The CIT-E Model Introductory Infrastructure Course: Summary of the "Fundamentals" Module

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The Need

During the 20th Century, the United States built an infrastructure to support an industrial age economy: the Panama Canal, railroads, the Interstate Highway System, water and wastewater treatment systems, the national power grid, and the other elements of the civil infrastructure. However, the world has changed. Larger portions of the U.S. population are located in urban metropolises and many of these are located in areas of high seismic, flood, or hurricane risk; domestic and international terrorism are constant threats; and the emergence of a global economy means that Boston may be more closely tied to Bangalore than it is to Brooklyn.

Recognizing that the infrastructure of the future will require a transformation in the development of engineering professionals, ASCE published *The Vision for Civil Engineering in 2025* (ASCE, 2006) in which they postulated a global aspirational vision for the civil engineering profession in the 21st Century. Key components of this vision are that civil engineers are "master integrators" and "master leaders in discussions and decisions shaping public environmental and infrastructure policy."

ASCE recognized and explicitly stated that achieving the *Vision 2025* would require a new way of preparing individuals to enter the civil engineering profession. In *Policy Statement 465* (ASCE, 2007), ASCE called for the attainment of a Body of Knowledge (BOK) as the basis for professional licensure as a civil engineer and articulated this in the *Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future, Second Edition* (ASCE, 2008). The BOK requires that engineers become competent in non-technical areas including humanities, contemporary issues and historical perspectives, public policy, business and public administration, and globalization.

The abilities to see infrastructure as a system, to act as master integrators, to lead in policy, and to be competent in a wide range of areas are often not currently addressed in undergraduate CEE programs but are readily addressed by an infrastructure course. It is the development of such a course, through the work of the Center for Infrastructure Transformation and Education (CIT-E) community of practice, that is discussed and presented herein.

The Innovation

CIT-E members have created the model introductory infrastructure course collaboratively (Haden et al., 2016). This course is aimed at sophomore-level civil and environmental engineering students. The model course may be adopted in its entirety by future users; however, it is more likely that adopters will want to "pick and choose" from the available materials to suit their own department's needs. Consequently, we have wanted to make sure that the model course is created to be as flexible as possible.

The collaborative nature of the course development as a whole, including the "backwards design" of the course learning outcomes and the arrangement of the course into 5 modules and 43 lessons has been described earlier (Parker et al., 2016). This paper presents the development of 12 lessons in the Fundamentals module. The innovation of this process is this: the authors are unaware of any other new course that has been collaboratively created by a community of scholars located across the US.

Work to Date

The Center for Infrastructure Transformation and Education (CIT-E) is a community of civil and environmental engineering faculty members representing more than 30 institutions interested in the scholarship of infrastructure education. CIT-E activities have evolved in a short period of time, starting with sharing materials from existing infrastructure courses at the University of Wisconsin-Platteville and West Point, to collaboratively creating sample "showcase" course lectures, to the current effort of collaboratively creating a model introductory infrastructure course.

The course outline and learning outcomes for a model introductory infrastructure course were collaboratively developed in 2015 by the CIT-E community. The student learning outcomes are:

1) An ability to analyze and propose solutions to infrastructure problems
2) An ability to describe and analyze infrastructure using systems and network approaches
3) An ability to identify traits of effective team members and apply these traits to course assignments
4) An ability to identify traits of effective spoken and written communication, and be able to apply these traits to make clear and compelling arguments
5) The desire to make a positive impact on the world, country, state, local levels and face infrastructure problems with an open-minded perspective
6) The ability to describe the influence of political, social, technological, environmental, and economic factors on infrastructure decisions
7) The ability to explain how infrastructure solutions affect society, the environment, and finances (i.e. the "triple bottom line")
8) The ability to evaluate the condition of existing infrastructure and recommend improvements
9) The ability to define and describe the components of an infrastructure system and their functions

To meet these outcomes, CIT-E members collaboratively created a course outline. The course outline contains 43 lessons, and is divided into five modules: Fundamentals, One Water, Transportation, Energy, and Capstone.

The Process

As noted in Parker et al., 2016, a modified Delphi process was used to create the course outcomes and to define the lesson topics for the model course. The process described herein is the process to create the first 12 lessons of the course, which comprise the Fundamentals module. The 12 lessons are:

1	What is infrastructure and why do we care?
2	Basic infrastructure functions
3	Systems/network analysis
4	Triple Bottom Line/Sustainability
5	Social impacts of infrastructure
6	Teamwork
7	Ethics I
8	Ethics II
9	Traits of effective written and oral communication
10	Financing public works
11	Safety/licensure
12	Land use and planning/growth/forecasting

The process to create these lessons is as follows.

- Team assignments – teams of faculty members were assembled to create each lesson. Faculty members were asked to give preferences to the 12 lessons they would like to develop. Teams contained three members and were responsible for three lessons. Each team member took the lead for one lesson.
- Pre-workshop assignments – team members met online to agree on lesson outcomes for each lesson and to assemble materials that would be needed for the face-to-face workshop.
- Workshop – the "Model Infrastructure Course Lesson Development Workshop" was held at UW-Platteville in May 2016. The team worked on the lesson materials in four different Work Sessions. Time was also built into every day for breaks to share progress with other attendees and to focus efforts; these breaks were also essential to building community.
- Lesson completion – teams left the workshop with varying degrees of completion. Some teams lacked focus and spent too much time in debating the content and coverage for each lesson. Other teams left with their lessons nearly complete. In the months after the workshop, teams continued to complete their lessons. Lessons 1-3 were completed by October 2016 and the remainder were completed in the Spring of 2017.
- Internal peer review – once a lesson was completed, the lesson leader shared it with the other two team members and requested feedback. The feedback was then incorporated to improve the lesson.

- External peer review- once a lesson had completed the internal peer review process, it was sent to 5-7 external peer reviewers. A rubric was provided to reviewers. Reviewers were anonymous. Lesson authors were required to incorporate the peer review process; once this step was completed, the lesson development process for that lesson was consider finished.

The Results

Lesson summaries for each of the 12 lessons are provided below:

- **1 What is infrastructure and why do we care?:** In this lesson, we place pictures of different types of infrastructure on a USA map to identify the types of infrastructure required to support one person. This lesson is significant because hopefully through it, students will start to identify the infrastructure they rely on just to get to work and the interconnectedness of that infrastructure to make all other infrastructure run smoothly.
- **2 Basic infrastructure functions:** This lesson exposes students to the breadth, depth, complexity, and interconnectivity of infrastructure throughout the United States using an instructor led slide presentation built around the Department of Homeland Security's 16 critical infrastructure sectors. Upon completion students should recognize the role of infrastructure in delivering services to populations, the social and political importance of infrastructure, and the vast scale of infrastructure systems in the US.
- **3 Systems/network analysis:** Students learn the systems thinking skills which provide a foundation for understanding infrastructure as a network of complex systems for the duration of the course. The instructor facilitates the LA Water Simulation Game to expose the pitfalls of the "don't fix what isn't broken" mindset in the context of the US Infrastructure Crisis as informed by the ASCE Report Card. Using the Los Angeles county water distribution system as a case study, students play the generational role of the LA Water Manager to learn to recognize and appreciate the interdependent nature of social, economic, political, and technical infrastructure systems. The students' newly acquired systems thinking skill will be transferable to other domains of infrastructure beyond water systems.
- **4 Triple Bottom Line/Sustainability:** The purpose of this lesson is to expose students to the concept of sustainability within the context of comparing project alternatives. Students will develop criteria used to evaluate project alternatives within the areas of the 3Ps of sustainability: people, planet, and profit. Next, students will use the 3P criteria within two connected tools called the Sustainability Triangle and Sustainability Index which will provide a metric for comparing the sustainability of project alternatives. This lesson includes examples of airport expansion and campus parking to help meet its objectives.
- **5 Social impacts of infrastructure:** The purpose of this lesson is to introduce students to the concept of social impact and how infrastructure can affect society in many different ways, both anticipated and unanticipated. This lesson provides a brief introduction to the concept of social impact, as it can begin to expand into many different discussions that can be the subject of individual lessons themselves (ie. environmental justice, socio-

economic impacts, etc.). The goal of this lesson is for students to understand what social impact is, how infrastructure impacts society in ways they may have never considered, introduce a tool that can be used to understand who may be affected by infrastructure projects, and provide additional examples of how infrastructure projects can be used to have a positive social impact.

- **6 Teamwork:** The purpose of this lesson is to help students understand how to be effective team members. They will learn the attributes of effective team members and decision-making and conflict resolution strategies for teams.
- **7 Ethics I:** The purpose of this lecture is to introduce students to the very basics of ethics so that they understand how ethical principles can be applied to decision-making. The modest goal is to lead students to the ASCE code of ethics through understanding a little about moral psychology and how they themselves think ethically. This will help them understand why there is a code of ethics, and this will have them prepared for the Ethics II lecture.
- **8 Ethics II:** This lesson exposes students to common workplace incidents of ethical misconduct, their causes, perpetrators of misconduct, and the impact of ethical misconduct on the overall culture of an organization. In addition, it outlines strategies employed to address workplace misconduct. The lesson further guides students to apply the ASCE code of ethics to case analyses involving civil engineering projects.
- **9 Traits of effective written and oral communication:** This lesson helps students see the necessity for engineers to be able to communicate effectively. A Technical Writing Primer is provided to students, and two specific writing skills are emphasized: incorporating meaningful graphics and the importance of clear and concise writing.
- **10 Financing public works:** This lesson aims to engage students in financial aspects of infrastructure, primarily through life cycle cost analysis. The importance of operations and maintenance costs for infrastructure with a long design life is emphasized. Engineering economics calculations such as net present value are not included in this lesson, but could be added (requiring an additional lecture). Typical sources of funding are identified. Differentiation between private and public infrastructure is presented along with an introduction to public private partnerships (which is covered in Part 2, a screencast to be available to students.) The lecture (Part 1) is a traditional PowerPoint presentation.
- **11 Safety/licensure:** This lesson contains two topics. For the safety portion of the lesson, students will learn the importance of safety and demonstrate their understanding by developing a site safety management plan and passing a safety quiz. For the licensure portion of the lesson, students will learn the benefits of having a P.E. license and understand the steps necessary to obtain their P.E. license.
- **12 Land use and planning/growth/forecasting:** This lesson aims to promote student understanding of the role of planning in infrastructure development and the effects of that planning on the success of communities. Basic elements like comprehensive planning and zoning are discussed with an emphasis on respecting the contribution of disciplines beyond engineering, like Law, Finance and Politics. The critical difference between

design, which can take place on many scales, and *infrastructure planning*, which entails an understanding of Systems, is also explored through a student activity.

As of submittal of this manuscript, three lessons are entirely complete, having successfully passed through the peer-review process. Six others are in the internal peer-review process and three are in the external peer review process.

Workshop Assessment

All twelve individuals who attended the 2016 Model Infrastructure Course Lesson Development Workshop provided feedback via a post-workshop survey. The workshop was highly rated and valued by participants. All participants rated the workshop as good or very good for content, organization, opportunities for participation and dialogue, and materials shared. All participants felt that the workshop supported connections across organizational and geographic boundaries, and provided the opportunity for developing shared resources to address needs. Of the respondents, the majority (91.7%) felt that the workshop was useful to their work and created interest in the topic. Overall workshop ratings were good (33.3%) or very good (66.7%).

Members of the community appreciated the opportunity to collaborate with colleagues who had similar ideals and goals for infrastructure education. Face-to-face time in this and past workshops has contributed to building a sense of community among members of CIT-E. Workshop participants felt that the face-to-face format allowed time for productive and concentrated collaborative and they highly valued the critical feedback from colleagues on the lessons they were co-developing. The workshop built understanding of how the model course is developing by allowing participants to share lessons with those outside of their working group. With respect to improving the experience, participants most frequently cited the need for more time for developing the lessons than the three-day workshop provided. They noted that consensus building among group members was not always easy and required time and open communication.

Planned assessment of the model course

The ability of students to learn to view infrastructure as a *system* will be assessed using the Infrastructure Concept Map instrument. Student attitudes toward various aspects of the infrastructure will be assessed using the Infrastructure Views Survey instrument. These instruments are under development and have been extensively tested to date.

The Infrastructure Concept Map instrument is used as a pre- and post-test for students in infrastructure courses (Roberts et.al, 2014). Students create a concept map in response to the question, "What is infrastructure?" Concept maps are scored using a quantitative approach by adding the number of concepts or links in the following six categories:

1. The number of concepts mentioning infrastructure "components" (e.g., roads, bridges, wastewater treatment plants, etc.),

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 (infrastructure components, infrastructure sectors, or engineering concepts),

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 to any other concept, and

6. The number of engineering concepts (e.g., constructability, design, resilience, etc.).

The six numeric scores from each category can then be compared between the pre- and post-test to determine student learning gains. To date, faculty members from eight institutions have used the Infrastructure Concept Map instrument. Scoring of maps and analyses of findings are ongoing to understand how the course impacts students' understanding of civil and environmental engineering in terms of interconnected systems (Roberts & Haden, 2016).

The Infrastructure Views Survey instrument contains a mix of closed-ended, Likert scale and open-ended items. The survey was developed to assess the impact of infrastructure education, with the goal of determining students':

- understanding of the importance of infrastructure to society,
- appreciation of the infrastructure problems in the US,
- understanding of the potential solutions to infrastructure problems, and
- interest in infrastructure challenges and solutions, including the pertinence of infrastructure management to their future careers.

To date, faculty members from ten institutions have used the IVS. Data analysis is ongoing (Roberts & Haden, 2016).

Lessons Learned and Next Steps

The project leadership team reflected on the success of the lesson development process and arrived at the following insights:

- The face-to-face opportunity afforded by the workshop is essential to building community and to brainstorming effective and interesting content
- It is essential that attendees complete their learning outcomes for each lesson ahead of time.
- Teams should be diverse in every possible aspect to ensure effective material development.
- A deadline for submittal needs to be defined clearly.
- The CIT-E Director needs to take a more active role in encouraging participants to finish in a timely manner.
- The CIT-E Director needs to ensure that attendees participate in lessons that align carefully with their expertise.

As the 12 lessons in the Fundamentals module are being completed, the CIT-E community is turning its attention to creating lessons for the next module (One Water). The intent is that these lessons will be created without any face-to-face interaction, and thus will test the importance of the necessity of the face-to-face workshop. A workshop is being planned this summer with the goal of starting the Transportation and Energy modules. Furthermore, community members are exploring the possibility of integrating ABET embedded indicators into the model course, as a means of providing users with ease of assessing ABET outcomes.

References Cited

American Society of Civil Engineers (ASCE). 2008. "Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future, Second Edition," ASCE, Reston VA 2008, Body of Knowledge Committee of the Committee on Academic Prerequisites for Professional Practice.

American Society of Civil Engineers (ASCE). 2007. "Policy Statement 465—Academic Prerequisites for Licensure and Professional Practice." ASCE, Reston VA, 2007, Committee on Academic Prerequisites for Professional Practice

American Society of Civil Engineers (ASCE). 2006. "The Vision for Civil Engineering in 2025," ASCE, Reston VA, 2006.

Roberts, M.W., C. Haden, M.K. Thompson, and P.J. Parker. "Assessment of systems learning in an undergraduate civil engineering course using concept maps." Proceedings of the 2014 ASEE Annual Conference, Indianapolis, IN, June 15-18, 2014.

Haden, C, P.J. Parker, M.K. Thompson, M.R. Penn, S.D. Hart, and M.W. Roberts. "Implementation of Infrastructure Education Courses Across Multiple Institutions". Proceedings of the 2016 ASEE Annual Conference, New Orleans, LA, June 26-29, 2016.

Parker, P.J., M.R. Penn, M.W. Roberts, S.D. Hart, C. Haden, and M.K Thompson. "Crowdsourcing an Outline for a Model Introductory Infrastructure Course Using a Modified Delphi Process." Proceedings of the 2016 ASEE Annual Conference, New Orleans, LA, June 26-29, 2016.

Roberts, M.W, and C. Haden. "Assessing Student Learning of Civil Engineering Infrastructure." Proceedings of the 2016 ASEE Annual Conference, New Orleans, LA, June 26-29, 2016.