// THE CIP REPORT

CENTER FOR INFRASTRUCTURE PROTECTION AND HOMELAND SECURITY

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School of Law

CRITICAL INFRASTRUCTURE PROTECTION PROGRAM

CENTER for INFRASTRUCTURE PROTECTION and HOMELAND SECURITY

We are pleased to offer this special issue of *The CIP Report* highlighting the work of a University of Wisconsin-Platteville led, National Science Foundation funded grant to develop and establish undergraduate infrastructure engineering courses. Initially begun at six universities, the program has grown to fifteen universities that are offering or are planning to offer an undergraduate infrastructure course. In this issue, authors explain these initiatives and highlight unique aspects of infrastructure education at their institutions.

In the first article, Dr. Mike Penn and Dr. Philip Parker, both of the University of Wisconsin-Platteville, and Dr. Steve Hart of the Virginia Military Institute describe the scope and purpose of the NSF grant proposal; provide a summary of the first Infrastructure Education Workshop; and introduce the Center for Infrastructure Transformation and Education (CIT-E).

Next, educators from the participating universities present unique aspects of their infrastructure course offerings. Dr. Mike Penn and his colleagues discuss the Local Infrastructure Assessment exercises developed for UW-Platteville's Introduction to Infrastructure Course. Dr. Keri Ryan describes her new course, Civil Engineering for a Sustainable Society, which is the freshman engineering course for the University of Nevada-Reno. Drs. Defne Apul, Constance Schall, and Cyndee Gruden with the University of Toledo discuss their freshman engineering experience similarly focused on sustainable infrastructure. MAJ Berndt Spittka of the United States Military Academy discusses West Point's course on Infrastructure Engineering and introduces us to the Goethals Infrastructure Challenge, an innovative student competition focused on infrastructure issues of the 21st century. Dr. Matt Roberts of Southern Utah University and his colleagues explain the use of concept maps to assess student learning and understanding in an infrastructure course. Dr. Roberts also writes on an emerging project—developing an infrastructure views survey to assess how students and other individuals perceive the infrastructure. Drs. Joe Dar_io and Ralph Dusseau of Rowan University explain how they use the impacts of extreme storms in their new infrastructure engineering course.

These educators are national leaders in developing and implementing infrastructure education at the undergraduate level. This unified, multi-year, nation-wide effort will produce significant numbers of leaders prepared to meet the infrastructure challenges of the 21st century.

We would like to take this opportunity to thank the contributors to this special issue; a short biography for each author is on the next page. We hope you enjoy this special issue of *The CIP Report* and find it useful and informative.

Mick Kicklighter

Mick Kicklighter
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Training Next Generation Faculty and Students to Address the Infrastructure Crisis

by Michael R. Penn, Philip Parker, and Steven D. Hart

At the University of Wisconsin-Platteville civil engineering and environmental engineering programs and the civil engineering program at West Point, we have successfully transformed the curricula over the last five years by developing, piloting, and institutionalizing two new infrastructure-themed courses.[1] As a result of our efforts, we have generated a wide variety of teaching materials for the two courses. Importantly, the transformation of our curricula has involved more than adding new courses; as a result of having all department faculty involved in planning and implementation, our institutions have experienced a "trickle down" effect in which new infrastructure-themed material has been added to nearly every course and entire course sequences have been modified. As a result, important topics such as resilience, infrastructure protection, environmental impacts, and sustainability are presented to students in a variety of courses within the context of infrastructure. At an even higher level, we have observed that we have changed the way in which many students see the world.

Through a National Science Foundation Transforming Undergraduate Education in Science, Technology, Engineering and Mathematics (TUES) grant titled T*raining Next Generation Faculty and Students to Address the Infrastructure Crisis*, UW-Platteville, West Point, Arizona State University, New Mexico Institute of Mining and Technology, Norwich University, Portland State University, Rowan University, the University of Toledo, and the Virginia Military Institute are partnering to advance the state of the art of infrastructure education. Through creating and sustaining a community of practice in the area of civil infrastructure education, infrastructure-themed courses will be offered at the collaborating institutions and continuous improvement of these courses will be possible. As the result of outreach and an Infrastructure Education Workshop, the community of practice has grown to include representatives from other institutions: Marquette University, Western Michigan University, University of Nebraska-Lincoln, University of Arkansas at Little Rock, University of Nevada-Reno, and Alabama.

One of the first major activities of this grant was the first annual Infrastructure Education Workshop held at Marquette University on June 25-27, 2014 and attended by 20 individuals representing 15 universities. The workshop began the formation of the community of practice by allowing us to meet each other face to face, share the goals and objectives of the grant, and collectively formulate our future directions. The workshop began with a presentation by Dr. Led Klosky of West Point on the need to provide infrastructure education for all college graduates, then proceeded to information exchange presentations where the infrastructure courses from the University of Wisconsin-Platteville and West Point were shared with the participants. On the second day, we discussed teaching techniques that enable infrastructure courses to move beyond the simple transfer of information to deep analysis of the underlying challenges. Dr. Cynthia Furse of the University of Utah gave an engaging presentation on the 'flipped classroom' and then participants prepared recorded video lectures for use in their courses and to share with each other. On the final day of the workshop, we established the 'way ahead' for our community of practice. Each participant committed to starting or updating an infrastructure education course, preparing video lessons to be shared with the community, and advocating for infrastructure education.

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[1] Steven D. Hart, J. Ledlie Klosky, Joseph P. Hanus, Karl F. Meyer, Jason Allen Toth, and Morgan Reese, "An Introduction to Infrastructure for All Disciplines," *118th ASEE Annual Conference & Exposition* (Vancouver; ASEE, 2011), available at http://www.asee.org/public/conferences/1/papers/293/view; Matthew W. Roberts, Philip J. Parker, Michael K. Thompson, and Barb A. Barnet, "Development of an Introduction to Infrastructure Course," *118th ASEE Annual Conference & Exposition* (Vancouver; ASEE, 2011), available at http://www.asee.org/public/conferences/1/papers/746/view.

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The participants have changed both what and how we teach, and our intent is that infrastructure education will grow beyond the grant participants.

To accomplish this, we are sharing all our materials, expertise, and experiences in both an on-line resource and through personal presence and actions. The activities, course materials, assessments, and projects described in this edition of the CIP Report are organized and managed under the umbrella of the Center for Infrastructure Transformation and Education, or CIT-E (pronounced "city"). CIT-E activities will eventually be housed on its own website, www.CIT-E.org. The intent is that CIT-E will be the "one-stop-shop" for all things related on infrastructure education, including:

- Proposal templates for adding an infrastructure course to a curriculum;
- Sample syllabi for a variety of infrastructure-related courses;
- Complete course materials including lecture notes, case studies, homework assignments and solutions, exams and solutions, project assignments, and in-class activities;
- *Peer-reviewed* video clips and screencasts on a variety of infrastructure topics. These media can be used for in-class viewing, or as the basis for a flipped class;
- Educational research studies pertaining to effective infrastructure education;
- Access to the Goethals Infrastructure Challenge, an innovative infrastructure-themed student competition described later in this edition of the CIP report; and
- Other items to be shared as CIT-E evolves to meet the needs of the infrastructure education community.

However, the most important part of CIT-E is the *community of practice* that is intended to be the "heart and soul" of CIT-E. A community of practice is a "group of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly".[2] As such, there are three aspects to this definition reflected in our community:

- The Group: a group of faculty members from around the nation who share a passion for infrastructure education and share a need to create a new course for their curriculum has been organized.
- The "Doing": Community members will continuously improve the content and delivery of infrastructure materials by sharing updates and improvements to lectures, assignments, assessments, etc.
- The Interactions: Regular interactions have been organized via the First Infrastructure Education Workshop in the summer of 2014, the Second Infrastructure Education Workshop in the summer of 2015, a seminar entitled "Adding Infrastructure Education to Your Curriculum" in the summer of 2015, and monthly internet meetings.

Consequently, the hope is that CIT-E is not only a repository of information, but an organic organization where materials are continuously updated and improved; new material and topics are introduced and developed; and new ways of thinking about and delivering infrastructure education are shared and discussed.

We hope that you are suitably impressed by the achievement of our members to date. More importantly, we hope that you are *inspired* to help us in the transformation of infrastructure education across the country. Our community is growing and new members are welcome. Inquiries can be sent to Philip Parker at parkerp@uwplatt.edu. ❖

[2] Etienne Wenger, Communities of Practice: A Brief Introduction (Wenger-Trayner, 2006), available at http://wenger-trayner.com/wp-content/uploads/2012/01/06-Brief-introduction-to-communities-of-practice.pdf.

Infrastructure Assessments: Providing Students Field Experiences to Strengthen Infrastructure Appreciation and Knowledge

by Michael R. Penn, M. Keith Thompson, Matthew W. Roberts, Kristina M. Fields, and Philip J. Parker

As part of an infrastructure-centric curriculum reform effort, the University of Wisconsin-Platteville developed an *Introduction to Infrastructure* course that is required of all civil and environmental engineering majors. The course is intended for second-year students after matriculating into the Civil and Environmental Engineering (CEE) Department from the General Engineering Program. As a result of completing the course, students are able to:

- describe the current condition of the nation's infrastructure;
- explain why properly functioning infrastructure is critical to the nation's economy, security, and general welfare of the public;
- describe the infrastructure from a systems viewpoint;
- describe the variety of tasks civil and environmental engineers engage in to keep infrastructure properly functioning (e.g. design, analysis, planning, monitoring, and inspection);
- explain how infrastructure decisions are influenced by a variety of technical considerations (e.g. risk, constructability, performance criteria) and non-technical considerations (e.g. politics, social priorities); and
- develop teamwork and presentation skills.

A hallmark of the course is the requirement for students to perform infrastructure assessments. Initially, motivation for integrating these assessments into the course came from the American Society of Civil Engineers (ASCE) *Report Card on America's Infrastructure*.[1] When assessing infrastructure, the students use a procedure modelled after the methodology used in the *Report Card on Wisconsin's Infrastructure* (two of the co-authors were integrally involved in the Wisconsin report).[2] The scale of a national- , state-, or even local-level assessment of infrastructure sectors is beyond the capabilities of second-year students. However, performing basic infrastructure assessments has helped students to meet multiple learning objectives, including:

- observe actual infrastructure components and systems in-the-field;
- document field observations quantitatively and qualitatively with notes, drawings and pictures;
- develop the ability to use the techniques, skills, and tools necessary for engineering practice;
- place infrastructure into context;
- develop teamwork skills (groups of three to five students perform each assessment);
- develop report writing skills; and
- prepare plans to minimize safety risks associated with field observations.

The *Introduction to Infrastructure* course also provides students with a background in each of the subdisciplines of civil and environmental engineering. Multiple infrastructure assessments, as summarized below, were developed to provide students with broad exposure to the subdisciplines.

Environmental – Student groups are assigned one of approximately fifteen storm sewer inlets near the

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American Society of Civil Engineers, 2013 Report Card for America's Infrastructure, accessed November 10, 2014, http://infrastructurereportcard.org/a/#p/home.

American Society of Civil Engineers, "Wisconsin," 2013 Report Card for America's Infrastructure, accessed November 10, 2014, http://infrastructurereportcard.org/wisconsin/wisconsin-overview/.

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UW-Platteville campus. The inlet and surrounding conditions are inspected and documented. A plan and profile drawing of the storm sewer segment is prepared after conducting field measurements. The contributing watershed is delineated and peak flow rates of runoff are estimated. Existing sewer capacity is estimated and compared to the peak runoff rate. A report is prepared to include the above information as well as suggestions for improvements necessary for proper system performance.

Geotechnical – Student groups are assigned one of approximately twenty retaining walls near campus. Description of the wall type, size, estimated age, and purpose are documented. A plan and profile drawing is prepared. The condition of the wall is assessed, and suggested maintenance or corrective actions are reported along with consequences of wall failure.

Structural – Student groups are assigned one of approximately fifteen local bridges. Deck, superstructure, and substructure elements are identified, and condition ratings are assigned using procedures utilized by the Wisconsin Department of Transportation (WisDOT) (see Figure 1). Students are encouraged to consult archived WisDOT bridge inspection reports. In addition to the condition rating, the purpose of the bridge, users of the bridge, and the societal impact/consequences of the bridge being out of service are reported.

Transportation and Construction – Student groups are assigned a local intersection and adjacent roadway to assess traffic signs and pavement conditions. The purpose of the street, as well as traffic volume (qualitative), number of lanes, parking conditions, and other significant features are reported. Traffic signs are identified, located, and assessed for condition, proper placement, and possible obstruction of view. Pavement condition is rated using the Pavement Surface Evaluation and rating (PASER) system developed by the University of Wisconsin-Madison Transportation Information Center. Cost estimates for corrective actions are prepared.

Figure 1. A student inspecting the condition of a rural bridge.

From the descriptions above, it is clear that the assessments are not merely technical calculations. *Qualitative* and *quantitative* assessments are intentionally integrated (noting that second-year students often have the misperception that engineering is purely quantitative). By the very nature of the projects, students see first-hand the true condition of aged infrastructure and the need for maintenance, which further broadens students' perspective of engineering to go beyond that of only *designing* infrastructure. Societal and economic impacts are also integrated to make students answer challenging questions such as "How much will this cost to fix?" and "Who will be affected, and to what extent, if this fails?"

The assessments provide opportunities for students to connect skills learned in prerequisite courses to the infrastructure (e.g. surveying and computer aided drafting). This not only refreshes student skill, it builds confidence and demonstrates the usefulness of prior learning. Equally valuable is the instructor's opportunity to connect the infrastructure assessments to upper-level CEE courses. This allows the students to see a "roadmap of learning" from the first year to the present, and onward to their senior year.

Student responses to end of semester course evaluations indicate that these projects are challenging, enjoyable, and educational—out-

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comes routinely associated with active learning. The infrastructure assessments require a substantial effort from students and account for a combined 40 percent of the final course grade. Negative experiences with the assessments are typically limited to problems of individual team members lacking motivation or isolated cases of unavailability of equipment. Additionally, some students struggle with time management. The *Introduction to Infrastructure* course does not follow a traditional "homework, homework, homework, exam…repeat" cycle. Students are often simultaneously working on an infrastructure assessment, readings, homework assignments, oral presentations, and/or exam preparation—all of which prepares them for the rigor of future courses and their profession.

Logistics of the infrastructure assessments require a significant effort on behalf of the instructors. In a given semester, between 40 and 60 students are enrolled in the course. A significant reconnaissance effort is required to identify infrastructure components that are within a reasonable distance from campus each semester. A large number of sites is necessary to cycle through each semester to lower the risk and temptation of plagiarism. Also, sites have to be selected that are of appropriate scope to match student capabilities. Ensuring that students have ready-access to field and safety equipment requires a "check-out/check-in" process. Students that have successfully completed the course are utilized as equipment managers.

Student safety is paramount. Second-year students typically have not yet had field and engineering experience as summer interns or in cooperative education programs. As such, it is assumed that students have no field safety experience, and one lecture period is devoted to safety, including a homework assignment requiring students to identify safety concerns for a field assessment. All students must also pass a safety quiz before being allowed to work in the field; re-takes on the quiz are allowed. Additionally, prior to checking out field equipment for any assessment, students must complete and receive approval of a Safety Management Plan, which was modelled after documents used by practicing consulting engineers. At the beginning of each semester, students sign a Hold Harmless agreement developed by the university Risk Management Officer.

The potential exists for enhancing the infrastructure assessment experience by incorporating a service learning component wherein students would be partnered with the university or local community facilities/public works offices to specifically provide information required for infrastructure management. A point for further consideration is the possibility of a network of students, both undergraduate and graduate, to assist with statewide infrastructure assessment.

Experience with this course has shown that motivated second-year students are capable of the type of work often associated with junior- or senior-level courses. Early in the curriculum, students are developing skills used by practicing engineers. These experiences provide confidence, shape their perspective, increase their motivation, and better prepare them for the challenges of upper-level courses. Furthermore, these experiences provide materials for a portfolio and valuable "talking points" during employment interviews. The UW-Platteville CEE Department is very pleased with the success of the infrastructure assessments and would be happy to share information with those interested.

Acknowledgements

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Broadening the Education of Civil/Environmental Engineers at University of Nevada, Reno through a Freshman Infrastructure Course

by Keri Ryan

Visionary leaders have advocated the need for engineering education reform to develop more well-rounded engineers with strong leadership, communication, and teamwork skills.[1] Besides just practicing engineering, these future leaders should drive public policy, embrace new technologies, act as entrepreneurs, and work on multidisciplinary teams to develop solutions that balance new infrastructure and sustainability needs. Developing a big-picture understanding of infrastructure, including its development, maintenance, and funding, as well as the Civil/Environmental Engineers' role in this process early in the education path is critical to the development of well-rounded engineers and their motivation for subsequent study. Until recently, students enrolled in University of Nevada, Reno's Civil and Environmental Engineering (CEE) degree programs took their first engineering courses (e.g. statics, mechanics of solids, environmental engineering systems) without any context to frame the value of the technical concepts within engineering practice. However, starting in Spring 2014, freshman in the CEE program enrolled in a new course, CEE 120: Civil Engineering for a Sustainable Society, which is a 21st-century introduction to infrastructure. The course interweaves an introduction to the CEE sub-disciplines: construction, structural, geotechnical, transportation, environmental, and water resources; an introduction to the analysis and design process; and a discussion of non-technical considerations, including planning, energy, sustainability, social, economic, environmental, ethical, political, and legal.

A unique aspect of the course is the integral role of teamwork in the learning process. Following the team-based learning approach,[2] students are placed in semester-long learning teams using a process that attempts to balance student assets among the teams. Students are asked to pre-read assigned readings from the *Introduction to Infrastructure* textbook[3] on their own, and the traditional lecture-style delivery of course content is replaced with an assessment and student-directed concept-clarification process. Students' conceptual understanding is assessed through an individual test and then again in a team test. The individual assessment holds each student accountable for studying the material. Following the individual test, the same questions are administered to the team using an Immediate Feedback-Assessment Technique (IF-AT) scratch-off form that reveals if an answer is correct or incorrect. Through the discussions that parallel their test taking, the students have the chance to develop team consensus and help each other clarify fuzzy concepts. Following the assessment process, the remainder of class time is used for team application exercises designed to achieve higher-level learning objectives.

As a culmination of the course experience, students complete several team projects that integrate introductory design concepts with communication and non-technical aspects. Although limited to basic design, the projects are open-ended without the usual constraints of pedagogic design examples to encourage creativity. For example, following a short introduction to reinforced concrete-beam design, students were asked to design a two-lane simply-supported bridge

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[1] National Academy of Engineering (NAE), *Educating the Engineer of 2020: Adapting Engineering Education to the New Century.* (Washington, D.C.: National Academies Press, 2005); American Society of Civil Engineers (ASCE), (2007). The Vision for Civil Engineering in 2025. Based on The Summit on the Future of Civil Engineering – 2025 (Reston, VA: ASCE, June 21-22, 2006).

[2] Larry K. Michaelsen, "Getting Started with Team Learning," in *Team-based Learning: A Transformative Use of Small Groups*, ed. Larry K Michaelsen, Arletta Bauman Knight, and L. Dee Fink (Westport, CT: Praeger, 2003), 27-52.

[3] Michael R. Penn and Philip J. Parker, *Introduction to Infrastructure: An Introduction to Civil and Environmental Engineering* (Hoboken, NJ: Wiley, 2012).

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spanning 75 feet with no constraints on the cross-section layout. In addition to design calculations, students were asked to develop design sketches and write an overall project proposal for the client. Students were asked to incorporate at least one enhanced design objective, such as enhanced functionality for bicycle or pedestrian traffic, use of sustainable materials, or context-sensitive design. The enhancements allowed students to think beyond the technical calculations to how the bridge meets societal needs. While the solutions lacked the realism of an experienced designer, students displayed their creativity in unexpected ways, meeting broader objectives for the course.❖

Sustainable Infrastructure Engineering Education at University of Toledo

by Defne Apul, Constance Schall, and Cyndee Gruden

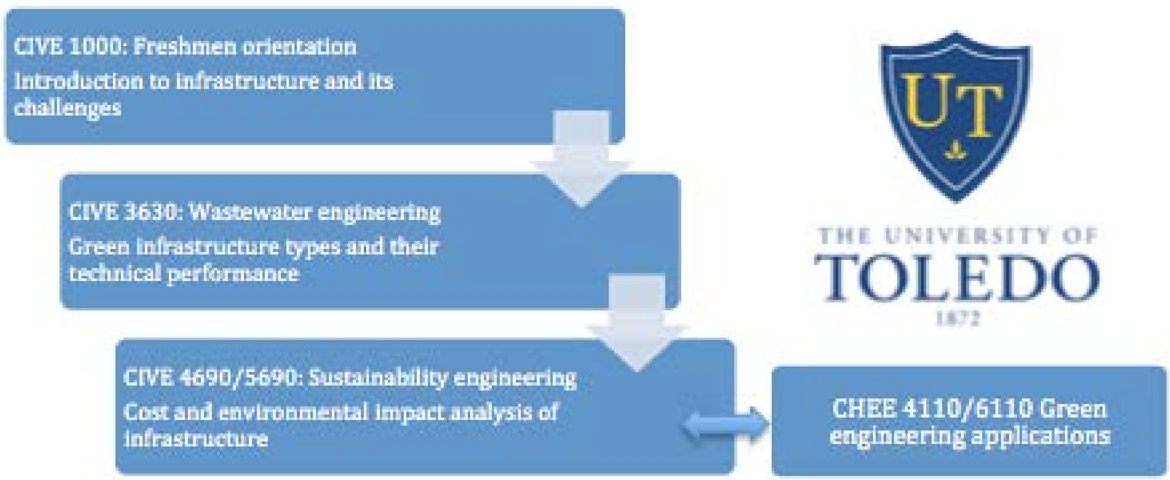

Figure 1: Sequence describing how infrastructure sustainability is taught at University of Toledo Civil Engineering and Chemical and Environmental Engineering Departments.

Design of infrastructure components such as buildings, roads, water, and wastewater systems is typically taught in civil engineering departments. These topics are also being covered in University of Toledo's civil engineering undergraduate curriculum. However, in the past several years, Toledo has made some major strides in modifying the curriculum content and reaching across departments to better prepare the students for designing and analyzing infrastructure systems with sustainability in mind. In this article we briefly review some key elements of the sustainable infrastructure engineering education being taught in civil and chemical engineering departments at University of Toledo.

Civil engineering students in Toledo are learning about different aspects of sustainable infrastructure engineering in three separate courses (Figure 1). The first course in the sequence is CIVE 1000, which is a freshmen orientation course. This is the only course the freshmen take from the department in their first semester on campus. As such, this course plays an important role in orienting students to the civil engineering profession. We designed this course such that civil engineering is introduced to students in the context of infrastructure and its challenges. By approaching the material this way, students develop a perception of civil engineering profession that is founded upon infrastructure engineering.

In CIVE 1000, four assignments are used to introduce students to infrastructure sustainability and engage them in the civil engineering profession (Figure 2). Within a few weeks at the beginning of their freshmen year, students begin working in teams to digest the ASCE report card website. Each team is assigned three to four different infrastructure categories included in the ASCE report card. Teams are tasked to present the status of these infrastructures nationally and in Ohio. This part of the presentation relies heavily on the information they gather from the national and state ASCE report card websites, at http://www.infrastructurereportcard.org/ and http://ohioasce.org/reportcard, respectively. However, students also have to discuss how their assigned infrastructure can withstand changes in input or demands on performance due to climate change. Student presentations on this assignment have been amazing. Instead of the instructor preaching to students that our crumbling infrastructure needs attention, the students learn through teamwork and educate each other

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1. Infrastructure issues	• Each team presents an overview of three to four different infrastructures included in the ASCE report card. They also discuss how climate change may affect the infrastructures.
2. Infrastructure data analysis	• Each student finds and discusses quantitative infrastructure data
3. Comparison of technologies	• Students compare technologies based on four criteria: technical, economic, environmental, and social performance
4. Innovative civil engineering technology	• Students research and discuss what is most exciting in civil engineering

Figure 2: Four assignments used in CIVE 100 Freshmen Orientation class to introduce civil engineering

The agencies responsible for intelligence collection and dissemination have been reorganized as a result of the September 11 attacks. In 2004, based upon the recommendations of the 9/11 Commission, Congress passed and the President signed the Intelligence Reform and Terrorism Prevention Act, which calls for the creation of an Information Sharing Environment (ISE). The ISE is a partnership between all levels of government, the private sector, and foreign partners in an effort to combat the threat of terrorism through the "effective and efficient sharing of terrorism and homeland security information."

While the lawful sharing of collected information regarding terrorism and other criminal activity is a legitimate government need, increasing government authority to collect and disseminate personal information about Americans poses risks to individual privacy and civil liberties.

about deficiencies of current infrastructure and investment needed to make it more robust. Immediately, a clear picture emerges that our infrastructure is in need of repairs and the students themselves can be a part of the solution by joining the civil engineering profession. In these presentations, the infrastructure situation and the effect of climate change on infrastructure can portray a very gloomy scenario. However, the assignment also requires students to discuss success stories in improving infrastructure, thereby, emphasizing that allocation of resources and solid engineering design can lead to amazing outcomes.

In the CIVE 1000 course, the second infrastructure assignment focuses on data interpretation and presentation skills. Students are tasked with finding and discussing infrastructure data in a short report. This assignment was designed to direct students to the different infrastructure-related websites, to introduce them to data driven aspects of civil engineering, and to teach them to effectively use figures in technical reports.

The third assignment requires students to continue working in teams but this time to compare a traditional and a 'sustainable' civil engineering technology based on four criteria: technical, economic, environmental, and social performance. Again, the assignment was carefully crafted to help students frame civil engineering projects and problems not only from a technical perspective but also from the perspective of the three pillars of sustainability that are the economic, social, and environmental dimensions of a problem. This assignment also introduces the students to varying green rating systems since the students are asked to determine if the technologies they are studying can help to earn credits from the LEED green building rating system,[1] the Institute for Sustainable Infrastructure (ISI) rating system,[2]

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[1] U.S. Green Building Council, http://www.usgbc.org.

[2] "Envision™ Sustainable Infrastructure Rating System," *Institute for Sustainable Infrastructure*, accessed November 10, 2014, http://www.sustainableinfrastructure.org/rating/.

(Continued from Page 12)
and the Green Roads transportation rating system.[3]

Lastly, students are asked to find and present on the most innovative civil engineering technologies of our time. This assignment was designed to facilitate the life-long learning outcome. The students again have to present the technical, social, economic and environmental aspects of the technology which further strengthens their multi-faceted approach to evaluating infrastructure. Our course evaluation and freshmen retention rates are very good suggesting that the infrastructure focus we placed in the course using these assignments are well received by the students and likely effective in engaging the students in the civil engineering profession

In CIVE 3630, students continue learning about sustainable infrastructure engineering this time focusing on green infrastructure (GI) technologies (e.g. bioswale, treefilter, raingarden, rainwater harvesting) used in stormwater management. The class is composed of undergraduate students from both civil and chemical engineering departments. Student teams are tasked with the design of a GI technology for managing stormwater at a local site. They also discuss how GI compares to gray infrastructure (traditional stormwater drains). They use the USEPA Stormwater Calculator to compare flows generated before and after the GI implementation. They tour the GI constructed on campus and the stormwater treatment process at the Toledo Water Reclamation Facility. We have collected some student feedback during their last year in our department. Students enrolled in senior design classes expressed enthusiasm about learning GI design approaches, since they view this as a relevant skill in the workplace. In addition, they have become interested in trying to incorporate GI in traditional designs such as transportation projects and building designs.

In CIVE 4690, students get deeper into sustainability analysis, and they apply these higher level skills into analyzing water and energy infrastructures. This course is currently in transition towards being offered fully online. However, its content will include several key assignments that will allow students to economically quantify the environmental benefits of green infrastructure, life cycle assessment of traditional and green infrastructure, inefficiencies of current water and energy infrastructure, and energy payback time (EPBT) of photovoltaic (PV) systems. The students will also learn about the interdependencies of the energy and water infrastructures. The video productions for this course are currently being developed and some of this content will also be taught in a chemical engineering department course (CHEE 4110/6110).

In CHEE 4110/6110, evaluation and improvement in sustainability of chemical manufacturing processes is emphasized. Metrics for social, economic and environmental impacts are developed and applied to these processes. Strategies for minimizing impacts are also developed and applied. Students assess selected manufacturing processes and from their evaluation, it becomes clear that the specific sources of energy (e.g. natural gas, coal, or PV) with its associated infrastructure produce large impacts. Joint assignments between CIVE 4690 and CHEE 4110 have been developed that demonstrate the link between energy infrastructure and sustainability that spans engineering disciplines. An example of this is the evaluation of energy payback time of PV installations through assessment of imbedded energy in manufacture and installation compared to energy production.

Students receive further practice with sustainable infrastructure engineering education in the civil and chemical engineering capstone senior design courses. However, these courses do not always include sustainability assessment or infrastructure assessment.

Within the past decade, University of Toledo had modified the content of its engineering curriculum to incorporate sustainability engineering. With the NSF CIT-E grant, the focus has shifted to infrastructure sustainability and we are now able to train a new cohort of students that can apply the sustainability knowledge and tools to analyze and solve not just general engineering problems, but also infrastructure problems. This transition to focus on infrastructure has also initiated much welcomed collaboration across departments especially on energy infrastructure. ❖

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[3] Greenroads, http://www.greenroads.org.

CE350: Infrastructure Engineering at West Point

by K?H @cp l br Qngrri_

To arrive at solutions to our nation's infrastructure problems, many disciplines must be able to communicate about infrastructure issues from a common basis of understanding. This need for greater communication was one of the driving forces in the creation of CE350: Infrastructure Engineering at the United States Military Academy (West Point). The military focuses on developing leaders who are able to understand, visualize, and describe the solutions to complex situations. That leadership as applied to infrastructure must be able to link the society that is being served by the infrastructure with the technical experts who design and construct the infrastructure, the financiers who fund the projects, and the politicians that represent the will of the people that infrastructure serves. This article describes how the elements of CE350 work to create infrastructure understanding for cadets at West Point.

In CE350, the students come from both the civil engineering major and every other non-engineering major offered at West Point. The civil engineering majors take the course as part of their accredited-degree requirements. The non-engineering majors take the course as part of their three-course engineering sequence (3CES) in analytical thought. The mix of students in CE350 sections varies by semester, but always includes engineers and non-engineers. This mix ensures that the course does not become too technical nor not technical enough, so that all students are engaged by the material. Additionally, the class discussion is enhanced by the diverse skill sets of the students.

The Blocks of the Course. CE350 divides itself into five blocks of instruction.

1. Infrastructure Systems. The Infrastructure Systems block focuses on the Systems Engineering nature of infrastructure. It is

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Figure 1: The CE350 Family of Models are used to guide cadets' understanding of infrastructure.

(Continued from Page 14)

Figure 2: Bringing fire alive in the classroom.

used to draw all students into the material through discussions on the national level of infrastructure that are structured around the Department of Homeland Security's 16 Critical Infrastructure and Key Resource (CIKR) sectors.

2. Water. A human being can only survive for three days without potable water. Distribution of potable water is one of the National Academies of Engineering's grand challenges for the 21st century. Understanding how the nation deals with water and wastewater is necessary for any future leader.

3. Energy. Many argue that water and energy should not be separate sectors, but at the undergraduate level it is easier to understand them separately. This block focuses on the processes and theory required for an individual to turn their lights on and industries to power their processes.

4. Transportation. America is obsessed with its love affair with the automobile. Coming from Michigan, I have seen what the auto industry can do both positively and negatively for a region. Being able to understand a bit more of what it takes to get from point A to B allows students of any discipline to better understand their world. This block goes through basic roadway planning, an overview of railroads, and an introduction to air and sea ports.

5. Military Doctrine and Infrastructure. Being a military academy, one of our stakeholders is the Army officer profession. Cadets are exposed to how the military has changed its view of infrastructure during the past 60 years and how a more informed view of infrastructure may have changed our operational approach in recent conflicts.

The West Point Infrastructure Models. Models are used to understand, visualize, and describe various and complex topics. Studying infrastructure, the student is often overwhelmed by the varied nature of the different intricate systems. West Point has developed a family of models to help students get their mind around the topic. The models have been described in depth in other publications, so only a brief

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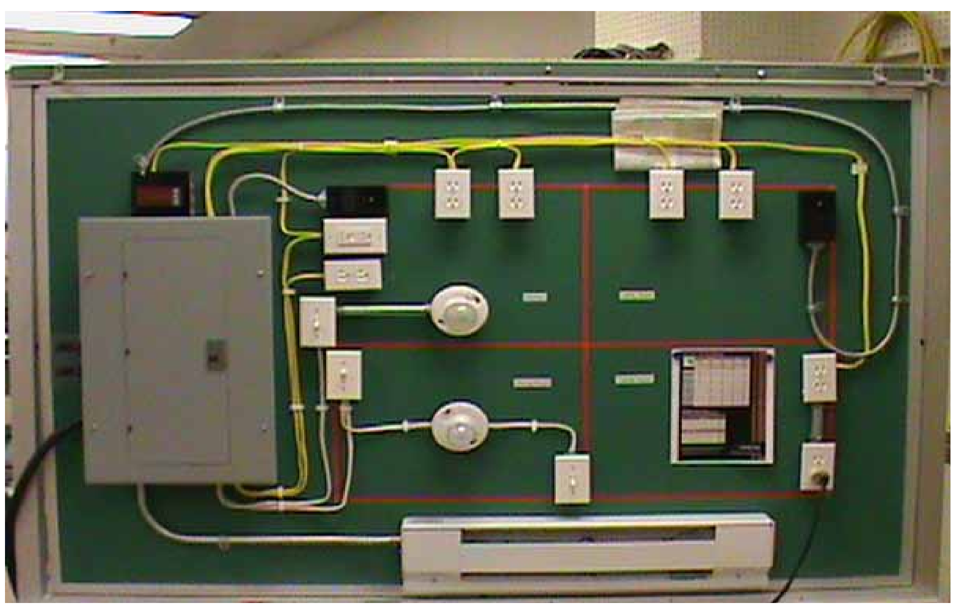

Figure 3: The "Power Board" used during the Power Consumption Laboratory with a live power feed.

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Figure 4: Cadets inspect an emergency backup generator at the West Point Transportation Motor Pool. Photo by Led Klosky.

overview will be given here (See Figure 1). The Component model allows the leader to visualize the infrastructure through six functions (Generation, Bulk Transmission, Distribution, Use, Waste Management, and Coordination). The Assessment model gives a more thorough understanding of the infrastructure through six prompts (Required, Ready, Organized, Tough, Redundant, and Prepared). The Resilience model enables protection through risk-based decision making and three tasks (Survive the Disruption, Defend the Hubs, and Fix the Links). The other models in the family (Development and Environment) are introduced in the class but not dealt with in depth.

The models enable a common basis of understanding because of their simplicity. There are numerous technical details that specific disciplines must address for any of the models to be able to effectively demonstrate how infrastructure functions in real life. These conceptual models allow the discussion to be carried across disciplines in the classroom and beyond.

The Multisensory Experience. Students have a better chance at retaining knowledge when they are able to engage the topic with multiple senses. To this end, the course has several multisensory experiences built into it. Some of those experiences are done in the classroom (See Figure 2).

Power Consumption Laboratory. Electricity is a topic that most students struggle with. After the theory is covered in the classroom, the cadets are exposed to a hands-on laboratory experience that centers around the "Power Board." The board is a mockup of a typical house. Live power is delivered to the board which allows an interactive testing environment that exposes cadets to what happens behind the walls of their house. Circuit breakers are overloaded, components are disassembled, and common safety errors are demonstrated.

Site Reconnaissance. The Army is continuously sending our soldiers to places that are very austere. The need to be able to support life on a base camp is integral to our operational success. To this end, the culminating exercise in CE350 is a field trip to the local transportation motor pool (TMP—where all of West Point's vehicles are stored, fueled, and maintained). The TMP has basic water treatment, wastewater treatment, and power generation capabilities. This gives the cadets the ability to exercise all the knowledge they have gained in the class in a military mission setting. Cadets are able to apply the Component Model, Assessment Model, and Resilience Model as part of the exercise scenario.

The Artwork. The ability to think critically is dependent on remembering the material that has been presented. The final homework assignment highlights the different ways people can activate their brain. Cadets are asked to create a drawing that depicts what they think

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Figure 5: Sample artwork from a former cadet submitted for the final homework of CE350

about infrastructure. The drawing can be anything from stick figures to elaborate pieces of artwork. By allowing cadets to engage another area of their brain through a creative application, the course allows them to further understand the topic (See Figure 5).

The Conclusion. Cadets have found that the multisensory experience of CE350 influenced their overall learning as well as their understanding of infrastructure. This is best described by a quote from one of the course-end surveys from a recent offering of CE350.

"… this course encouraged a more nuanced understanding of 'the problem solving process' that physics and MC300 [Statics and Mechanics of Materials] used. Problems in other West Point classes showed me all the information needed for a problem, and required me to use the principles and equations that I memorized, and spitting out an easy-to-calculate answer. This course encouraged me to challenge given assumptions, make my own assumptions, research their validity, and seek all the information that I needed to solve the problem on my own. Even after all of that initial work, I still needed to critically analyze the problem in the context of all the new information that I brought to the solution. This singular demand makes this course immensely valuable not only as a component of a liberal education, but as a cornerstone in teaching new ways of critical thinking. The second is that infrastructure is just important. Institutions dealing with all of the following depend are intricately interdependent with the state of infrastructure in any given country: domestic political, international political, economic, social, and military. Knowing how to critically analyze the interdependencies improves any student's ability to think of a problem from an interdisciplinary perspective." (A former CE350 cadet)❖

The Goethals' Infrastructure Challenge: www.infrastructurechallenge.org

by Major Berndt Spittka and Steven Hart

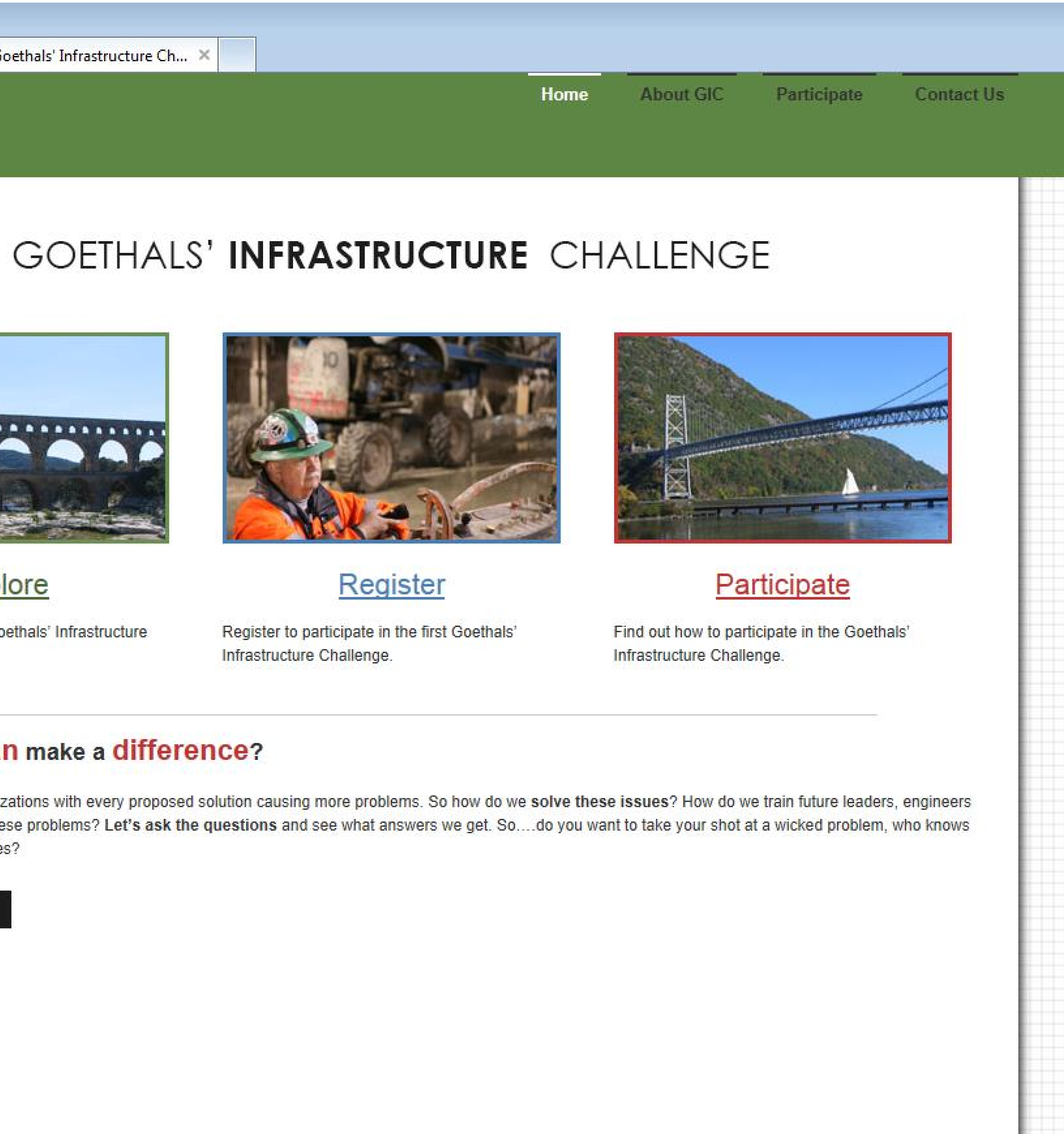

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Figure 2: Thinking hard, yet still smiling. Students wrestle with

Guiding Principle 3: See the Future. The I-35 bridge collapse, New Orleans levees failure during Hurricane Katrina, and the current American Society of Civil Engineers (ASCE) Infrastructure Report Card all paint a bleak picture of our nation's infrastructure. To solve the problem we must be able to see the future we want to create. Without a vision of what our infrastructure can be, we will never be able to solve the wicked problems that we face.

The Problems We Face. The problems of today are not the same as we have faced in the past. The purely technical problem must still be solved in order for a dam or bridge to be built, but before that technical problem can be framed, a broader scope of problem that goes even beyond social, complex, or adaptive-complex must be addressed. The term *wicked problem*, first suggested by Horst Rittel in 1973, has no formal definition but includes several characteristics of the issues we currently face: No stopping rule, no definitive formulation, no right or wrong answer, each solution at-

(Continued on Page 20)

Figure 3: Sample Prompt for previous GIC.

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tempt changes the system.[1] In order to find solutions to problems that morph as we solve them, we must be comfortable with thinking, and not just in our historic discipline lanes.

The Challenge. The challenge itself is based around a website, infrastructurechallenge.org (see Figure 1). All of the prompts, communication with the participants, and proposed solutions flow through the website. This allows the competition to be executed with no travel costs. Teams of up to five people are given 96 hours to propose a solution to a wicked infrastructure problem. The prompts are deliberately ill-structured. Two pictures with minimal words and some stakeholder considerations are all the participants are given (see Figure 3). At the end of the 96 hours, the participants are expected to communicate their solution to a loosely-defined set of stakeholders, usually politicians, investors, technical experts, and the general public. The solution must justify their position while convincing the stakeholders.

We have found that students will attempt anything we ask of them, as long as we are willing to ask. The willingness of students to tackle nearly anything means that the challenge forces its developers to move out of their comfort zone as well. We must ask questions that we do not already know the answer to (something we have all been taught *not* to do). In the end, we must trust that the experience of framing a difficult problem and proposing a solution (all in 96 hours) will leave the students who engage in the challenge better prepared to approach wicked problems in the future.

Self-perceived educational benefits reported by students have found that the competition increased their overall critical thinking, their ability to solve multidisciplinary problems, and integrate numerous factors into their solutions (social, political, economic, technical, sustainability, etc.). Judges also observed that the students ability to think critically and solve multidisciplinary problems increased. A full explanation of the perceived educational benefits of the GIC is available in a previously published ASEE paper.[2]

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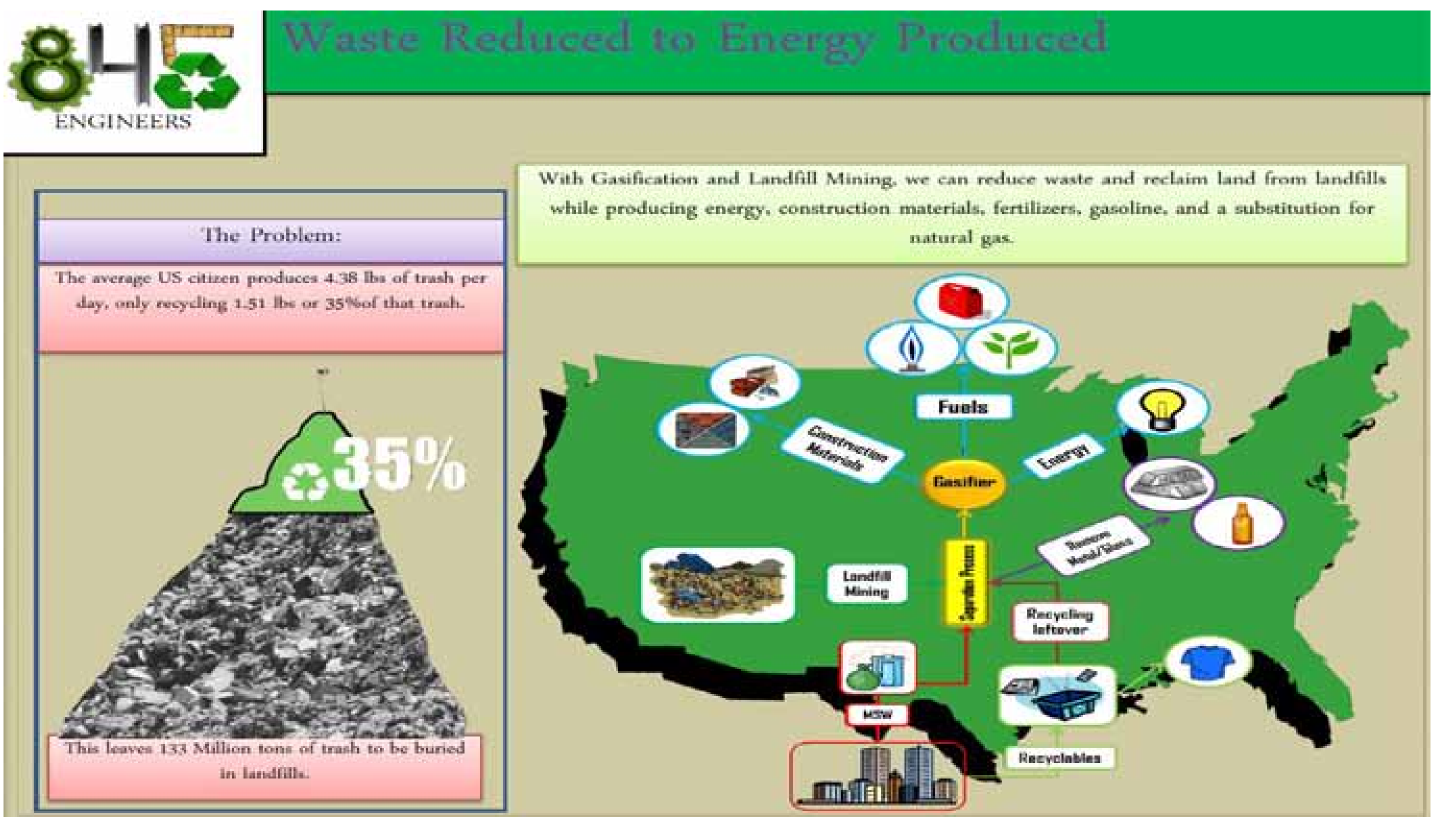

[1] Horst W. J. Rittel and Melvin M. Webber, "Dilemmas in a General Theory of Planning," Policy Sciences 4, no. 2 (1973): 155-169, available at http://www.uctc.net/mwebber/Rittel+Webber+Dilemmas+General_Theory_of_Planning.pdf.

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The Players. The judges come from a variety of disciplines themselves. They are given a loose rubric that consists of six general areas, Problem Framing, Resilience, Sustainability, Viable, Functionality, and Social Value. Each judge rates the overall submission and each of the six areas. We ask that any school who has students participating in the challenge have their faculty participate in the judging. A full description of the GIC development is available in a previously published ASEE paper.[3]

The participants come from the undergraduate to master's degree level of a university. While this is an infrastructure-based challenge, wicked problems cannot be solved by engineers alone. The teams are expected to take a multi-disciplinary approach, but there is no restriction on the training each member should have. The winning teams in the past have had Civil Engineers, Economists, Environmental Engineers, Historians, Nuclear Engineers, Systems Engineers, and Engineering Management Majors. The participants have included foreign language to social science majors. Everybody's viewpoint is important to proposing a solution to a wicked problem, and all are encouraged to add their analysis to a proposed solution as part of the GIC (see Figure 2).

The Prompts. The prompts are centered around infrastructure problems that face our nation (see Figure 3). The teams are given an option of three to five prompts to choose from. Even as we attempt to drive students out of their comfort zones, we still find the students choosing to address prompts that they feel they know more about. The visual representation of the prompts allows the participants to struggle with how to frame the problem before they can start proposing a solution.

The Solutions. In early GIC iterations, the teams were expected to submit a 500 word OpEd, a 60-second video elevator speech, a 7,000 word position paper, and a single PowerPoint slide poster (see Figure 4). We found that the participants attempted to craft answers to the judges' expectations. To correct for this and emphasize the open-ended nature of the competition, there will be no requirement to submit a certain product. Now the teams will simply be told to communicate, justify, and convince stakeholders of the proposed solution.

Spring 2015. The GIC is looking for any students who think they have what it takes to solve a wicked infrastructure-based problem. The complex nature of the problems were inspiring to the students, but the appeal goes beyond just a difficult problem. When asked what they liked about the GIC, students responded: "Working with my team on a project that had no clear answer. It was a great deal of work but it felt like we were really accomplishing something." "I liked the opportunity to approach problems from an interdisciplinary standpoint, rather than just a Civil Engineering one. It made all of our specific skill sets relevant."

For students who want to be the answer to today's wicked infrastructure problems and write the plans that create a path for the future, the GIC is waiting. Students have the opportunity to leave the 96-hour window feeling as the past participants have felt. The challenge will be open from 1 January through 1 May 2015. Each team will need to dedicate up to 96 consecutive hours to complete their proposed solution. If you are interested in participating, please contact the GIC organizers at info@infrastructurechallenge.org. ❖

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[1] Berndt Spittka, Erik R. Wright, Steven D. Hart, and Evan Hansen, "Goethals' Infrastructure Challenge Part 2: The Challenge Begins," 121st ASEE Annual Conference & Exposition (Indianapolis: ASEE, 2014), available at http://www.asee.org/public/conferences/32/papers/10791/view.

[2] Steven D. Hart, Johnette C. Shockley, Leah R. Ellis, and Berndt Spittka, "The Goethals Infrastructure Challenge: A Proposal for a New Student Competition," 120th ASEE Annual Conference & Exposition (Atlanta: ASEE, 2013), available at http://www.asee.org/public/conferences/20/papers/6050/view.

Assessing Student Understanding of Infrastructure Systems using Concept Maps

by Matthew W. Roberts, Carol Haden, M. Keith Thompson, and Philip J. Parker

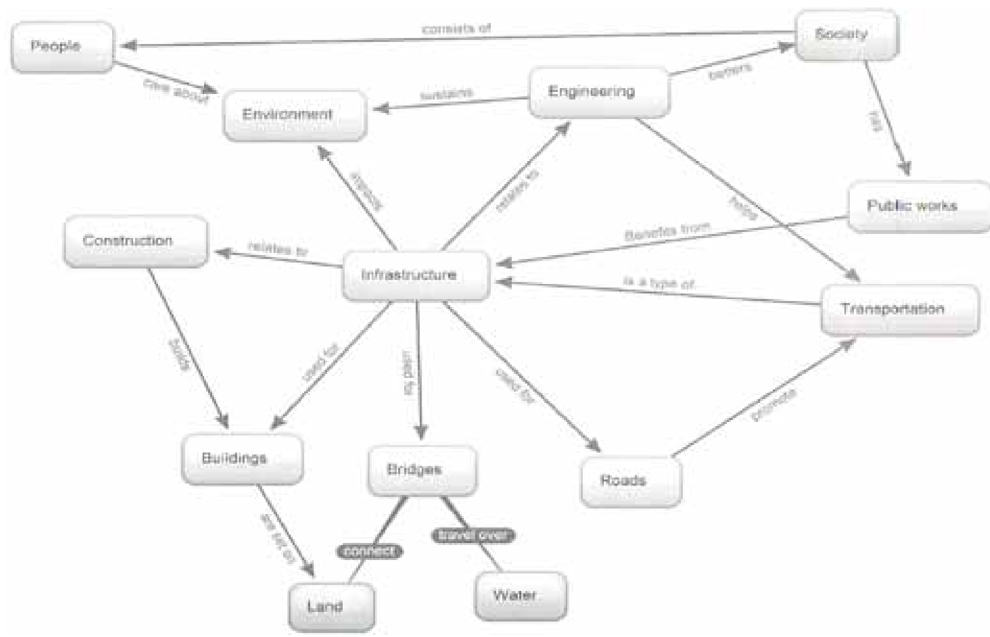

Figure 1 - Student concept map pre-test in the introduction to infrastructure

Background

An Introduction to Infrastructure course was recently developed at UW-Platteville (see the article "Infrastructure Assessments" in this issue for more details on the course). Two of the primary goals of the course are:

1. To introduce the students to the sub-disciplines of civil and environmental engineering while emphasizing the interconnectedness between sub-disciplines.
2. To help students think holistically about civil and environmental engineering, including non-technical and societal aspects of engineering.

In order to assess the effectiveness of the course in meeting these goals, students completed concept maps. Concept maps are diagrams that provide a means of organizing knowledge by identifying key relationships between concepts. They have been used for several decades in all types of courses. In a concept map, concepts are enclosed in circles or boxes with lines linking related concepts together. A word or phrase is written with the linking line indicating the relationship between the concepts.[1] A typical student concept map about infrastructure is shown in Figure 1.

Concept maps are typically created through a series of steps.[2] These include (a) defining the topic or focus question, (b) identifying the key concepts that apply to this domain, (c) ordering concepts from general to specific, (d) drawing links between concepts, (e) creating phrases that describe the link, and (f) cross-linking concepts in different segments or domains of knowledge on the map. When used for assessment, they can be scored quantitatively through techniques involving counting of concepts, links, and propositions, and qualitatively based on the overall morphology of the map.[3]

Assessing Student Understanding

Students in the Introduction to Infrastructure class were asked to develop concept maps about infrastructure. They completed concept

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[1] Joseph D. Novak and D. Bob Gowin, *Learning How to Learn* (Cambridge: Cambridge University Press, 1984).
[2] Joseph D. Novak and Alberto J. Cañas, T*he Theory Underlying Concept Maps and How to Construct and Use Them* (Pensacola: Florida Institute for Human and Machine Cognition, 2006), available at http://cmap.ihmc.us/Publications/ResearchPapers/TheoryUnderlyingConcept%20Maps.pdf.
[3] Mary Besterfield-Sacre, Jessica Gerchak, Mary Rose Lyons, Larry J. Shuman, and Harvey Wolfe, "Scoring Concept Maps: An Integrated Rubric for Assessing Engineering Education," *Journal of Engineering Education* 93, no. 2 (April 2004): 105-115; Charles R. Ault Jr., "Concept Mapping as a Study Strategy in Earth Science,"

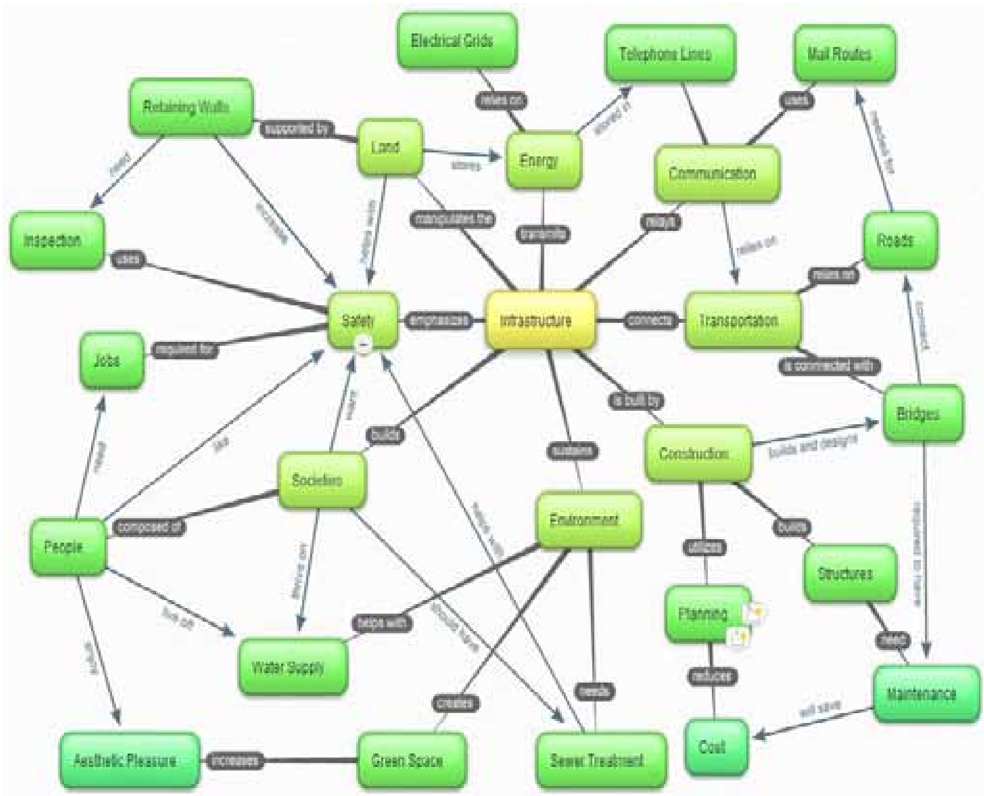

Figure 2 – Student concept map for the post-test. This was submitted by the same student who submitted the sample in Figure 1.

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maps prior to the start of the semester (pre-test) and at the end of the semester (post-test.) In both cases the students were asked to create a concept map using the focus question, "What is infrastructure?" The pre-test was e-mailed to the students before class had started and students were required to complete the work before the first lecture period. Figure 1 shows a representative concept map completed by a student for the pre-test. Figure 2 shows a concept map submitted as the post-test, which was completed as a take-home portion of the final exam.

The concept maps were scored by summing the number of concepts or links in the following six categories:[4]

1. The number of infrastructure "components" (e.g., roads, bridges, wastewater treatment plants, etc.) listed as concepts
2. The number of infrastructure "sectors" (transportation, structures, flood control, etc.) listed as concepts or implied by the infrastructure components
3. The number of correct links between technical concepts. The technical concepts were infrastructure components (item #1 in this list), infrastructure sectors (item #2), or engineering concepts (item #6)
4. The number of concepts for non-technical aspects of infrastructure (e.g., economic growth, ethics, pollution, etc.)
5. The number of correct links between a non-technical concept (item #4) and any other concept
6. The number of engineering concepts (e.g., constructability, design, resilience, etc.)

We initially planned to have the concept maps scored by a trained evaluator who did not have extensive civil engineering infrastructure expertise. However, as mentioned by Cañas et al. (2003)[5], it soon became clear that deep conceptual understanding was needed to evaluate the student concept maps, so course instructor should score the concept maps. The results presented here come from Spring 2013, comprised of 49 total students in two sections with two different instructors. To increase reliability in scoring, one of the instructors scored all of the concept maps.

Results

The radar chart in Figure 3 shows the average student pre-test and post-test concept map scores for each of the six categories mentioned above. The findings from the data analysis show that:

- Average student scores improved in each of the six categories from pre-test to post-test;
- There was not a statistically significant increase from pre-test to post-test in the number of *infrastructure components* identified or the number of *non-technical links*;
- The increase in the number of *infrastructure sectors* identified was statistically significant, but students, on average, did not identify a large

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[6] Roberts et al., "Assessment of Systems Learning."

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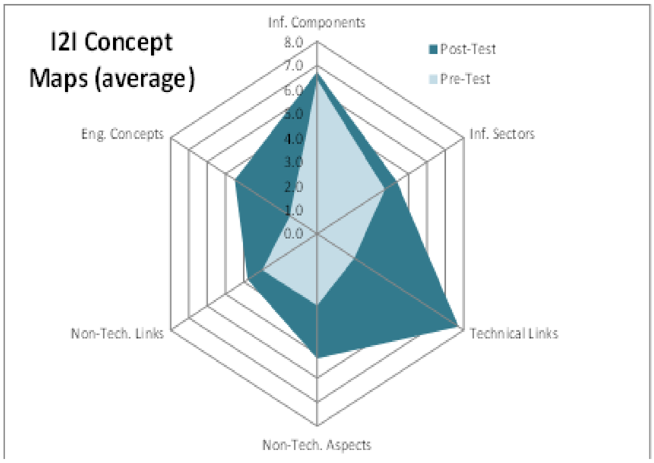

Figure 3 - Pre- and Post-test concept map average student scores for the six categories (n=49).

number of infrastructure sectors on either the pre- or post-test; and

- There were statistically significant gains in the number of *technical links, non-technical aspects,* and *engineering concepts* identified on student concept maps.

A more complete statistical analysis is presented in Roberts, et al., (2014).[6]

Conclusions

Based on the results of the pre- and post-tests, the following conclusions are worth noting:

- The large and statistically-significant gain in the number of technical links indicates that the course is helping students to see connections between the technical areas of civil engineering and infrastructure. Helping students to see these connections was a primary goal of the course.
- The statistically-significant increase in the number of non-technical aspects of infrastructure identified by students on their concept maps indicates that the course is helping students to achieve the course goal of thinking holistically about non-technical and societal aspects of engineering.
- The small gain in the number of infrastructure sectors identified was somewhat disappointing. This seems to indicate that students are not becoming more aware of the various types of infrastructure found in the built environment. As can be seen in Figure 4, a very high percentage of students identified infrastructure in the transportation (roads, highways, etc.) and structural (buildings, bridges, etc.) sectors. This seems to indicate that course content is focused too much on these more prominent aspects of the infrastructure and that more discussion of the full variety of infrastructure would be helpful.
- While there was an increase in the number of non-technical links on the student concept maps, the increase was not statistically significant. This would suggest that instructors need to be more explicit about making connections between course modules, particularly concerning non-technical aspects. Concept maps are a particularly powerful way to determine the knowledge gains of students with respect to infrastructure topics and the cognitive links they make between technical and non-technical aspects of engineering.

Acknowledgements

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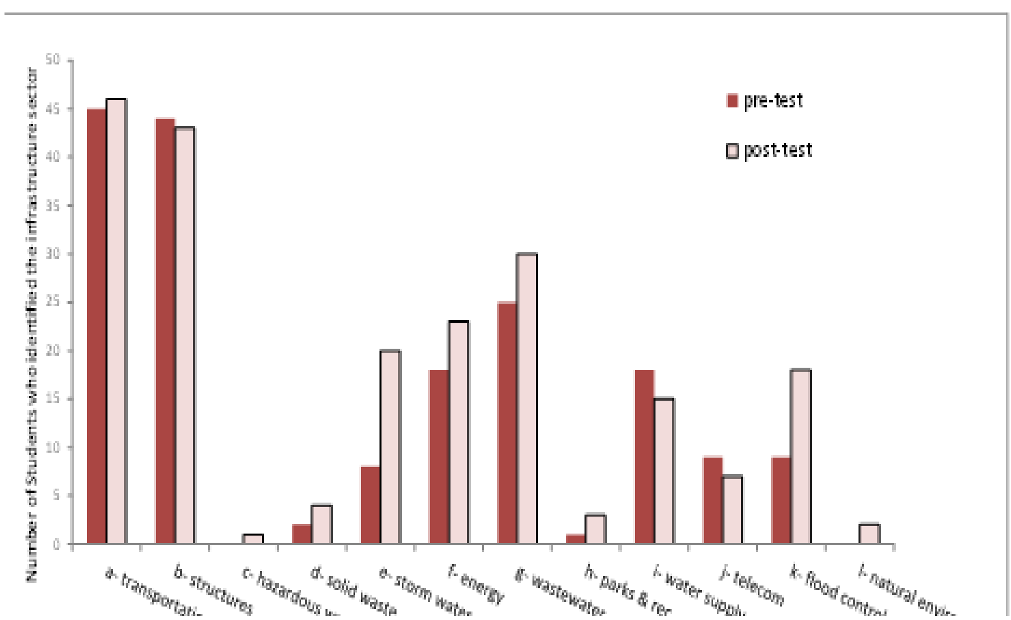

Figure 4 - Sectors identified on student concept maps (n=49)

Development of an Infrastructure Views Survey

by Matthew W. Roberts and Steve Barney

The current U.S. infrastructure crisis finds its roots in a lack of public awareness of the importance and the financial commitments necessary to maintain and enhance the infrastructure. Recent water main ruptures in Atlanta and Los Angeles have brought to light an aging infrastructure that is "out of sight, out of mind."[1] A first step in addressing lack of awareness of infrastructure is to measure public perceptions and attitudes about infrastructure. With this in mind, an "Infrastructure Views Survey" is currently under development. This report documents the efforts to develop the survey and explains how it will be used.

With support from the National Science Foundation, several universities across the United States are implementing content on infrastructure into engineering curricula. In order to assess the impact of this new content, students will complete the Infrastructure Views Survey, which will seek to determine the students' (1) understanding of the importance of infrastructure to society, (2) appreciation of the infrastructure problems in the US, (3) understanding of the potential solutions to infrastructure problems, and (4) interest in infrastructure challenges and solutions, including the pertinence of infrastructure management to their future careers.

The Infrastructure Views Survey is currently under development by a collaboration with engineering educators and the Psychology Department at Southern Utah University (SUU). The development of the survey will be performed by students in the *Principles of Assessment* class at SUU. The psychology students will be given information about infrastructure and the current state of America's infrastructure in order to give them background knowledge. Using information and feedback from engineering educators, the students will develop the survey questions and then work with focus groups to calibrate the questions for reliability. The engineering educators will ensure that the survey covers important aspects of infrastructure while the psychology students will do the work to create the survey, pilot the survey, and develop guidelines for analyzing and interpreting the results.

When completed, the Infrastructure Views Survey will be used to measure changes in engineering student attitudes about infrastructure resulting from what they learn in class. The survey will be administered as a pre-test to gauge civil and environmental engineering students' initial awareness and appreciation of infrastructure. After completing the course, students will again take the survey as a post-test. The results of the survey will be analyzed to gauge the impact that the course materials have had on the students' understanding and appreciation of the current state of infrastructure and the importance of infrastructure to their standard of living.

While the initial purpose of the survey will be to assess student learning, it is anticipated that a modified version of the survey will also be useful in measuring the attitudes of the general public regarding infrastructure. The survey will be further refined after the first student results are analyzed. Eventually, the survey could be used to provide valuable information about public perception of infrastructure to policy makers, business leaders, and educators in a variety of disciplines. ❖

[3] Mark Strassmann, "America's Aging Water Infrastructure Raises Safety Concerns," CBS News (August 9, 2014), available at http://www.cbsnews.com/news/americas-aging-water-infrastructure-raises-safety-concerns/.

Infrastructure Education Using Extreme Storm Impact

by Joseph A. Daraio and Ralph A. Dusseau

Introduction

In spring 2015, Rowan University will begin offering a new course titled "Introduction to Infrastructure" that will be required for all first-year students in the civil and environmental engineering (CEE) program. Seniors in our program have often commented that they do not have a good understanding of what CEE is, and what civil and environmental engineers *do* until they are juniors. One of the goals of this course is to provide students with an early exposure to the practice of CEE and its importance to society. We will analyze retention rates to assess if the new course better prepares students and affects their motivation to continue in the CEE program. The primary goal of the course is to introduce first-year CEE students to civil infrastructure. Additionally, given the current state of infrastructure in the United States, the development of this course is of particular importance to the education and development of future engineers. In fact, this is the primary reason why Rowan University joined the effort led by UW-Platteville[1] and West Point[2] to improve infrastructure education in the US.

Our course will be a 2-credit lecture course consisting of two 75-minute periods per week of about 40 students per section. It will include sections on structural systems, foundations, transportation systems, water and environmental systems, as well as a general overview of the state of infrastructure in the US. Throughout the course, we will emphasize how the quality of infrastructure directly affects the economy and security of the US, and that the next generation of civil and environmental engineers needs to be more skilled and more able to design and create sustainable infrastructure. The authors will team-teach the course, with one section officially assigned to each faculty member. Dr. Dusseau will teach structural systems and foundations in both sections, and Dr. Daraio will teach water resources and environmental engineering in both sections. A key challenge in teaching this course is highlighting the interdependence and integrating infrastructure sectors for students. We intend to accomplish this through an emphasis on the impacts of extreme storms on infrastructure.

Water Infrastructure and Water's Impact on Civil Infrastructure

The course will include broad coverage in water resources and environmental infrastructure, including distribution systems, storm water, dams and levees, and water and wastewater treatment. Rowan University is located in southern New Jersey, and the majority of our students were born and raised in the state. This provides us with an opportunity to emphasize the impacts of extreme events on water infrastructure. Superstorm Sandy hit New Jersey in October 2012 with significant direct impacts on New Jersey's water infrastructure and significant impacts on other infrastructure due to storm surge and flooding. In particular, the storm caused major damage in coastal

(Continued on Page 27)

[1] Matthew W. Roberts, Philip J. Parker, Michael K. Thompson, and Barb A. Barnet, "Development of an Introduction to Infrastructure Course," 118th ASEE Annual Conference & Exposition (Vancouver; ASEE, 2011), available at http://www.asee.org/public/conferences/1/papers/746/view.

[2] Steven D. Hart, J. Ledlie Klosky, Joseph P. Hanus, Karl F. Meyer, Jason Allen Toth, and Morgan Reese, "An Introduction to Infrastructure for All Disciplines," 118th ASEE Annual Conference & Exposition (Vancouver; ASEE, 2011), available at http://www.asee.org/public/conferences/1/papers/293/view.

[3] Matthew J.P. Cooper, Michael D. Beevers, and Michael Oppenheimer, Future Sea Level Rise and the New Jersey Coast: Assessing Potential Impacts and Opportunities (Princeton, NJ: Princeton University, 2005), available at https://www.princeton.edu/step/people/faculty/michael-oppenheimer/recent-publications/Future-Sea-Level-Rise-and-the-New-Jersey-Coast-Assessing-Potential-Impacts-and-Opportunities.pdf.

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counties in New Jersey. New Jersey's coastal counties are home to approximately 60 percent of the state's total population,[3] and this is reflected in the student population at Rowan. Many of Rowan's students were either directly affected by the storm or knew someone who was affected.

Dr. Daraio will discuss the fact that a large range of the state's infrastructure was badly damaged by the storm, including roads, bridges, electrical systems, and water infrastructure. Broader impacts include the fact that the storm resulted in 34 deaths across New Jersey (out of a total of 125 in the US), and economic losses were estimated to be at least $7.1 billion for New Jersey in just the final quarter of 2012,[4] while the total economic cost is still to be determined. Water and wastewater infrastructure sustained an estimated $2.7 billion in damages as a direct result of the storm.[5] Storm water sewer lines were blocked contributing to flooding, almost 100 wastewater treatment systems either failed or had significant interruptions in service, and the loss of electrical power caused many others to go offline.[6] Over 70 percent of New Jersey's water supply systems were impacted by the storm, mostly due to loss of power, and approximately 360,000 residents were under a boil water advisory, of which around 10,000 homes in Ocean County were still under a boil water advisory after one month.[7] Students will choose locations (most likely their home towns) and prepare reports on impacts to various sectors of infrastructure.

While a little less close to home for Rowan students, the importance of civil engineering infrastructure for the protection of lives and property was clearly demonstrated during Hurricane Katrina.[8] The storm struck on August 29, 2005. Two days later 80 percent of New Orleans was under flood water, and some parts of New Orleans were left under as much as 20 feet of water. The extensive flooding was caused by a combination of strong winds, heavy rainfall, and storm surge. Out of a total of 284 miles of federal levees and floodwalls in New Orleans, 169 miles were damaged. Many pumping stations in New Orleans were left either inaccessible or inoperable by the flooding. Bridges along interstate highway I-10 and along US highway 90 in Louisiana, Mississippi, and Alabama were extensively damaged or destroyed by storm surge, by wind, and/or by wave action. Many other federal, state, and local bridges in all three states were also severely damaged or destroyed by the storm. The transportation systems and subsequent relief and reconstruction efforts in Louisiana, Mississippi, and Alabama were severely disrupted by these bridge failures. Dr. Dusseau will discuss these impacts and how students and faculty from Rowan University helped to play a role in the relief effort for New Orleans. Teams of Rowan students, as part of their Junior/Senior Engineering Clinic courses, traveled to New Orleans in 2005, 2006, and 2007 to assist with relief, cleanup, and reconstruction. In addition, Rowan University played host to students from New Orleans who were displaced by the flooding. Students will have the opportunity to compare the impacts of Sandy and Katrina, and assess and critique infrastructure recovery efforts in both areas.

Conclusion

We believe the emphasis on the impacts of extreme events on civil infrastructure will provide a strong point of interest with students. It is likely this interest will be even greater at Rowan because a majority of our students were either directly or indirectly affected by Hurricane Sandy. Additionally, as the impacts of climate change

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4 New Jersey Department of Community Affairs, Community Development Block Grant Disaster Recovery Action Plan (Trenton, NJ: New Jersey Department of Community Affairs, 2013), available at http://www.nj.gov/dca/announcements/pdf/CDBG-DisasterRecovery-ActionPlan.pdf.
5 Ibid.
6 Ibid.
7 Ibid.
8 New Jersey Department of Community Affairs, Community Development Block Grant Disaster Recovery Action Plan (Trenton, NJ: New Jersey Department of Community Affairs, 2013), available at http://www.nj.gov/dca/announcements/pdf/CDBG-DisasterRecovery-ActionPlan.pdf.
9 Ibid.

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have become measurable and as climate change projections suggest increased frequency and intensity of extreme events, the need to account for climate change in design for infrastructure is becoming more clearly recognized.[10] Design that accounts for climate change is vital to increase reliability and decrease the nation's risk and vulnerability to the failure of infrastructure in the future. Finally, we are hoping that the emphasis on extreme storms will help us highlight the connection of all civil infrastructures by providing students with a unifying context. ❖

[10] Kevin Wilcox, "Planning for Climate Change," Civil Engineering 84, no. 9 (2014): 62-65, available at http://cedb.asce.org/cgi/WWWdisplay.cgi?323342.

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