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Infrastructure Education in Unprecedented Times: Strengthening a Community of Practice

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Infrastructure Education in Unprecedented Times: Strengthening a Community of Practice

Abstract

CIT-E (the Center for Infrastructure Transformation and Education) was founded in 2013, catalyzed by a National Science Foundation grant. During the grant, faculty members from around the country gathered for six workshops to co-create an entire model introduction to infrastructure course. These materials have been peer-reviewed and are available at no charge to anyone who wants to use and/or adapt them. CIT-E has remained active since the conclusion of the grant. Through the organization of yearly workshops, it has been welcoming new members and providing participants an opportunity to grow as educators, increase their professional network, and develop new materials collaboratively. This paper describes the results of an impact analysis of CIT-E through the lens of a community of practice.

Introduction

The Center for Infrastructure Transformation and Education (CIT-E, pronounced "city") is an existing, thriving community of practice (CoP) with a shared domain of interest in supporting more effective Civil and Environmental Engineering education [1]. The CIT-E CoP exists in both physical and cyber environments. In-person workshops have been held at various locations over the years, and the Canvas LMS is used to host the CIT-E community. CIT-E in-person workshops have shifted to being fully online during the COVID-19 pandemic, connecting faculty members via Zoom. Faculty members from more than fifty colleges and universities across the world make up the CIT-E CoP. By improving the online environment of CIT-E, more members have been able to participate and engage in our shared practice. CIT-E members primarily have practiced the co-creation of learning modules. By exchanging stories, tools, strategies, and personal experiences, faculty members create course-level learning outcomes, a course outline, lesson-level learning outcomes, and teaching materials. Nearly 40 peer-reviewed lessons for a model undergraduate introductory infrastructure course have been developed to date.

Currently, the community of practice has about 100 active members; we define an "active" member as someone who has authored or co-authored a lesson, peer-reviewed a lesson, and/or attended one of the nine workshops hosted by CIT-E. Sixty-one people registered for two virtual CIT-E workshops in Summer 2020; this total included both previous and new participants. One of these workshops ("Infrastructure Education in Unprecedented Times") spurred the creation of three new lessons focused on the relationship between systemic racism and civil infrastructure and one on the impacts of COVID-19 on transportation systems and stakeholders.

The CIT-E model Introduction to Infrastructure course contains complete lesson materials for an entire one-semester course. The course introduces first or second year civil and environmental engineering students to infrastructure and helps students see infrastructure as a system rather than a collection of discrete subtypes. Consequently, it provides students with the knowledge,

skills, and attitudes needed to effectively design, build, manage, and maintain our public works by considering social, economic, environmental, and political impacts in addition to technical considerations. Individual modules and lessons, which serve as the building blocks for the model course, can be adopted and/or adapted to integrate into other courses. All course materials are available through the Canvas learning management system (LMS) at no cost.

During the Summer of 2020, members in the CIT-E CoP began exploring the question "what impact has CIT-E had?" Intentional evaluation at our workshops had demonstrated that the workshops were effective in meeting their outcomes, including building a sense of community and helping attendees learn new skills. Another important and far-reaching impact was the creation and use of the model introductory infrastructure course materials. And we could point to powerful anecdotes as an indicator of our impact, such as a colleague who has organized two national infrastructure conferences in Ghana attributing his activity to the influence that CIT-E has had on him. But we were still left with unanswered questions related to the demographics of CIT-E and its impact. For example:

1. Who makes up the CIT-E CoP, and how does it reflect the demographics of CEE faculty?
2. To what extent is the model course being used, and by whom? Why? Which lessons are being accessed the most?
3. What skills have faculty members gained from their association with CIT-E, and has it made a meaningful impact on faculty professional networks?
4. What else do faculty members want out of CIT-E, and what are the next steps for CIT-E as a CoP?
5. Which aspects of the CIT-E CoP reflect the characteristics of a CoP as found in the literature?

Finding answers to these questions became the impetus for this paper.

Research Approach

Following IRB approval, we distributed a survey (Appendix A) to the CIT-E mailing list on January 6, 2021. The CIT-E mailing list includes 165 names, consisting of people who have attended our workshops, signed up via www.cit-e.org, or otherwise asked to be included. The survey was created in Qualtrics. In creating the survey, we were mindful of ensuring that the survey would be as streamlined and as efficient as possible for participants to complete: 1) we included skip logic - for example, participants who had not used the model course were not asked questions about the course; 2) the large table asking respondents to rate their usage of each lesson was prepopulated with the "I did not use the lesson" response, as we (correctly as it turned out) assumed that most participants had used only some of the lessons.

After one week, 34 faculty members responded to the survey. At that point, four of the co-authors sent personal emails to non-respondents with whom they had an existing relationship, encouraging them to complete the survey. In total, 64 faculty members completed the survey, with a 39% response rate. Respondents were asked to share their names for the purposes of tracking who had completed the survey, thus allowing us to "nudge" the non-respondents. However, as provided in our IRB approval, and as stated at the beginning of the survey, all identifying information was deleted from the survey results prior to analysis.

Results and Discussion

We analyzed the 64 responses to understand more about the demographics of those who are part of the CIT-E CoP and the impacts CIT-E has had in terms of the use of model course materials, professional development, and development of professional networks. In addition, to better shape the future of the CoP, we investigated CIT-E members' current and future interests as well as their willingness to continue to participate in the development of new materials. We recognize that those who responded to the survey are more likely to have used CIT-E materials than those who did not and consider the responses in that context.

Who makes up the CIT-E CoP, and how does it reflect the demographics of CEE faculty?

We wanted to know more about the demographics of our community and how they compare to the broader civil and environmental engineering faculty community.

In 2019, there were 3,101 tenured or tenure track faculty members in U.S. civil engineering, civil/environmental engineering, and environmental engineering programs [2]. As mentioned previously, CIT-E has approximately 100 active members, not all of whom are tenured or tenure-track faculty members, and a few of whom are from disciplines outside of civil engineering. Therefore, the number of respondents to our survey represents a very small percentage of tenured and tenure-track civil and environmental engineering faculty. Nevertheless, a comparison of CIT-E's current demographics to this community is instructive as we contemplate how to build a diverse and inclusive CoP.

Figures 1 and 2 show the gender and ethno-racial characteristics of the survey respondents, and Figure 3 compares them to the percentages reported for tenured/tenure-track faculty members civil, civil/environmental, and environmental engineering in *Engineering by the Numbers*. [2]

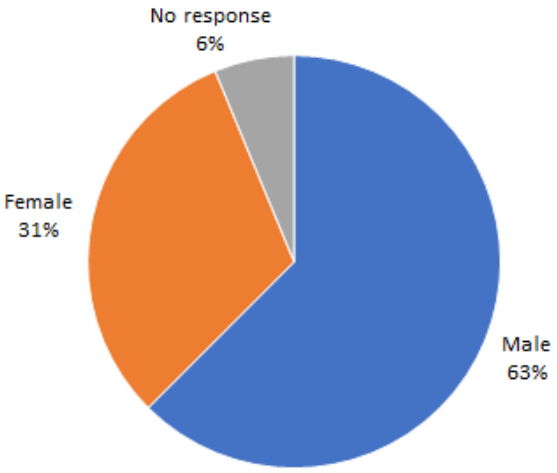

Figure 1. Gender of survey respondents.

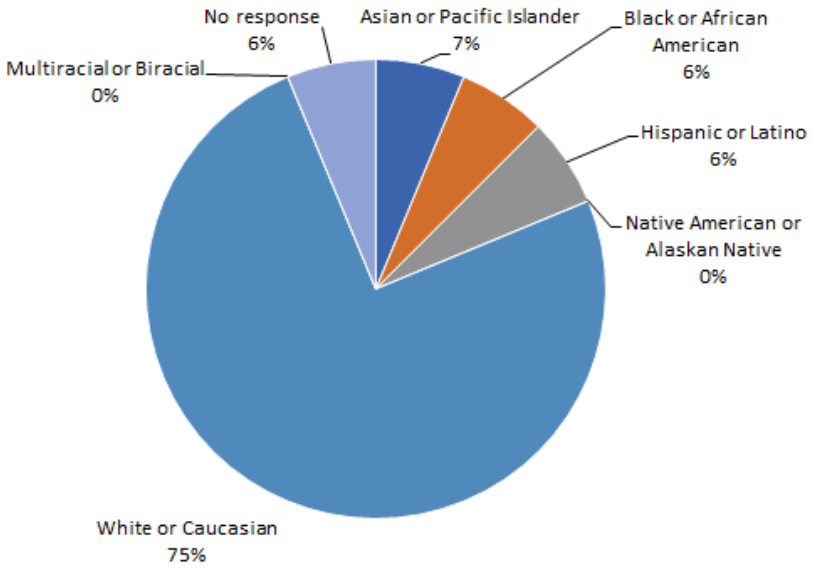

Figure 2. Ethno-racial background of survey respondents.

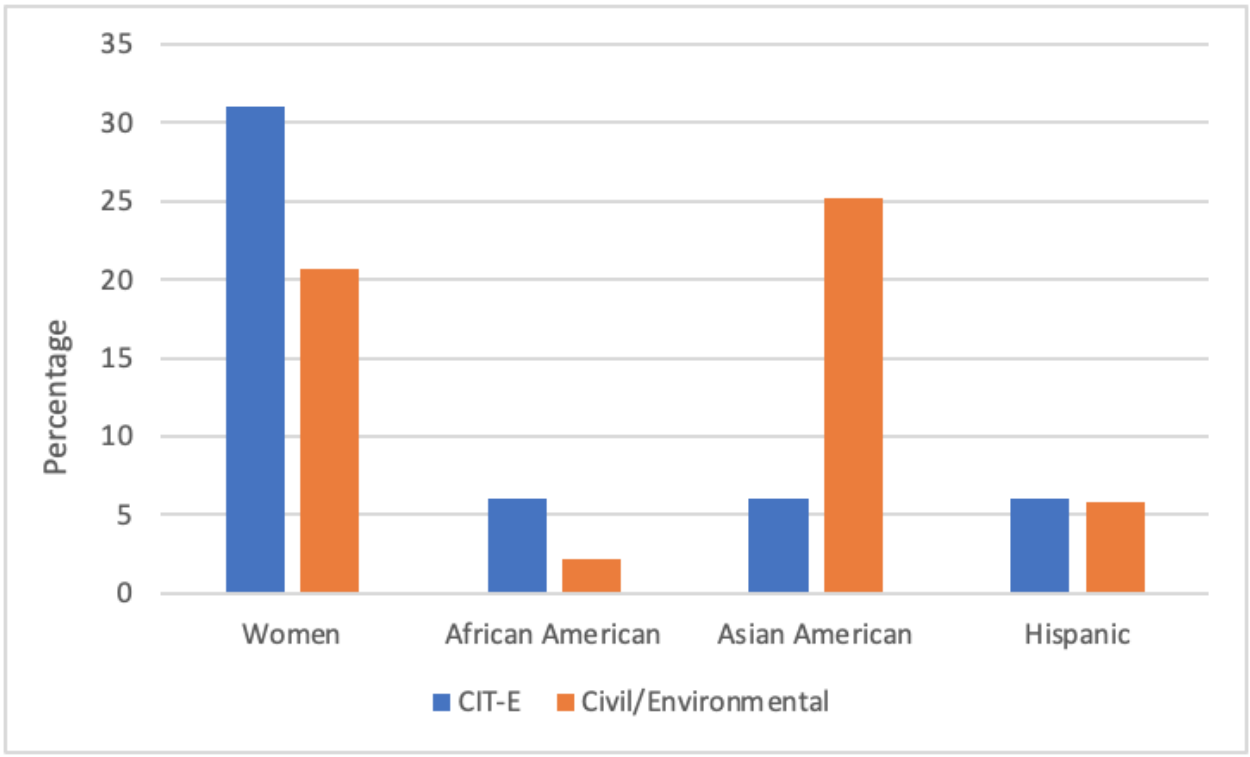

Figure 3. Comparison of gender and ethno-racial background of survey respondents to national data.

Those faculty identifying as females made up 31% of survey respondents, which is slightly higher than the 28.1% of women faculty tenured/tenure-track members in environmental engineering and much higher than the percentages of 21.9% and 17.6% in civil/environmental engineering and civil engineering, respectively. The CIT-E community is predominantly white, with a slightly higher percentage of African American participants and a much lower percentage

of Asian American participants when compared with national data for tenured/tenure track faculty. Although the CIT-E CoP is more diverse than the civil and environmental engineering engineering faculty as a whole, the proportions are still small enough that attempts to analyze survey results by gender or race/ethnicity are not meaningful.

Figure 4 shows that the majority of survey respondents have been faculty members for more than 10 years, with roughly even numbers with 1-5 and 6-10 years of experience. Comparing faculty experience to national averages was not possible, because *Engineering by the Numbers* only includes data on faculty rank, not years of experience [2].

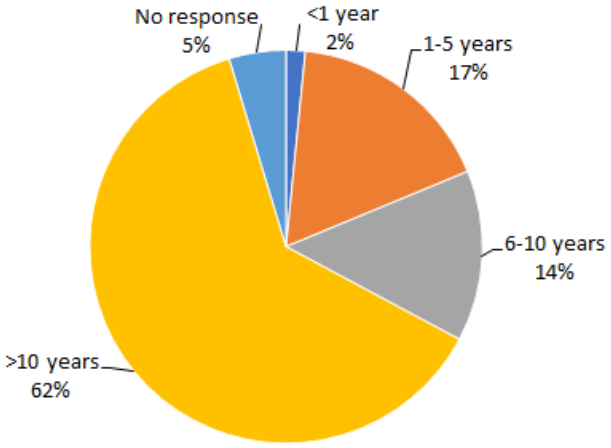

Figure 4. Length of time in faculty position of survey respondents.

In summary, the 64 CoP members who responded to the survey represent 49 different institutions. They are overwhelmingly white and male with more than 10 years of experience. However, there was a higher proportion of women in the respondents as compared with civil and environmental engineering faculty nationally, but a lower percentage of Asian Americans.

To what extent is the model course being used, and by whom? Why? Which lessons are being accessed the most?

The CIT-E model course comprises 44 lessons divided into five modules: Fundamentals, Water, Transportation, Energy, and Capstone. Appendix B lists the lesson topics in each module.

Of the 64 survey respondents, 35 had utilized course materials and provided opinions on the quality and ease of adoption; these responses are summarized in Figures 5 and 6. Ninety-seven percent of the survey respondents who had used or adapted CIT-E materials indicated that they were of high quality (Figure 5), and 94% of these individuals indicated that they were easy to adopt for their classes (Figure 6). Respondents reported that more than 4,000 students have gained exposure to CIT-E course materials.

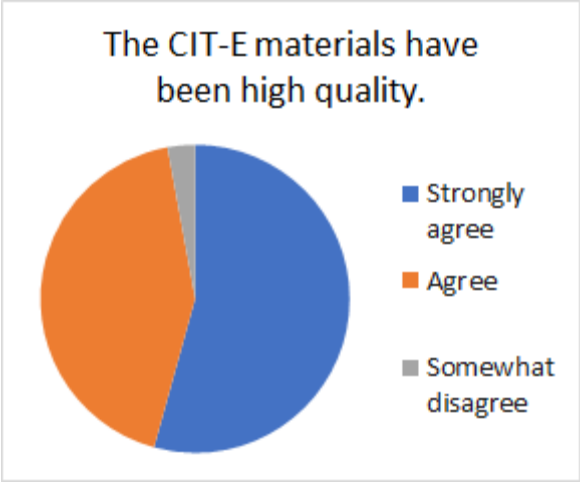

Figure 5. Perceived quality of CIT-E materials.

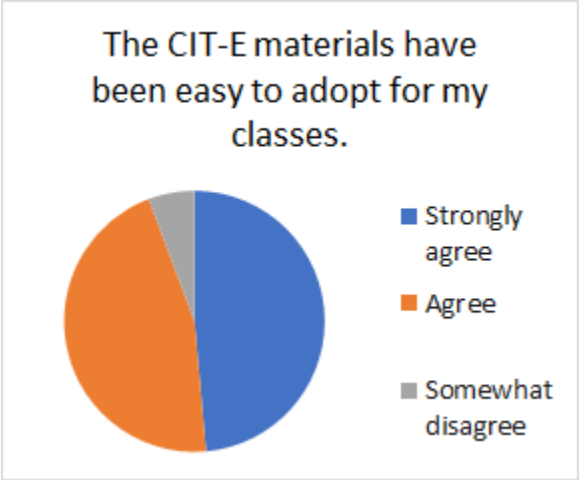

Figure 6. Perceived ease of adoption of CIT-E materials.

Survey participants were asked which lessons they have used and the extent of usage. Of the 64 who responded to the survey, 35 (55%) had used at least one lesson and each on average had used more than 10 lessons. The survey asked participants to respond to the following prompts: "I used portions of the lesson (e.g. screencast, homework, etc.)," "I used the full lesson, mostly as-is," and "I used the full lesson, and I significantly revised." Both the full lessons and their components were useful to respondents; of the lessons used, the full lesson was used mostly as-is 24% of the time, full lessons were used after significant revision 11% of the time, and a portion of the lesson was used 66% of the time. (Numbers do not add up to 100% due to rounding.) Seventeen of the lessons were used by ten or more respondents. Table 1 shows the six most popular lessons. Lessons on sustainability were either the most popular or second-most popular lesson adopted in each of the first four modules (Fundamentals, Water, Transportation, and Energy; the Capstone module does not have a readily identifiable lesson on sustainability), indicating that faculty have a significant interest in accessing teaching materials related to sustainability.

Table 1. Use of lessons by survey respondents.

Lesson Name	Number of times used
Infrastructure and You	22
Triple Bottom Line	20
Infrastructure as a system	18
Basic infrastructure systems and functions	16
Social Impacts of Infrastructure	16
Resilience and risk	16

What skills have faculty members gained from their association with CIT-E, and has it made a meaningful impact on faculty professional networks?

Survey respondents who had utilized course materials were asked to rate the impact of CIT-E on their development as an educator. Figure 7 shows that almost 90% of those who had used course materials believe that CIT-E has had a positive influence on their professional development as an educator. Additionally, Figure 8 shows that CIT-E has had a positive impact on developing the professional networks of these faculty members.

When asked the open-ended question "How has your experience with CIT-E affected your attitude toward teaching in general and your perspective toward civil and environmental engineering education in general?" 27 of the 35 that had utilized course materials provided responses, which are categorized in Table 2. Note the combined number of comments exceeds the number of respondents due to the fact that some had provided multiple comments. We also note that the answers to this open-ended question may have been influenced by the questions to which participants had responded already.

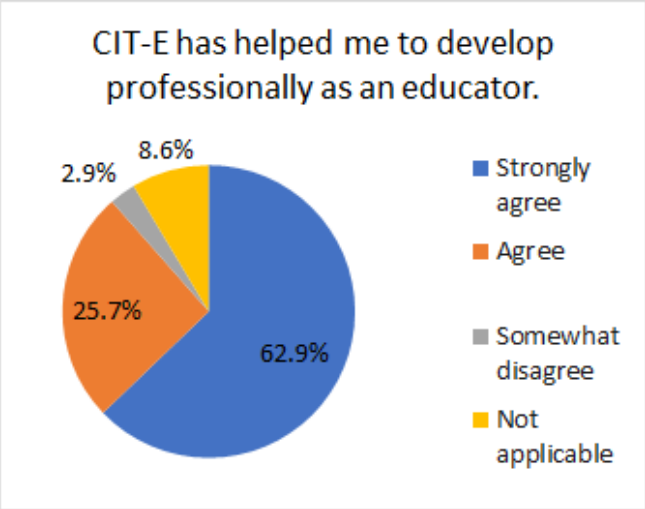

Figure 7. Survey respondents' perceptions of CIT-E's impacts on development as an educator.

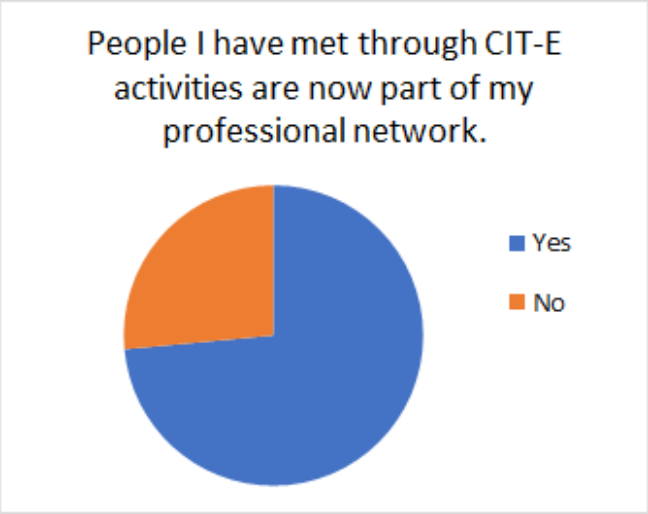

Figure 8. Survey respondents' expansion of professional networks due to CIT-E.

Table 2. Themes in open-ended comments related to impacts on development as an educator.

Theme	Number of Comments
Sense of community/shared values/enthusiasm	12
Improved teaching methodology	8
Holistic approach to infrastructure	6
Importance of sharing ideas and materials	5
Did not shift attitude/perspective	3
Other	2

These results suggest that CIT-E has developed high quality and easily utilized materials that have, to date, contributed to the infrastructure-related education of thousands of civil and environmental engineering students. Furthermore, CIT-E has contributed to the improved teaching effectiveness and growth of professional networks of engaged members of the community.

What else do faculty members want out of CIT-E, and what are the next steps for CIT-E as a CoP?

All survey participants were asked about their interest in modules on select topics. Figure 9 shows that 84% claimed that they would likely use a module on social impacts of infrastructure, 66% would possibly use a module that addresses the intersection of infrastructure and systemic racism, and 83% expressed interest in materials related to community engagement for infrastructure projects. Participants also expressed interest (or potential interest) in the following additional resources that could be developed by CIT-E: the incorporation of indicators for ABET assessment purposes (81%), the development of an asynchronous online Introduction to

Infrastructure course that students could take for credit or a certificate (77%), and a model undergraduate course on Infrastructure and Social Impacts dealing with intersections of infrastructure and inequality (70%). The development of a model graduate-level infrastructure course was less attractive to several of the participants (almost 41% expressed no interest), but it still attracted 27% of the respondents, while 30% stated that they might have an interest in such course (approximately 3% declined to respond). Finally, participants were less attracted to the incorporation of micro-credentials (i.e. 'badges'), with 45% stating they had no interest, 25% stating that they might be interested, and only 23% claiming to be interested (a little over 6% declined to answer.)

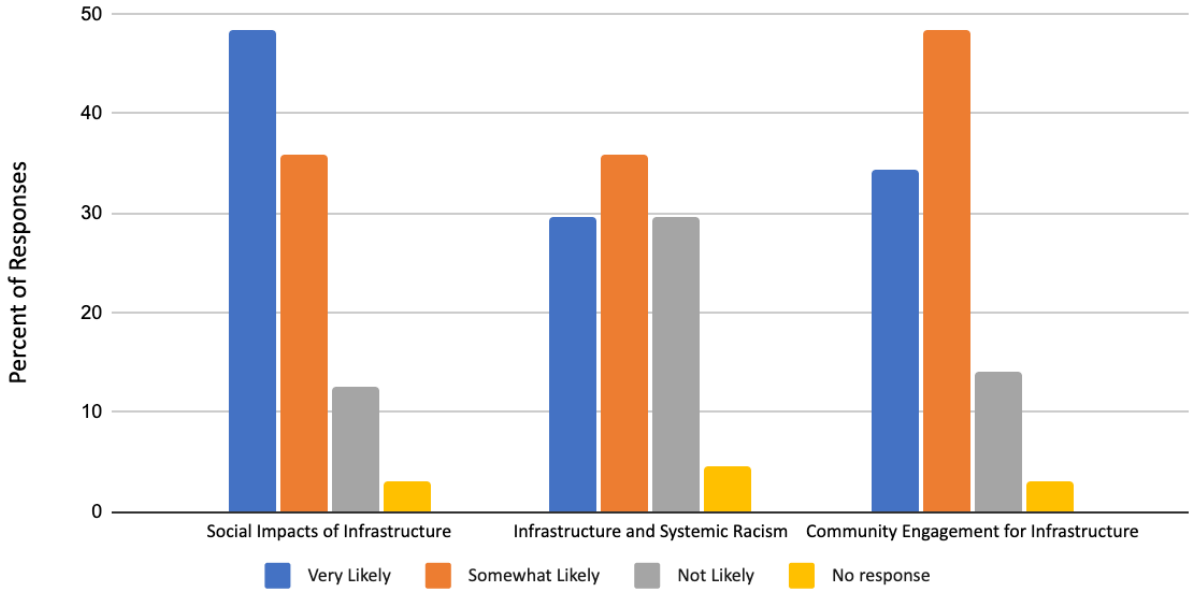

Figure 9. Survey respondents' reported likelihood of using modules related to social issues.

Participants were enthusiastic in recommending potential topics for new materials that could be created by CIT-E. In fact, 45% of the respondents made at least one suggestion. A wealth of topics were suggested and they varied tremendously, ranging from the addition of introductory lessons in geotechnical, structural, and construction engineering to specific areas of infrastructure that could be explored, for example: airports, waste management, telecommunications, or natural gas infrastructure. Although some of the topics suggested had a weaker connection to the course objectives usually associated with an Introduction to Infrastructure course, for example calculation of loads, foundations, structural analysis, and structural dynamics, this interest might be indicative of the value these instructors are seeing in the materials created by CIT-E and of their desire for similar modules in these other areas.

When asked about the reason for their interest in the CIT-E community developing these new materials, there was a fairly even split in participants' responses: 19% mentioned they would like to integrate the suggested topic(s) into their classes, but did not have time to develop the materials themselves, 17% wanted to integrate the proposed content, but did not feel qualified to develop the materials themselves, and 17% claimed that they have expertise in the areas suggested and would like to collaborate with others to create course materials. Some of the

additional reasons for their interest in CIT-E creating these new materials were: to reduce the dependence on guest lecturers, to integrate the materials developed into multiple courses, to increase awareness of particular topics, and to introduce students to systems-level skills at an early stage of their studies. The interest participants displayed in these responses was very encouraging to CIT-E, but even more encouraging was the fact that 53% of the respondents expressed their willingness to participate in updating existing materials or generating new materials for CIT-E.

Which aspects of the CIT-E CoP reflect the characteristics of a CoP as found in the literature?

Communities of Practice are "groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly" [1]. We use the three attributes of CoP identified by Wenger-Trayner and Wenger-Trayner to evaluate CIT-E in Table 3. The information provided in the 'Evidence' column is obtained from survey results presented in this paper and observations of CIT-E. The results indicate these attributes are present in this CoP.

Conclusion

The survey distributed to all active CIT-E members provided insight into the composition of the membership, the value of the materials developed, additional impacts CIT-E has had on its members, and a sense for members' future needs and interests. We discovered that:

1. lessons are being used and are impacting a large number of students, while assisting multiple instructors (who may not have time to develop the lessons themselves or may not have expertise in these areas) bring important concepts to their classes;
2. CIT-E has helped its members develop as educators and broaden their professional networks;
3. members suggested numerous topics for new materials, but more importantly, they volunteered to help develop them; and
4. CIT-E has been fulfilling its purpose as a community of practice.

We are optimistic about the potential of CIT-E to facilitate change in infrastructure education. Based on what we learned in the survey described here, some of the authors are initiating an effort to more formally identify gaps in CIT-E's resources (human and otherwise) and engage with colleagues (whether they have or have not previously been involved with CIT-E) to develop an understanding of successful individual efforts to integrate diversity, equity, inclusion, and justice (DEIJ) into infrastructure education. Further, although respondents to the CIT-E survey were predominantly white men, the interest expressed in broadening CIT-E's work to promote diversity, equity, inclusion, and justice (DEIJ) in the civil engineering curriculum is encouraging. To leverage this interest, CIT-E will be facilitating workshops in summer 2021 in which civil engineering faculty will develop skills and competencies for addressing DEIJ in the classroom, particularly in the context of infrastructure education.

Table 3. CIT-E as a Community of Practice (CoP)

Attribute	Evidence
Shared practice	• co-created, crowd-sourced introductory course • mentoring of new members • more than half of respondents expressed willingness to assist in new material development (survey) • positive impact on development as an educator (survey) • training provided in course design and lesson design
Shared domain of interest	• extensive adoption and adaptation of CIT-E course materials (survey) • 49 people have accessed the learning management system since summer of 2020 • 64% of active members responded to survey • significant interest in proposed topics such as social impacts of infrastructure (survey) • strong attendance at workshops
Community	• purposeful organization of CIT-E as network rather than hierarchy • free sharing of information at "Office Hours" held in Fall 2020 • expressions of gratitude for role of CIT-E (survey) • 12 respondents noted sense of community in free response (survey) • positive impact on professional networks (survey)

Acknowledgments

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2. American Society for Engineering Education. (2020). Engineering and Engineering Technology by the Numbers 2019. Washington, DC. https://ira.asee.org/wp-content/uploads/2020/09/E-ET-by-the-Numbers-2019.pdf

Appendix A - Survey Instrument

Q2 In order to better serve the civil and environmental engineering education community, we'd like to ask you to complete the following survey, which will help us to improve the resources offered by CIT-E (Center for Infrastructure Transformation and Education). The survey should take approximately 15-20 minutes to complete. Participation in this survey is voluntary and you may decline to answer any question or select to exit the survey at any time. Results will be presented at the 2021 American Society for Engineering Education Conference.

Q3 What is your name?
Your name will be immediately removed prior to analyzing the data. We are collecting this information for tracking purposes only (i.e. to nudge people who have not responded!).

Q4 Are you familiar with CIT-E?
o Yes
o No
Skip To: Q18 If Are you familiar with CIT-E? = No

Q5 Have you participated in a CIT-E Workshop (including either or both of the 2020 virtual workshops)?
o Yes
o No

Q7 Have you participated in the creation/review of CIT-E materials?
o Yes
o No

Q6 Have you adapted and/or used CIT-E materials?
o Yes
o No
Skip To: Q35 If Have you adapted and/or used CIT-E materials? = No

Q30-35 For each CIT-E lesson that you have used in the list below, please indicate the extent to which you used the lesson.

I used the full lesson, mostly as-is	I used the full lesson, and I significantly revised	I used portions of the lesson (e.g. screencast, homework, etc.)	I did not use this lesson

[Each of Questions 30-35 lists groups of lessons by module]

Q9 Approximately how many total students have been enrolled in the course(s) in which you have used CIT-E materials?

Q10 In what level classes have you used CIT-E materials (select all that apply)?
▢ High School
▢ First year or Sophomore Undergraduate
▢ Junior or Senior Undergraduate
▢ Graduate
▢ Other _____

Q11 Which lesson(s) have you found to be the most useful?

_____

Q12 Indicate your level of agreement with each statement below.

	Strongly agree	Agree	Disagree	Somewhat disagree	Not Applicable
The CIT-E materials have been easy to adopt for my classes.					
The CIT-E materials have been high quality.					
CIT-E has helped me to develop professionally as an educator (e.g. how to use concept maps, how to develop reflective writing assignments, etc.)					

Q13 People I have met through CIT-E activities are now part of my professional network.
o Yes
o No

Q14 How has your experience with CIT-E affected your attitude toward teaching in general and your perspective toward civil and environmental engineering education in general?

_____

Q18
CIT-E is interested in continuing to develop new materials and growing its community of practice.
Based on the existing course outline (click here to view a PDF of the lesson topics: Model course outline). Can you recommend any topics for potential development?
o Yes
o No

Q20 Please recommend topics for potential development in the text box below.

_____

Q19 What are your primary reasons for wanting the CIT-E community of practice to create these new materials? (Check all that apply)
▢ I'd like to integrate this material into a class but I do not feel qualified to develop it by myself
▢ I don't have time to develop the materials myself
▢ I have expertise in this area and would like to collaborate with others on this topic(s).
▢ other _____

Q21 How likely are you to use a module (i.e. a collection of lessons) on the following topics:

	Very Likely	Somewhat Likely	Not Likely
Social impacts of infrastructure			
Intersection of infrastructure and systemic racism			
Community engagement for infrastructure projects			

Q22 Would you be interested in any of the following resources if they were to be developed by CIT-E?

	Yes	No	Maybe
A model graduate level Infrastructure course			
A model undergraduate course on Infrastructure and Social Impacts dealing with intersections of infrastructure and inequality			
An asynchronous online Introduction to Infrastructure course that students could take for credit or a certificate			
Micro-credentials (i.e. 'badges')			
Embedded indicators for ABET assessment purposes			

Q23 Which of the following best describes you?
o Female
o Male
o Non-Binary
o Prefer not to answer

Q24 Which of the following best describes you?
o Asian or Pacific Islander
o Black or African American
o Hispanic or Latino
o Native American or Alaskan Native
o White or Caucasian
o Multiracial or Biracial
o Prefer not to answer

Q25 What is your job title?

_____

Q26 At what College/University do you teach?

_____

Q27 How long have you been teaching at the post-secondary level?
o<1 year
o1-5 years
o6-10 years
o>10 years

Q28 In which of the following areas do you teach? (choose all that apply)
▢ architectural engineering
▢ construction engineering
▢ environmental engineering
▢ geotechnical engineering
▢ project/construction management
▢ structural engineering
▢ transportation engineering
▢ water resources engineering
▢ Other: _____

Q15 Are you willing to help update existing materials or generate new materials for CIT-E?
o Yes
o No

If Are you willing to help update existing materials or generate new materials for CIT-E? = Yes
Q16 Please let us know your name and email so we can contact you about developing new lessons, maintaining existing materials, or sharing lesson materials that you have modified.

o Name _____
o Email _____

Q37 Is there anything else you would like us to know?

_____

Appendix B – CIT-E Lessons Usage and Module and Lesson Names

Figure B.1 shows the number of survey respondents using each of the lessons and how each lesson was used. The CIT-E modules and lesson titles are shown in Table B.1.

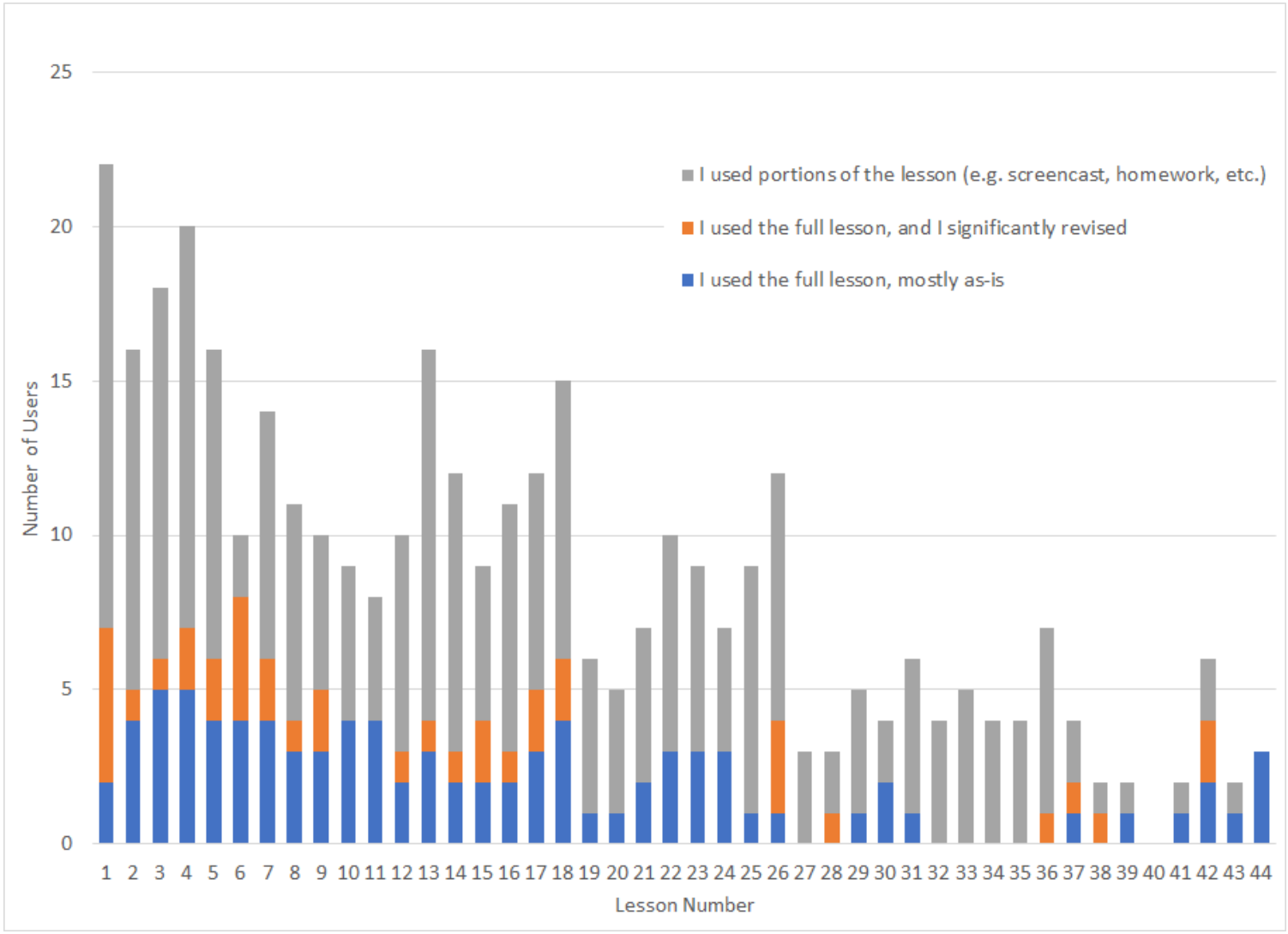

Figure B.1. Survey respondents' reported usage of CIT-E lessons.

Table B.1. CIT-E Modules and Lessons.

Fundamentals Module	Water Module	Transportation Module	Energy Module	Capstone Module
1 Infrastructure and You	14 One Water	22 Intro to Transportation 1	31 Society and Energy	40 Rural Water Case Study
2 Basic Infrastructure Sectors and Functions	15 Drinking Water Supply	23 Intro to Transportation II	32 Electrical Energy Use	41 Dams
3 Infrastructure as a System	16 Wastewater Sources and Treatment	24 Bridges	33 Electricity Generation	42 Hazardville
4 Triple Bottom Line	17 Stormwater Infrastructure and Basic Calculations	25 Roadways	34 Electricity Transmission	43 Flint Michigan Case Study
5 Social Impacts of Infrastructure	18 Green Infrastructure	26 Complete Streets	35 Electricity Distribution	44 Impacts of COVID-19 on Transportation Systems and Stakeholders
6 Teamwork	19 Water Security	27 Parking	36 Renewable Energy	
7 Ethics 1	20 Water Re-Use and Conservation	28 Transit	37 Air Pollution	
8 Ethics 2	21 Global Water	29 Route Selection	38 Energy/Food and Energy/Transportation Nexuses	
9 Written and Oral Communication		30 Cross Harbor Case Study	39 Water/Energy Nexus	
10 Financing Infrastructure				
11 Safety and Licensure				
12 Infrastructure Planning				
13 Risk and Resilience				