AC 2007-1173: DISASTER-MITIGATING DESIGN AND PRACTICE: A STUDENT-CENTERED PROGRAM DEVELOPING SUSTAINABLE AND EARTHQUAKE-RESISTANT DESIGNS FOR RESIDENTIAL STRUCTURES IN DEVELOPING REGIONS

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Disaster-Mitigating Design and Practice: A Student-Centered Program Developing Sustainable and Earthquake-Resistant Designs for Residential Structures in Developing Regions

Abstract

Earthquakes frequently strike the neediest regions of the planet with devastating consequences for their inhabitants. Impacts of such disasters extend beyond the immediate casualties, which may reach several 10,000, including the destruction of residential and commercial property and infrastructure, which severely weakens the regional economy in the longer term. Simple residential dwellings from adobe, brick, or un-reinforced concrete blocks, which are the predominant structures in significant portions of the reviewed developing regions, are frequently damaged to structural failure and collapse by earthquakes, which may obliterate entire villages and their livelihood within minutes.

Designing such small residential structures to be more resistant to earthquake loads, followed by physical testing of scaled models and implementing the design concepts in an actual prototype are the objectives of the program development for a two-semester course sequence that is currently being undertaken by the authors. This program began when guest presentations by Peace Corps alumni and the founder of Engineers Without Borders caused the students and their faculty mentors to realize that the traditional course of study in civil engineering did not sufficiently prepare them for addressing engineering problems within a global context. Since then, an introductory course on sustainability has been added to the curriculum and the students have founded a student chapter that has begun to participate in organizing the outreach to a partner community in a developing region.

In a new course sequence on disaster-mitigating design and practice, the undergraduate civil engineering and architecture students are working together in entrepreneurially oriented teams. Faculty members and representatives from industry and from foreign aid organizations are collaborating in guiding the courses. The course activities address several accreditation outcomes, have been structured to expose students to all six levels of Bloom's taxonomy of educational objectives, and accommodate different learning styles. Active student participation in the course, including setting intermediate objectives, performing, presenting, and critiquing their literature review, creative design work, and testing in the laboratory are essential to the coursework. The features of this student-centered learning environment are presented along with recommendations for implementing learning experiences that groom globally aware and socially engaged young engineers.

Background and Development

Several years ago two alumni of the university gave a guest presentation about their two years of Peace Corps work in Central America to improve the access to clean water for the particular community. More recently, the founder of Engineers Without Borders (EWB) presented his vision of "building a better World, one community at a time" through this organization of student and professional chapters that reach out to partner communities in developing regions and work on improving their quality of life. The students and their faculty mentors realized that the traditional U.S. course of civil engineering study does not sufficiently prepare engineering graduates for assisting developing communities around the World. The American Society of Civil Engineers (ASCE) student chapter therefore requested that the Department of Civil Engineering expand its teaching portfolio to introducing the students to the needs of developing regions and building their skills to solve problems within a global framework of sustainability.

Since then the faculty members have taken steps towards developing such programs, beginning with offering the "Sustainable Development Principles and Practice" course that covers sustainable development, international practices, policy, and ethics and complements the "Construction Systems and Planning" and "Civil Engineering Systems Management" course where engineering and architecture students create a detailed proposal for a semi-realistic team project (1). Subsequently, a task group examined the feasibility of further courses. A new student chapter of EWB has been founded at the university, which crystallizes the interest of the engineering students in bringing their skills to developing regions and which is enjoying an exceptionally active group of members. The research and education project described in this paper has grown from these original student-driven efforts.

Need for Earthquake-Resistant Residential Structures

While the news coverage in Western media often highlights the massive devastation caused by earthquakes in developing regions of the World for only a few weeks until other topics capture the public's attention, their effects are felt by the inhabitants of the affected regions for decades. Severe earthquakes of larger than a moment magnitude of approximately 6.5 may injure and kills thousands if not ten thousands of individuals and can cause billions of dollars of damages to the built environment.

The recent example of the Pakistan earthquake of 2005, which is only one among a long and frequently expanding list of seismic events that cause damages and destruction, may give an impression of the dimension of the typical impacts. On the morning of October 5, 2005 the mountainous Kashmir region experienced a shock with a strength of 7.6 on the moment magnitude scale. Kashmir borders the Hindu Kush region of Afghanistan and is situated in a tectonically active area between the Eurasian and the Indian Plates that also have created the highest mountain range on the planet, the Himalayas (2). Approximately 87,350 fatalities, most of them in Pakistan, and an only slightly smaller number of injured people, 75,266, were directly caused by collapsing buildings and landslides. Some 32,355 buildings were destroyed and entire villages were obliterated. Up to 4 million people were displaced or left homeless.

The severe loss of human life and the destruction of residential and commercial property and infrastructure are weakening the regional economy and are threatening an entire society. This is neither the first, not will it be the last natural disaster that impacts developing regions. In fact, most developing regions are located in tectonically active areas of the Pacific Rim, also known as the "ring of fire" due to the concentration of volcanoes and seismic events around the Philippine, Pacific, Cocos, Caribbean, and Nazca Plates, in Asia Minor along the Arabian Plate, and in Southeast Asia along the Indian and Australian Plates and are therefore prone to being frequently affected by earthquakes.

An overview of selected significant earthquakes that have struck developing regions in the last two decades is given in Table 1. Note that only major earthquakes were included, and that many less severe earthquakes that also caused numerous fatalities, injuries, and millions of dollars worth of damages to personal property and infrastructure had to be omitted due to the limited space. The predominant traditional residential structures in many of these areas are mostly simple one and two-story adobe, rubble or brick masonry, or un-reinforced concrete block buildings (3, 4, 5, 6).

Table 1: Impact of Recent Significant Earthquakes in Developing Regions

Date	Region	Magnitude	Fatal	Injured	Displaced	Houses Destroyed or Damaged
5/26/06	Indonesia	6.3	5,749	38,568	600,000	578,000, $3.1B
10/8/05	Pakistan	7.6	87,350	75,266	4,000,000	32,355
3/28/05	Indonesia	8.7	1,313	400	-	300
12/26/04	Indonesia	9.1*	297,200	125,000	1,126,900	costliest ever
12/26/03	Iran	6.6	31,000	30,000	75,600	85%, $32.7M
5/21 and 5/27/03	Algeria	6.8, 5.8	2,275	10,461	180,000	43,500, $0.6B to $5B
3/25 and 3/27/2002	Afghanistan	6.1, 5.6	1,000	100's	1,000's	2,000
1/26/01	India	7.7	20,085	166,836	-	1,122,000
1/13/01	El Salvador	7.7	852	4,723	-	over 258,226
11/12/99	Turkey	7.1	894	4,948	-	extensive
9/20/99	Taiwan	7.5	2,400	8,700	600,000	82,000, $14B
8/17/99	Turkey	7.4	17,118	50,000	500,000	$6.5B
1/25/99	Colombia	6.2	1,885	4,750	250,000	60%
7/17/98	New Guinea	7.0	2,683	1,000's	9,500	several villages
5/30/98	Afghanistan	6.9	4,000	1,000's	1,000's	-
2/4/98	Afghanistan	6.1	2,323	818	-	8,094
9/29/93	India	6.2	9,748	30,000	-	extreme
12/12/92	Indonesia	7.5	2,500	500	90,000	50-80% to 90%
7/16/90	Philippines	7.8	1,621	3,000	-	severe
6/20/90	Iran	7.7	50,000	60,0000	400,000	nearly all
12/7/88	Armenia	6.8	25,000	19,000	500,000	20 towns, 342 villages, $16.2B
3/6/87	Colombia	6.9	5,000	-	20,000	extensive, 27 km pipeline
9/19/85	México	8.1	35,000	30,000	100,000	3,536, $4B

** This seismic event was the fourth-strongest earthquake since 1900 and the worst in casualties. Regions may include neighboring countries. Missing persons are included under fatalities. - indicates unknown data. Values of casualties and damages are estimates.*

Compiled from (7, 8, 9)

Integration with Educational Outcomes

This massive need to address this devastation and severe loss of lives in developing regions through solutions that improve the earthquake-resistance of simple residential structures has long been addressed by researchers (10, 11), but has not yet been tied effectively into the educational context. There is a need to educate globally aware and socially engaged young engineering graduates who holistically consider the complex interplay of technical, socio-economic, political, and cultural factors in designing and executing their projects. The research and education project that is presented in this paper has been designed to cover such educational outcomes as have been defined by the Accreditation Board for Engineering and Technology (12, p. 2), including:

> *(b) an ability to design and conduct experiments, as well as to analyze and interpret data*
> *(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability*
> *(d) an ability to function on multi-disciplinary teams (…)*
> *(g) an ability to communicate effectively*
> *(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context (…)*
> *(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.*

This paper describes the background, elements, and experience with this new interdisciplinary program development project that places the students into the center of the educational process. It challenges students in an entrepreneurial environment to creatively invent sustainable ways to mitigate potential damages and improve the performance of simple structures under seismic loads. The project integrates structural engineering and construction engineering principles with materials science, environmental engineering, and other specialty topics. Laboratory experiments that test scaled models are included to assess the achieved performance of potential solutions.

Need for Student-Centered Learning

Recent changes in the ABET accreditation requirements for engineering education as listed in the previous section have placed even more weight on the learning output on the student side than on the teaching input on the faculty side (13) during the didactic process. Other characteristics of this new educational paradigm are an emphasis on teamwork in working on projects, as will be experienced by the engineering graduates upon entering the construction industry, and instilling an appreciation of lifelong learning in the students. Under this so-called student-centered learning philosophy the students are given a significant amount of personal responsibility and freedom to create their individual learning experience to the extent that the concept might "initially be met with uncertainty and irritation" (1) by students who have never experienced this approach. Nevertheless, the success of student-centered learning has been documented extensively in the literature (14) and is generally accepted as a highly innovative educational approach.

Students are taking on an active role in developing their own processes and products while exploring the subject matter at hand. Typically, the depth of understanding and the appreciation for the material that students gain when exposed to a student-centered learning environment exceeds what traditional teaching is able to achieve. Faculty members take on the role of facilitators to the learning process of the students, set the scope, pose challenges, provide guidance, and be partners to the students. While student-centered learning may at first glance appear less formal and structured, it is certainly richer in opportunities for students to develop their own learning styles. At the same time, the teacher is challenged even more than in traditional teaching, as the lessons change from a monologue style to a constructive dialogue. This also poses a higher demand on utilizing assessment techniques that reflect the original work that students generate during a course rather than following one prescribed narrow format. Among the types of assignments that lend themselves well to student-centered learning are project assignments (15). A previous study had described how such project-based learning can complement a regular course in construction engineering and management and can integrate the different topics that are part of this discipline (1). The following sections of this paper describe an educational approach that goes beyond such blend of new and old methodologies by creating an entire course sequence that embodies student-centered learning and also adds an entrepreneurial outreach component that connects the classroom with the field implementation of the students' work product.

Bloom's Taxonomy of Learning

In addition to addressing several accreditation outcomes, the elements of the course sequence have been designed to adhere to Bloom's taxonomy of learning (16), following all six competence levels from the simple acquisition of knowledge via comprehension of said knowledge, its application to new circumstances, analysis and interpretation of results, and integrating synthesis that develops new ideas, to the high-level critical evaluation of concepts. The taxonomy and the respective project elements that occur at each level are listed in Table 2.

Table 2: Bloom's Taxonomy and Project Elements
Adapted from (16)

Level	Competence	Instructional Activities	Project Elements
6	Evaluation	Compare, critique, justify, optimize	Progress evaluations, feedback incorporation, final detail design
5	Synthesis	Propose, formulate, create, design	Performance specifications, prototype design development
4	Analysis	Classify, arrange, derive, predict	Model testing evaluation, business plan development
3	Application	Illustrate, experiment, modify, calculate	Creativity techniques, conceptual design, model fabrication
2	Comprehension	Associate, distinguish, paraphrase, explain	Regional presentations, progress documentation, project report
1	Knowledge	Identify, collect, list, define	Building methods, seismology, socio-economic environment

Every student has their own unique preferred learning style that in many cases may be different from the predominant traditional teaching style of lectures. While early learning models as published in the literature focused primarily on the human senses and which one dominates the intake of information, whether visual, auditory, tactile, or kinesthetic (1), modern approaches to modeling and understanding the learning process in students go beyond this first step recognize that the second step of processing the information that has been acquired is equally important. Such comprehensive model has been presented by Felder and Silverman (17), to include the dimensions of input, perception, processing, and understanding in somewhat of a chronological order and at least two preferences for each of them. The authors ensured to incorporate elements into the project that address each of these different aspects and learning styles so that the students are exposed to a wide range of educational opportunities as shown in Table 3.

Table 3: Learning Styles and Project Phases
Adapted from (17)

Dimension	Preferences	Project Elements
Input	Visual	Model fabrication and laboratory testing, site visits
	Verbal	Guest presentations, regional and final presentations
Perception	Sensing	Model fabrication and laboratory testing
	Intuitive	Creativity techniques, performance specifications
Processing	Active	Conceptual design teamwork, progress evaluations
	Reflective	Feedback incorporation, model testing evaluation
Understanding	Sequential	Building methods, seismology, socio-economic environment
	Global	Regional and final presentations, project report

Project Participants and Elements

The core unit of the participants in this research and education project is the entrepreneurially oriented collaborative team or E-Team (18):

> *An E-Team is a multidisciplinary team of students, faculty, and industry mentors associated with an educational institution, who work together to bring a product or technology from idea to prototype to commercialization. The "E" stands for excellence and entrepreneurship. The NCIIA encourages E-Teams to develop sustainable technologies that help address issues of environmental degradation and meet basic human needs such as shelter, food, water, health, and education.*

The project has been set up initially as an interdisciplinary two-semester undergraduate course sequence at the junior and senior levels entitled "Disaster-Mitigating Design and Practice for the Developing World I and II" that is open to all engineering and architecture students at the university and at other consortium institutions based on the new concept of merging structural design and sustainable construction practices into a challenging project for E-Teams to serve the most fundamental level of Maslow's hierarchy of human needs, shelter (19).

The E-Teams develop innovative solutions from conceptualization through research and design to prototype building and testing in the laboratory. They begin with researching the socio-economic environment of developing regions and their traditional residential construction technologies and labor practices. Regions that have been examined to date are Northern Africa and Asia Minor, Southeast Asia, Central America, and South America.

Students collect information on and build an understanding of the history and present use of low-tech and low-cost alternative construction techniques. Regular presentations then introduce earthquake engineering with its interrelated areas of seismology, wave propagation, structural dynamics, and passive seismic control. A special session is devoted to stimulating innovative thinking with various creativity techniques that the students can apply in the following design work. Active student participation in all aspects of the student-centered coursework, including setting intermediate objectives for themselves, critiquing their ongoing work, and working collaboratively on design ideas have proven successful in the experience of the authors.

Moving to higher levels in Bloom's taxonomy, the students then begin the design work by defining the specific scenario and scope for the structure. The design is guided by considerations on the constructability (design for construction and use) to reflect the local building traditions, economy regarding the affordability and longevity of the materials, and sustainability to create a solution that provides a more earthquake resistant habitats with a healthy indoor building climate that use renewable or environmentally preferable materials and thus protect the natural resources.

Scaled Modeling

A particularly interesting challenge for the E-Team lies in translating the life-size design into a scaled solution. Scaled models are subject to similitude requirements to react in an equivalent way to the loading conditions as the actual structure would with respect to the phenomenon of interest (20). At the same time, size effects create a vexing puzzle, as length, area, and volume all scale with a different exponent and therefore e.g. a model of 1/10 scale in its exterior length dimensions will only have 1/1000 of the weight of the original unless the material properties are adjusted as well, e.g. by increasing the density of the model material or by adding extra weights. Developing the exact specifications for the scaled model prototype, finding a balance between the disproportional size effects, and setting up a testing regime to ascertain the performance under simulated seismic loads (whose frequency and amplitude are also subject to size effects when scaled down) are central elements of the practical work in the second semester of the course sequence. The structural resistance of the scaled model prototype will be assessed on so-called shake table in the earthquake research laboratory as shown in Figure 1. This 2.5 m by 1.5 m unidirectional seismic simulator can provide sinusoidal, white noise, random, and seismic excitation with a peak accelerations of 1.5 g. Analyzing failure mechanisms will give valuable guidance for large-scale performance and can lead to independent studies for the students and also to further research into sustainable housing.

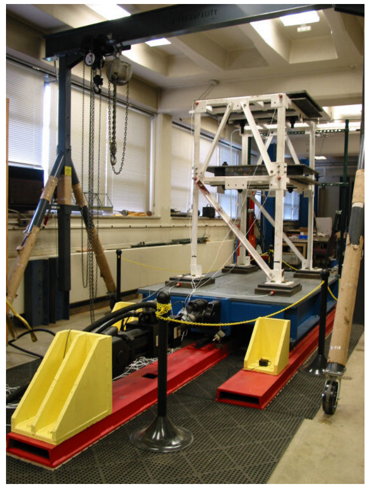

Figure 1: Seismic Simulator

Entrepreneurial Elements

Since the E-Teams are charged with developing a viable solution that fulfills sustainability criteria, the course sequence includes special sessions on entrepreneurship and developing a business plan, which will include a feasibility analysis and a financial forecast. Value engineering principles will be applied to fine-tune the cost-effectiveness of the design. Input from partners in industry and foreign aid is actively solicited throughout the project development. Guest speakers are invited to build a broader contextual understanding and site visits to specialty construction project in the metropolitan region show practical applications of innovative solutions. The E-Team is working in conjunction with the newly founded EWB student chapter, which to date has developed into an active interdisciplinary group with a strong student membership. The chapter maintains a close cooperation with the regional professional chapter and the national organization, which facilitate the outreach to the host community in a developing region.

Documentation and Evaluation

The E-Teams document their work progress and the understanding of the complex interplay of factors for more earthquake-resistance residential structures in a comprehensive report. It is written in several phases that detail the research on the devastating impacts of earthquakes on residential structures, the traditional building materials and practices of selected developing regions, the creative process that the E-Team underwent and their proposed design, the seismic testing setup, results, and analysis, and a business plan. The business plan transforms the technical contents into entrepreneurial contents, including the process for deployment and field implementation, its expected challenges and possible ways to overcome them, and a budget with economic forecast and analysis. The students also create meeting minutes throughout the work.

Evaluation of all written, oral, and physical work considers (a) sustainability, (b) cost efficiency and seismic retrofit effectiveness, (c) integration of region-specific resources and traditions, (d) enhancement of living conditions, and (e) the implementation plan for the proposed solution. The success of the work of the E-Teams is measured by clearly defined student-centered learning outcomes that conform to the new Engineering Criteria 2000 of ABET (12).

All E-Team members are asked for improvement suggestions on the course through pre-course, mid-semester, and semester-end surveys using both structured and open-ended questions. This feedback is carefully examined and implemented as appropriate. The members also critique each other's work constructively to elevate the level of knowledge and understanding attained by the entire group. Members of the advisory council of the department, a dedicated group of current and former senior industry executives, serve as a jury for critiquing the final open presentations, which is followed by a group discussion to capture highlights and key points of the accomplished work.

Student Reflections and Learning Experience

Before attending University, I understood them to be about an individual's pursuit of knowledge. As a senior I have to come to see them as professional training centers. Institutions teaching students the minimum they need to be competent in their intended profession. This is especially the case with engineering programs where the knowledge that is needed can be quantified based on concentration. Compounded with accreditation requirements these programs are forced into rigid schedules of learning with little variance in the material covered. While the benefits in uniformity of education and professional qualification are obvious, the adverse effects are not being attended to. Students are learning because they are required to learn and not because they are willing to learn.

I am so refreshed to see the implementation of this course into our program. The course has the immediate scholastic benefits similar to a capstone design course where students pool their knowledge of simple engineering components to solve complex engineering problems. The key difference being that these are real projects and real problems. There is now an outside drive of compassion and satisfactions which motivates students to learn. The structuring of the course is also crucial to its success. For students to have any sort of control in a course it automatically locks their interest in their course. The sense of involvement and responsibility ensure active participation.

I can say that because of this course and my involvement with the student chapter of Engineers Without Borders I have been forced to revaluate the importance of my education. Before their was the drive to do well and get good grades now there is the drive to learn more so that I can apply them to these projects which are so important. The class is much more than learning information it's about understanding the value of the information I am learning.

Senior, Civil Engineering

The class entitled *Design for the Developing World,* I think was a great new learning experience for the teachers and the students. To begin, it was nice to have a very small class which consisted of four students and two professors. The learning experience focused both on the class as a whole and on each individual member as if they were the only one in the class. The teachers actually sat amongst us students and not in front of the classroom giving a lecture the entire time, like in most classes. Therefore the professors and students were at the same level in the classroom. The students and teachers worked together as a group developing the class to achieve its goal by the end of the semester. The class was mostly structured by the students in going about ways of learning that would benefit us the most in understanding the material we wish to explore and the teachers were there to give advice and their help based on their expertise when needed. We worked together in presenting research on a great deal of information and we brainstormed ideas off each other in discussions until we could come up with a final conclusion that we all agreed upon. This made the class more interesting and a project that is our own.

I personally learned a lot from this way of teaching, not only about the work we accomplished but about myself too as a student. It was easier to comprehend what we were doing because we went at our own pace and there was not a ton of information thrown at us at one time that we must fully know before the next class. It is nice to know that soon we will be able to put what we learned to the test in the real world and we will be helping many people at the same time. I learned how to think more critically and outside of the box and to better voice my opinion. Finally knowing that the professors wish to be able to consider their students as colleagues made the environment feel less like a classroom setting.

Junior, Civil Engineering

It has been my experience, not only as a student myself, but also in my observations of other students alongside me, that perhaps the most motivating academic force one can have, is the a sense of ownership of the outcome of his or her hard work. When all is finished, the student will be able to think with satisfaction to him/herself “I *built* this!” or “I *designed* this!” knowing that the result was made possible by his or her individual skills, regardless of whether the project was an individual or group effort. Such a sense of ownership of the result causes the feeling of success to be sweeter and, in the unfortunate case of a poor result, the lessons from failure to be more easily learned. Should such an endeavor be successful, it is likely that the confidence of the students who participated will receive a firm boost, and their eagerness to begin the next project will increase as well.

In a traditional approach to instruction, a student may feel less committed to his or her studies if the end result is simply a grade on a transcript determined by the professor’s (or school’s) criteria, rather than an achievement of a personal goal or the production of a tangible final product – as seems to be the case in Student-Centered Learning. If the criteria for success are set, agreed upon, pursued, and achieved by the students – with the *guidance* of a professor – the students will likely feel more committed to their studies, and embrace the process of achieving such goals. In this approach, the relationship between professor and student takes on a much different and more familiar role, with the professor being the guide who “knows the terrain” and the student being a “newcomer to the terrain,” seeking direction from a trusty guide.
My concern is that this type of relationship will only work well in classes of small size, where the professor can give personal attention to each student each time the class meets. If the professor is not easily accessible to the students, it is likely that the students become “lost” and will not reach the goals they set out to achieve. Returning to the idea of commitment for a moment, I also fear that there is more of an academic load on a student enrolled in a course using a Student-Centered Learning approach, than that of a student enrolled in the same course taught with a traditional approach. Given the typical fifteen credit-hour semester (five courses), a student may become *over*-committed if each of these five courses are taught using the Student-

Centered Learning approach. Perhaps a solution to this problem would be to increase the number of credit hours a Student-Centered course is worth, or restrict students from registering in more than one or two of such courses.
My experience in CE 434 was that the workload was honestly lighter than I had expected – yes, contradictory to the above paragraph. I imagine that the workload will increase once we enter the design phase next semester. I thoroughly enjoyed and benefited from the dual-professor approach. We (the students) were able to get a taste of two often different, yet equally valid, approaches both to the problem of Seismic Disaster Mitigation, and to the more "everyday" task of decision-making. As a computer scientist, I feel that I am not able to contribute as much as I would like, and I'm afraid this will become more apparent when we begin designing a structure and testing it on the shake table. I'm a little worried that this may put an unequal academic load on those students who do have the proper background for this kind of design and testing. I have appreciated a great deal how both professors have tried to relate many of the concepts taught in the course to ones that I am familiar with from my computer science background.

Senior, Electrical Engineering and Computer Science

I believe that taking CE 434 - Disaster-Mitigating Design and Practice for the Developing World I, was a very positive and useful experience. One of the reasons is that it has been the only class in my career in which I have felt that I participated in a very noble cause, which is to help design low-cost seismic resistant structures and develop sustainable construction practices that can be implemented in seismic-prone areas in developing counties to help protect low-income communities.

This class gives students the liberty to help structure the development of the course itself, which pushes students to participate more actively, and to be more independent and proactive in the undertaking of the course activities. I enjoyed the experience of collectively setting course objectives with both classmates and professors and the freedom to determine to a certain extent the length and quality of class assignments; however, depending on the student, the liberty to determine certain parameters on the amount and depth of class assignments can lead to work overload. Overall, I think this type of teaching approach increases the productivity and performance of students because they themselves are setting the goals to be accomplished, which in many cases takes away any feelings of boredom or perceptions of feeling dragged to complete imposed tasks.

In CE 434 I gained valuable knowledge about earthquake and construction engineering as well as the importance and positive impact that engineering can have in our environment and in the various segments of society.

Graduate Student, Civil Engineering

Conclusions and Future Research

The research and education project described in this paper addresses a major need – how to better design and construct residential structures in developing regions to protect against earthquakes. The new course sequence on "Disaster-Mitigating Design and Practice for the Developing World I and II" has had a successful start and will continue to be offered annually. It offers a unique integration of earthquake engineering principles with construction engineering techniques with the goal of creating innovative solutions that mitigate the potentially devastating impacts of earthquakes on developing regions. Specialty lectures add a broad background on socio-economic and entrepreneurial topics. The earthquake laboratory is used to test and evaluate models of prototypes in this student-centered learning environment.

Student-centered learning projects, such as the one presented in this paper, present rich opportunities to move beyond the traditional boundaries of coursework toward creative teamwork by students and faculty members. The interdisciplinary background of the theme has attracted the student's interest and the outreach component – developing solutions for a developing region – is creating much synergy with the work of the new EWB student chapter and supports the outreach mission of the School of Engineering and the university. The Department of Civil Engineering will utilize this project to work on recruiting more women and minorities and nurture their skills. The need in engineering to grow these groups is recognized unanimously across higher education and the construction industry (21).

The outcomes from the work of the E-Teams can be used to build an ongoing initiative into simple, affordable, efficient, effective, resilient, and sustainable technologies for developing regions. In the future, this project may serve as an incubator for growing an active area of scholarly inquiry in conjunction with students crafting and implement their ideas.

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