4-1-2017

Inclusion of an Introduction to Infrastructure Course in a Civil and Environmental Engineering Curriculum

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Accepted version. *Journal of Professional Issues in Engineering Education and Practice*, Vol. 143, No. 2 (April 2017). DOI.

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Civil and Environmental Engineering Faculty Research and Publications/College of Engineering

Journal of Professional Issues in Engineering Education and Practice, Vol. 143, No. 2 (2017): 04016020-1-04016020-8. DOI.

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Abstract

Civil infrastructure refers to the built environment (sometimes referred to as *public works*) and consists of roads, bridges, buildings, dams, levees, drinking water treatment facilities, wastewater treatment facilities, power generation and transmission facilities, communications, solid waste facilities, hazardous waste facilities, and other sectors. Although there is a need to train engineers who have a holistic view of infrastructure, there is evidence that civil and environmental engineering (CEE) programs have not fully addressed this increasingly recognized need. One effective approach to address this educational gap is to incorporate a course related to infrastructure into the curriculum for first-year or second-year civil and environmental engineering students. Therefore, this study assesses the current status of teaching such courses in the United States and identifies the incentives for, and the barriers against, incorporating an introduction to infrastructure course into schools' current CEE curricula. Two distinct activities enabled these objectives. First, a questionnaire was distributed to CEE programs across the United States, to which 33 responses were received. The results indicated that

although the majority of participants believe that offering such a course will benefit students by increasing the breadth of the curriculum and by providing a holistic view of CEE, barriers such as the maximum allowable credits for graduation, the lack of motivation within a department—either because such a course did not have a champion or because the department had no plans to revise their curriculum—and a lack of expertise among faculty members inhibited inclusion of the course in curricula. Second, three case studies demonstrating successful inclusion of an introduction to infrastructure course into the CEE curriculum were evaluated. Cases were collected from Marquette University, University of Wisconsin-Platteville, and West Point CEE programs, and it was found that the key to success in including such a course is a motivated team of faculty members who are committed to educating students about different aspects of infrastructure. The results of the study can be used as a road map to help universities successfully incorporate an introduction to infrastructure course in their CEE programs.

Introduction

Infrastructure is a platform for governance, commerce, and economic growth and is a lifeline for modern societies. Coping with global climate change, managing energy crises, and finding innovative ways to address sustainability challenges require close collaboration among professionals in multiple engineering, social, and science fields. To successfully address complex, contemporary challenges related to infrastructure, educational institutions must train engineers to not only develop a deep knowledge of a single discipline but also to be able to collaborate across disciplinary boundaries (Richter and Paretti 2009).

The American Society of Civil Engineers (ASCE) recognizes that the infrastructure of the future will require transformation in the role and development of engineering professionals. In *The Vision for Civil Engineering in 2025*, ASCE envisions that “civil engineers will serve as master builders, environmental stewards, innovators and integrators, managers of risk and uncertainty, and leaders in shaping public policy” (ASCE 2007, p. 2). Although engineering graduates from most civil engineering programs across the United States have a well-rounded knowledge of the field’s technical issues, they generally are underprepared to engage in the multidisciplinary problem solving required for environmental stewardship, innovation, risk management, and public policy.

The National Academy of Engineering (NAE) also discusses this shortcoming in the typical approach to engineering education. In *The Engineer of 2020*, the NAE describes how engineers will have to solve technical problems in a social-political-economic context that includes issues of sustainability, changing demographics, security, emerging technologies, and increased urbanization. The NAE further alludes to engineers moving beyond traditional technical fields and “[assuming] leadership positions from which they can serve as positive influences in the making of public policy and in the administration of government and industry” (NAE 2004, p. 50). Though these organizations continue to appreciate that learning theoretical concepts is necessary for success as an engineer, they underscore the reality that simply learning theory and skills will no longer be sufficient in the near future.

One effective approach to address this educational gap is to incorporate a course related to infrastructure into the curriculum for first-year or second-year civil and environmental engineering students. The authors have conducted a study to assess the current status of teaching such courses in the United States and to identify incentives for, and barriers against, incorporating an introduction to infrastructure course into the current civil and environmental engineering (CEE) curriculum. Information was obtained using a questionnaire that was distributed to CEE programs across the United States. Additionally, three case studies demonstrating successful inclusion of an introduction to infrastructure course into the CEE curriculum were evaluated. The results of the study were synthesized to create a plan to help universities successfully incorporate an introduction to infrastructure course in their CEE programs.

State of the Field

Although the importance, extent, and complexity of infrastructure has evolved in the past century, the current CEE curriculum has not kept pace to prepare civil and environmental engineers for 21st century challenges. A literature review reveals the limitations in the current body of knowledge. The most important issues that come to light in the review include the transformation of infrastructure through time, the shortcomings of CEE curricula, and the current practices in teaching infrastructure-related courses in the United States. The salient findings are summarized below.

Prioritization and Scope of Infrastructure in Recent History

United States government agencies have regularly updated the definition of infrastructure. In the 1980s, the Congressional Budget Office limited the definition of infrastructure to public works that were considered critical for economic activity, including “highways, public transit, wastewater treatment, water resource works (ports, canals, dams, etc.), airports, and municipal water supplies” (CBO 1984, p. 15). In 1988, the National Council on Public Works Improvement added bridges, intermodal transportation, and solid and hazardous waste management to this list (National Council 1988). The inclusion of solid and hazardous waste management was significant as the inclusion signified that the Council recognized that some traditionally private ventures should be counted as infrastructure.

In 1997, the list was expanded once again when national security threats began to influence what was considered infrastructure. President Clinton’s Commission on Critical Infrastructure Protection included all of the categories previously mentioned plus emergency services, government services, banking and finance, oil and gas, electricity, and telecommunications (President’s Commission 1997). The Commission was also quite clear in defining infrastructure management as a shared responsibility of public and private interests. In 1998, ASCE published its first Report Card on the Nation’s Infrastructure, which at that time was not as inclusive as the Clinton Commission list, citing only traditional civil engineering works; however, energy was added as a sector to the 2013 Report Card

(ASCE 2013). The last notable expansion of the infrastructure *laundry list* occurred with the creation of the Office of Homeland Security, which included everything that had been listed previously but also added chemical facilities, agriculture and food, commercial facilities, national monuments, and the defense industrial base—i.e., private companies and the few government-owned facilities that manufacture military equipment (Homeland Security Council 2007). Seemingly, infrastructure currently includes almost everything.

Among the various documents defining the scope of infrastructure, the ASCE Report Card deserves special note. The first infrastructure report card predates ASCE's Report Card, and appeared in the 1988 *Fragile Foundations* Report by the National Council on Public Works Improvement (at that time, infrastructure received an average grade of C; National Council 1988). Since then, the Report Card has been an evolving document, adding sectors and refining the grading process; however, the document has remained consistent in one aspect: it motivates change in infrastructure policy (Grigg 2014). The Report Card was created to act as a simple and familiar metric for quantifying infrastructure conditions, one that could be understood by politicians (and their public constituencies), who generally do not have engineering degrees but who control infrastructure spending. The grades themselves and the criteria for assessing them are debatable, but few parties disagree that U.S. infrastructure is overstressed and undermaintained. However, despite much movement in public awareness, after 25 years, little positive change in public infrastructure funding has occurred—in fact, the gap between the recommended infrastructure budget and the actual budget has increased each year that it has been tracked on the Report Card (ASCE 2013).

Shortcomings of CEE Curricula

Although there is a need to train engineers who have a holistic view of infrastructure, CEE programs do not fully address this increasingly recognized need. Russell and Stouffer (2005) conducted a comprehensive study of the CEE curricula in the United States. They surveyed more than 40% of the nation's undergraduate CEE programs and found that the curricula are highly specialized in terms of technical subjects but lack focus regarding the liberal arts, professional skills, and systems thinking. The study concluded that current CEE curricula are too specialized and do not help students integrate multiple engineering and science disciplines. Research conducted by Richter and Paretti (2009) showed that students usually cannot connect interdisciplinary subjects to their own areas of expertise; moreover, students often fail to identify and value the contributions that multiple fields make to complex problems. The multifaceted nature of contemporary engineering work is highlighted in several studies around the world (Markes 2006; Harrison et al. 2007; Spinks et al. 2007), all of which speak to the need for a broader lens on the topic of interdisciplinary focus.

One of the main limitations of the current general CEE curriculum is that it requires students to learn via courses whose relationships to one another and to the engineering process are not explained until late in a baccalaureate education (Bordogna 1998). In fact, most CEE curricula focus on developing specialized courses (Bonasso 2001) in spite of the fact that solving unique infrastructure problems in contemporary society requires a more holistic view to visualize alternative scenarios and to think in terms of large, complex systems. Rather than a piecemeal approach, Bordogna (1998) advocated for a new philosophy to look at the problem as a whole and claimed that addressing this problem calls for a new focus on the integrative nature of engineering and on programs that train engineers as *master integrators*. Integrating a course into the curriculum that educates first-year or second-year students about general concepts of infrastructure systems can help provide this focus.

Research Methods

In February 2015, an online survey was developed and distributed among 238 CEE program chairs or directors across the United States. Respondents were asked to identify their institution, years of experience, state, and other demographic information. They were asked to indicate whether they were offering a course related to infrastructure, and if they were, to provide details about the size of the class, semesters it was offered, participation of other majors in the class, and whether it was a required course. Respondents' opinions regarding the incentives for, and barriers to, the inclusion of an introduction to infrastructure course in the current CEE curriculum were solicited. Furthermore, the questionnaire posed several open-ended questions that asked respondents to identify the steps universities need to take to offer a course on infrastructure. The last part of the questionnaire invited respondents to provide a list of knowledge, attitudes, and skills needed to develop a well-designed infrastructure course.

In addition to distributing surveys, three case studies were evaluated to further investigate current practices of including an introduction to infrastructure course in CEE programs. The focus of the case studies was to identify the driving force behind incorporation of the course, areas and disciplines covered in the class, and the specific benefits that emerged. The experiences implementing an introduction to infrastructure course into the CEE curricula at Marquette University, University of Wisconsin-Platteville, and West Point are considered here. Case studies were an important component of this study as little is known about current practices regarding the incorporation of introduction to infrastructure courses into existing curricula. Such case studies provide a strong assessment methodology in instances where the nature of research questions is exploratory, the research team cannot control the site and participants, and the phenomenon under study is contemporary (Yin 2003). The results of the survey and case studies are summarized in the following section.

Questionnaire Results and Discussion

In total, 33 chairs or directors of CEE departments from institutions in 24 states across the United States responded to the survey (Fig. 1). They reported an average of 22 years of experience (SD=10.1). Responses revealed that 40% (13) of the universities represented in the survey had a semester-long course dedicated to infrastructure, and 60% (20) did not have such a course. Among respondents whose institutions did not have a course specifically related to infrastructure, only 10% (2 out of 20) had a plan to incorporate such a course in their curricula within the next two years.

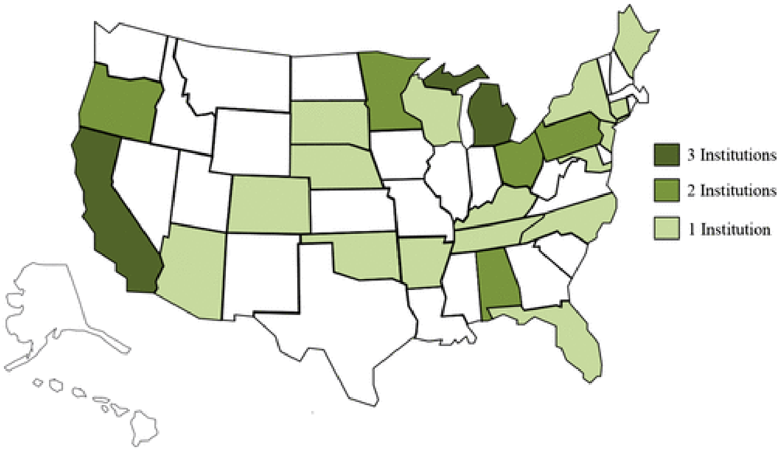

Fig. 1. Distribution of survey respondents across the United States

Incentives and Barriers to Incorporating an Infrastructure Course

One objective of the study was to explore the potential incentives of developing a course specifically related to infrastructure for civil or environmental engineering students. Therefore, respondents were asked to identify the incentives of incorporating an infrastructure course into their curricula. Responses showed that such a course can increase the breadth of the curriculum and provide a holistic view of CEE (67%), provide better training and skill sets for students who graduate from the program (19%), and motivate students to consider infrastructure as their professional career (14%). One of the respondents mentioned that this course links the curriculum to *real-world* issues and careers. Another stated that it provides "a blanket view of the problem." It can be concluded that a majority of CEE programs would see benefits in providing a course specifically related to infrastructure.

Respondents identified several barriers to incorporating an infrastructure course in a CEE curriculum. The first major barrier to introducing an infrastructure course is a lack of resources, as identified by 11 out of 21 respondents (53%). The most important resource for such a course is a qualified and interested teacher to lead the course. Many universities cited an inadequate number of faculty members to introduce this course. Lack of other resources such as textbooks and course materials were also mentioned as potential barriers. Previous studies showed that providing additional case studies, textbooks, and other publications can facilitate incorporation of a new course into a curriculum (Rens et al. 2000). Respondents were asked whether they would consider offering an infrastructure course if they were provided with a complete course package (consisting of course notes, homework assignments and solutions, and project assignments) as well as instructor training. Six respondents said they would definitely offer the course under these circumstances, and 19 said that they might offer the course. Only one respondent stated that providing course materials would not impact their decision, and they did not plan to offer this course in future.

The second barrier, mentioned by 10 out of 21 respondents (47%), cited the restrictions created by credit loads. Respondents stated that too many other courses compete for limited credit hours, and it was not clear if this new course would satisfy any of the ABET requirements. They mentioned that the number of credits to graduate had been reduced by state law for many universities. Some of the respondents also stated that they did not have the capacity in their curriculum to offer the course. Credit-hour constraints were reported in previous studies, as well. Rens et al. (2000) found that although a majority of colleges recognized the importance and need to provide failure analysis topics in CEE courses, they also felt the undergraduate curriculum was already crowded. In fact, compared to 1950s curricula, which included 140 credit hours, the number of credit hours has decreased in most CEE programs (Pennoni 1992). A solution to credit hour restrictions can be the development of an integrated curriculum. Grigg et al. (1996) used an integrated curriculum as an option for accommodating new topics without increasing the number of courses. They drew material from different areas to teach CEE students about design and problem solving. The results of their experience showed that an integrated approach can be used to cover crosscutting subjects without creating additional separate courses.

The third most common response for not developing a course specifically related to infrastructure stemmed from a lack of motivation in the department, as mentioned by 5 out of 21 respondents (24%). For example, some respondents stated that the infrastructure course was not among the highest priorities of their department and there did not seem to be a demand for such a course. These respondents also mentioned that they already had courses devoted to specific aspects of infrastructure—such as energy—and that each area of concentration preferred to discuss infrastructure from its own perspective. Therefore, the faculty did not see the need to offer a holistic course about infrastructure. The responses made clear that there is a need for a champion in the department who is willing to take the lead and initiate such a change.

Another barrier was class size, mentioned by 2 out of 21 respondents (10%). When a class is not required by the department, there are often fears about low enrollment. In addition, nonrequired courses often lead students to perceive that the course does not apply to them. Another barrier mentioned by a respondent was that this course might weaken the program by reducing the students' ability to study a particular subdiscipline in greater depth. Others said a single semester course is not long enough to provide depth of coverage and some freshmen might not be adequately prepared for advanced topics. They also stated that obtaining adequate real-world examples would be difficult.

Respondents also addressed the steps universities need to follow to overcome these barriers. General consensus identified three critical steps: (1) convince the faculty of the need for the course by highlighting the importance of the topic and receive departmental approval; (2) increase the number of credits in the curriculum, remove a course from the curriculum, or change the content in existing courses to incorporate infrastructure topics; and (3) provide resources, such as course materials.

Focus Areas of an Infrastructure Course

Survey respondents were asked to identify areas of knowledge, attitudes, and skills that should be incorporated into introductory infrastructure courses. These knowledge areas were mentioned by the respondents: sustainability, historical perspectives, the evolution of infrastructure, societal issues, racial issues, communications, plan reading, urbanism, failing infrastructure (transportation, water supply, etc.) in the United States, the importance of infrastructure and the manner in which it is designed and constructed, the role of civil and environmental engineers in infrastructure development and preservation, design aspects, approaches to open-ended design problems, and contributions of multiple disciplines to a project's success.

In particular, sustainability was a knowledge area mentioned by several respondents. Previous studies show that there is an emergent need to train sustainability-conscious engineers (Siller 2001; Watson et al. 2013); however, to achieve this objective, holistic knowledge in multiple fields of science is required to equip a new generation of professionals with the means and methods to incorporate sustainable solutions in infrastructure design (Chau 2007). A specific course related to infrastructure in the curriculum provides an opportunity for CEE programs to further educate their students in sustainability issues.

Participants believed that the following attitudes should be encouraged in an infrastructure course: social and economic importance of infrastructure to civil society, ability and confidence in making decisions, working with practitioners, willingness to collaborate, and ability to take and give constructive criticism on a multitude of design solutions to a complex problem. The authors' literature review concurs with these responses. An effective way to develop these attitudes is to use collaborative learning techniques to encourage students to participate in a joint intellectual endeavor to become knowledgeable about a particular topic (Koehn 2001). Because students find collaborative teaching and learning approaches interesting and informative (Koehn 2001), it is highly recommended that collaborative learning techniques be implemented in introduction to infrastructure courses.

In regard to the skills that an infrastructure course should develop in students, respondents first indicated that students should learn teamwork and the ability to work collaboratively in a design charrette environment. As more integrated delivery methods gain traction in the construction industry, civil and environmental engineers should learn to work in a more collaborative environment during the design and construction of a project (Raisbeck et al. 2010; Hall et al. 2014). In addition to teamwork, respondents noted that such a course should foster communication abilities in engineering students. Again, there was concurrence between these responses and the literature. The importance of developing engineering students' communication skills—i.e., presentation and speaking skills—was highlighted in previous studies (Koehn 2001; Sageev and Romanowski 2001; Shuman et al. 2005). Respondents also recognized the importance of technical skills, including technical design skills (students still have to get the right answer), timesheets and billability, audience awareness, defending decision making to broad audiences, ability to communicate through hand drawings and graphics, data mining, geographic information systems (GIS), and building information modeling (BIM). Considering the multifaceted lens of introductory infrastructure courses, these skill sets would likely be appropriate inclusions.

Case Studies

Considering the importance of training future leaders to take a holistic view of infrastructure, Marquette University, University of Wisconsin-Platteville, and West Point have all pioneered introduction to infrastructure courses. In this section, the authors present the three case studies, wherein each case study addresses the barriers cited in the department head's survey.

Marquette University implemented its three-credit course at the freshman level (CEEN 1200) during the fall 2013 semester. The course is designed to introduce students to civil infrastructure and the built environment, with modules focused on the natural environment and environmental infrastructure, structural infrastructure and construction, transportation infrastructure, civil engineering history and heritage, and civil infrastructure systems. All students in the Civil, Construction and Environmental Engineering program take CEEN 1200 during their first semester, and students from other disciplines also are able to enroll.

The CEEN 1200 course is coordinated by senior faculty members and incorporates guest faculty speakers from each of the subdisciplines. This collaborative approach directly addresses faculty knowledge barriers stemming from the breadth of the course. Each speaker follows a similar format in terms of assigning homework to provide continuity throughout the course. Typical homework format includes computational problems from the *Introduction to Infrastructure* textbook (Penn and Parker 2012), short answer questions, an essay-style question requiring independent research, and a file of annotated pictures related to the subject (e.g., "take a picture of an example of sustainable engineering on campus and submit a one paragraph description of the picture.") Additionally, students participate in a team-based infrastructure design project. Each team prepares a design report and final presentation for submission at the conclusion of the semester. These course components map well to ABET accreditation criteria, and student perceptions of the course have been very positive in evaluations.

In implementing the course at Marquette, the major barrier that had to be overcome was credit load restrictions because the graduation credit requirements could not be changed. To address this challenge, the course replaced a general introduction to engineering course, which previously had been required for all incoming civil, construction, electrical, and mechanical engineering students. This course substitution avoided the need to adjust the number of credit hours required for graduation and offered a more in-depth treatment of a degree-relevant introduction to the analysis and design of civil infrastructure.

No inertial resistance to implementing the course was encountered in the department thanks to the fact that faculty strongly supported development of the course and were motivated to introduce students to integrated infrastructure as early as possible in order to kindle excitement about civil and environmental engineering. Additionally, the course gives students the opportunity to link topics together holistically because specific focus areas are introduced in subsequent classes. Previously, disciplinary topics were introduced in a more isolated, siloed approach, giving students limited opportunity to put their various classes all together until the senior capstone design project.

Similar to the Marquette University course, the purpose of the University of Wisconsin-Platteville Introduction to Infrastructure course (colloquially termed *I2I*) is to introduce students to civil and environmental engineering as a system. This three-credit course is required of all environmental engineering and civil engineering majors and is typically taken by students in their sophomore year. Based on the prerequisite chain, students take Surveying and Computer Applications before or concurrently with I2I, and concepts from these prerequisite courses are integrated into the I2I course. The University of Wisconsin-Platteville course also uses the *Introduction to Infrastructure* textbook (Penn and Parker 2012).

This course introduces students to the various subdiscipline areas; highlights the interrelationships among them; and focuses on the social, political, environmental, economic, and other nontechnical aspects of the infrastructure. After 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 nontechnical considerations (e.g., politics, social priorities); and
- Develop teamwork and presentation skills.

A hallmark of the University of Wisconsin-Platteville I2I course is its emphasis on physical analysis of real infrastructure systems, which is modeled after the ASCE Infrastructure Report Card. This course provides sophomores with infrastructure assessment experiences whereby they assess five infrastructure components: single-span bridge inspection, storm sewer segment analysis, retaining wall inspection, pavement surface evaluation, and traffic signal inventory. The objectives of these inspections are to allow students to

- Document field observations quantitatively and qualitatively with notes, drawings, and pictures;
- Observe actual infrastructure components and systems in the field;
- 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 I2I course is intended to fill a weakness in the previous curriculum: many students had to wait until their final semester or final year before they understood how the different junior-level courses (i.e., the “introduction to the subdiscipline” courses) fit together and how their future career would affect society. Some students might never have made these connections and consequently would graduate with a very narrow view of infrastructure. With this new sophomore-level course, students are shown early in the curriculum how the subdiscipline areas are connected to one another and how these areas have a direct effect on society. Additionally, as University of Wisconsin-Platteville CEE faculty members become more familiar with the material in I2I (more than half have taught the I2I course to date), the content is being integrated throughout the CEE curriculum. Most notable has been the complete restructuring of the structural engineering emphasis.

The University of Wisconsin-Platteville instructors faced many of the barriers listed by questionnaire respondents. For example, the number of credits offered by the two degree-granting programs could not be increased. In order to keep the overall credit load the same, the civil engineering program dropped the dynamics requirement. For the environmental engineering curriculum, the number of required electives was decreased from 12 credits to 9 credits. One barrier that was not faced by University of Wisconsin-Platteville was a lack of motivation by the faculty—the entire faculty met to brainstorm desirable characteristics of the future graduates and then created the course jointly based on these characteristics. However, the barrier of faculty expertise had to be overcome; it is very unlikely that any one instructor has all of the expertise needed to teach such a course. To surmount this, content developers compiled background readings for instructors.

In 2008, the Department of Civil and Mechanical Engineering at West Point engaged in a deliberate curriculum review process in response to both calls from professional engineering societies—found in ASCE’s *The Vision for Civil Engineering in 2025* (ASCE 2007) and *Guiding Principles for the Nation’s Critical Infrastructure* (ASCE 2009), and the NAE’s *The Engineer of 2020: Visions of Engineering in the New Century* (NAE 2004)—as well as changes to the U.S. Army doctrine that sought to foster leadership in the Army and the engineering profession. The result was the creation of a new course, CE350

Infrastructure Engineering, which aims to meet the need for leaders in both engineering and society at large, particularly in the development, funding, construction, and maintenance of infrastructure.

The logic behind the course, the course's developmental process, and the course's content have been described extensively (Meyer et al. 2010; Hart et al. 2011; Klosky et al. 2012). The course is required for civil engineering majors in their junior year and for nonengineers as the second course of their engineering sequence (all nonengineering majors at West Point are required to take a three-course engineering sequence in one of the engineering disciplines). Blocks of instruction include infrastructure and network theory; water, wastewater, and trash; energy and electricity; transportation; and infrastructure in doctrine. A family of conceptual infrastructure models (infrastructure environment, components, assessment, protection/resilience, and development) developed for the course (Hart et al. 2014a, b) serves as a framework for teaching and a scaffold for information upon which all graduates can continue to build their understanding of infrastructure after they have completed the course and their formal education. The course has been continuously offered since the fall of 2010 and has an enrollment of about 50 civil engineers and 70 nonengineers each year. The course relies on two books that serve as textbooks: *Infrastructure: A Guide to the Industrial Landscape* (Hayes 2014) and *Electric Power System Basics for the Nonelectrical Professional* (Blume 2007).

West Point overcame two major barriers in implementing the course: credit hour limitations and faculty development. The credit-hour limitation was solved by eliminating dynamics as a required course for civil engineers because the required physics courses included sufficient coverage of dynamics to allow cadets to pass the dynamics portion of the finite element (FE) exam. The decision to move away from a traditional engineering course to the new infrastructure course was contentious but not difficult based on analysis that both the military and civil engineering constituencies were demanding graduates with fundamental proficiency in building and managing infrastructure.

Faculty development began by selecting a team of faculty with infrastructure-related experience in Iraq and Afghanistan as well as from private and personal practice. These experiences enabled faculty to develop the course and to include sufficient background materials for future instructors to also master the course material. Furthermore, because of the rotational nature of the West Point faculty, future instructors for CE350 are directed into a master's curriculum that supports their role as the infrastructure course director. Instructor and departmental enthusiasm was not an issue as, similar to the University of Wisconsin-Platteville experience, many of the department's faculty members participated in the course development and taught the course in subsequent offerings.

Conclusions

Contemporary engineering is characterized by its multifaceted nature. However, students in CEE programs usually cannot connect interdisciplinary subjects to their own areas of expertise or fail to identify and value the contributions of multiple fields to complex problems. Understanding this challenge, some departments have started incorporating an introduction to infrastructure course into their CEE curricula; however, the limited credit hours, lack of resources, and absence of a champion in CEE programs have hindered many other universities from incorporating this course into their curricula. This study attempted to assess the current status of teaching such courses in the United States and to identify incentives for, and barriers against, incorporating such a course. Conducting in-depth case studies on CEE programs that have incorporated this course into their curriculum showed that it is feasible to provide such a course and that students will benefit from it. The findings of the study revealed that to implement this course, a department may need to increase credit hours or substitute the course for existing credits, provide extra resources for faculty members, and motivate department faculty members. The body of knowledge required for civil engineers has increased dramatically in the past two decades; however, at the same time, the number of credits required to earn the traditional four-year undergraduate engineering degree has decreased (ASCE 2014). Increasing the number of required credit hours or even increasing the education requirements for civil engineering degrees from four to five years might be considered to address this emergent need.

One potential limitation of the current study is that only educators from universities participated in the survey, and there was no input from the employers who will eventually hire the students. To address this limitation, another study should be conducted to determine the market demands for the infrastructure-related knowledge and skills that are necessary for civil and environmental engineering graduates. Furthermore, a longitudinal study can be conducted to measure the impact that taking an introduction to infrastructure course has on long-term career success.

Appendix

Data Collection Instrument

The survey used for data collection follows:

Introduction

Purpose: Considering the importance of training future leaders who should have a holistic view to infrastructure, Marquette University and West Point pioneered teaching a course related to infrastructure. These institutions implemented an Introduction to Infrastructure course at the freshman level that is a required three-credit-hour course offered once per year. The course is designed to introduce the natural environment and environmental infrastructure, structural infrastructure and construction, transportation infrastructure, civil engineering history and heritage, and civil infrastructure systems.

To further explore current practices in teaching courses specifically related to infrastructure, we are distributing a questionnaire to civil engineering programs in United States. The results of the study will help educational institutions and policy makers to better understand potential benefits, enablers, and barriers of incorporating infrastructure related courses in civil engineering curriculum. Please help us by completing the questionnaire. The questionnaire should take 10–15 min to complete.

Confidentiality: The questionnaire does not ask for any confidential information. The information you provide will be kept in strict confidentiality. Only the primary investigators will have access to the information. In the event of a publication or presentation based on the results of this study, no personal or company identifiable information will be shared.

Participation: Your decision to participate in this research is voluntary and you may withdraw at any time. There is no direct compensation; however, participants may request a copy of the final reports.

Questions

- Name: ________;
- Years of experience: ________;
- Current position: ________;
- Phone: ________;
- Email: ________;
- Name of institution: ________;
- Degrees offered: ________.
- Educational system? (1 = Quarter; 2 = Semester).

1. Do you have any specifically related to infrastructure (as a whole), rather than specific components or sectors in your program? (1 = Yes; 2 = No)

   a. If yes, please specify: Name/number of the course; Number of students; Year the course started; Level (e.g., freshman, etc.); Credit hours; Is it a required course (Yes, No); and Are other majors allowed in the course? (Yes, No).

   b. If no, do you plan to incorporate such a course in your curriculum in the next two years? (1 = Yes; 2 = No)

      (1) If yes, please specify: Name/number of the course (if known); Expected number of students; Proposed start date; Level (e.g., freshman, etc.); and Credit hours.

      (2) If no, please specify the reason: ________.

      (3) If you do not have, what steps would need to be taken at your institution for you to offer a course on infrastructure?

2. What are the benefits of incorporating an infrastructure course into your civil or environmental engineering curriculum? (Please provide at most five benefits).

3. What are the barriers to incorporate an infrastructure course into your civil or environmental engineering curriculum? (Please provide at most five barriers).
4. If you do not have an infrastructure course but would like one, what would it take for you to offer one?
5. If someone gave you a complete course package and provided instructor training for your professor, would you consider offering an infrastructure course? (1 = Definitely; 2 = Maybe; 3 = Not at all)
6. Courses offered by the CIT-E partners incorporated the following knowledge: (1) code of ethics; (2) licensure; and (3) contemporary issues. Is there other knowledge you think should be incorporated in an infrastructure course?
7. Courses offered by the CIT-E partners encouraged the following attitudes: (1) appreciation of open-ended problems; (2) awareness of infrastructure systems; and (3) encouragement of a holistic viewpoint. Are there other attitudes you think should be encouraged in an infrastructure course?
8. Courses offered by the CIT-E partners included the following skills: (1) facility with *AutoCAD*; (2) ethical decision making; (3) writing reports; (4) oral presentations; and (5) critical thinking. Are there other skills you think should be taught in an infrastructure course?

Acknowledgments

The authors gratefully acknowledge the support of the National Science Foundation Division of Undergraduate Research (Collaborative Research: Training Next Generation Faculty and Students to Address the Infrastructure Crisis; Award Number 1323279). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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