL TREATMENTS FOR THE GREAT HALL AT THE HARTFORD TRAIN STATION

The Great Hall is a large, open waiting room area within the Train Station in downtown Hartford. It currently has poor speech intelligibility, and efforts to utilize the space for live concerts have resulted in excessive build up of sound and muddy, unclear musical experiences. The students would analyze the current acoustical characteristics of the Great Hall by making on-site acoustical measurements as well as modeling the acoustic behavior in a spreadsheet. The students would determine the type, amount and location of surface treatments and wall/ceiling configurations to achieve proper sound dispersion during the rooms' intended uses.

<u>Spring 2008 Project Descriptions</u>

PROJECT 1: ENGINEERS WITHOUT BORDERS – DEVELOPABLE OF A DEPENDABLE WATER SUPPLY FOR ABPEYPUR, INDIA

This project, sponsored by the Engineers Without Borders Student Chapter (http://uhaweb.hartford.edu/cee/ewb/index.html) is concerned with providing easier access to clean water to about 3000 villagers in Abheypur, India. Last spring, a section of ES242 designed a solar power groundwater pump and storage system that will provide 9500 gal/day of water to the village. The design was presented EWB's Technical Advisory Board and approved for implementation. During the winter break (January 2008), five University of Hartford engineering students are traveling to India to implement their design.

The spring 2008 class will work on a follow-on project for the same village with the goal of implementing the design in January 2009 (It is not a requirement of the course to go to India to implement your design, but please indicate on the survey form if you are interested in traveling to India). The specifics of the project will be determined during the implementation trip in January to make sure that the project meets the needs of the villagers. Examples of likely projects are:

- Evaluate the sustainability of the groundwater supply by adding a water meter to the solar powered pump system and installing a sensor in a nearby well for measuring the depth to the water table. One alternative is to use a sensor(s) that could be read locally by the villagers and also wirelessly transmit the data so it can be accessed by University of Hartford students.

- Design of a water distribution system to increase the number of locations where clean water is available so as to reduce the time and effort required to collect the water and carry it back to their homes.

- Design of a waterless latrine to improve sanitation for protecting the water supply

- Incorporate a hand pump into the solar powered groundwater pump design so that villagers have access to water on cloudy days and during the rainy season.

- Design of a second solar powered well if water demand for village exceeds capacity of current design.

- Design of a rainwater collection and filtration system so that villagers have an alternative water supply during the rainy season.

The number of projects undertaken will depend upon the complexity of the design needed to implement the project. Also, the goal is for professional mentors to actively participate in the class by leading a technical aspect of a project where they have extensive field experience.

PROJECT 2: SOLAR HEATING

Of all the possible sources of renewable energy, the energy density of the sun makes it a prime candidate for future power generation. The project will consider a number of uses of solar input as a source of heating. The candidate projects will be based on the pioneering work of William A. Shurcliff, a member of Harvard University Physics department, in his book <u>New Inventions in Solar Heating</u>, published in 1979.

The class will be divided into 3-4 groups with each group working on their own project. The objective is to obtain an appreciation and understanding of solar energy while designing and building a prototype of the selected “invention”, following the design procedure described in the text.

PROJECT 3: DIGITAL HEALTH – WIRELESS SENSOR DIAGNOSTICS

Digital health is the monitoring, diagnosis and treatment of health conditions, both chronic and acute, through the use of medical devices, remote sensing technologies, local area networks, signal processing, data mining and other statistical treatments. This is an especially important area of engineering design because it can effectively extend the scarce (and costly) resources of health care professionals, especially with regard to the changing demographics of an aging population in the USA and other industrialized nations. The development of digital health technology will enables more thorough distributed diagnosis and treatment based on long term monitoring rather than single point of service evaluations.

The class with be divided into about 4 groups with each group responsible for monitoring a different location (for example, classroom, student services, hallway, or computer lab). Wireless sensors will be installed (for example, heat sensors, motion detectors, load cells), data collected and statistically analyzed to determine if any trends can be identified. Control tests may also be used to verify the predicted outcomes. Finally, the reliability of the distributed sensor system will be analyzed to determine the issues that must be overcome to make a wireless sensor network applicable for monitoring mobility.

PROJECT 4: DESIGN ACOUSTICAL TREATMENTS FOR THE HARTFORD SEMINARY

There is a large, voluminous conference room at Hartford Seminary. It currently has poor speech intelligibility, which is especially prevalent during teleconferences. The students will analyze the current acoustical characteristics of the conference room by making on-site acoustical measurements as well as modeling the acoustic behavior in a spreadsheet. The students would determine the type, amount and location of surface treatments and wall/ceiling configurations to achieve proper sound dispersion during the rooms' intended uses.