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Co-creating a Teaching Module on the Impacts of COVID-19 on Various Transportation Systems and Stakeholders

Dr. Claudia Mara Dias Wilson, New Mexico Institute of Mining and Technology

Dr. Claudia Mara Dias Wilson is an Associate Professor in civil engineering at the New Mexico Institute of Mining and Technology (New Mexico Tech). She earned her Bachelor's, Master's and Ph.D. degrees from the Florida State University. Although she specialized in earthquake mitigation and the development of control algorithms for semi-active dampers to reduce seismic vibrations on buildings, her research interests are broad and include topics in structural engineering, earthquake engineering, construction management, transportation engineering, and engineering education. She also advises the Student Chapters of the Society of Women Engineers (SWE) and the American Society of Civil Engineers (ASCE) at New Mexico Tech.

Ms. Janille A. Smith-Colin, Southern Methodist University

Janille Smith-Colin is an Assistant Professor in the Department of Civil and Environmental Engineering and a Fellow of Caruth Institute for Engineering Education at Southern Methodist University (SMU). She also leads the Infrastructure Projects and Organizations Research Group at SMU, whose mission is to advance sustainability and resilience goals through infrastructure systems research and education focused on developing methods and tools for engineering projects and organizations. Dr. Smith-Colin received her Ph.D. in Civil and Environmental Engineering from the Georgia Institute of Technology, where she simultaneously earned a Certificate in Higher Education Teaching and Learning. Her engineering education research interests include the formation of engineering identity in underrepresented girls and women, social threats to this identity, and the development of professional skills and systems thinking amongst civil engineers. Dr. Smith-Colin was a 2019 American Society of Civil Engineering (ASCE) ExCEED Teaching Fellow.

Dr. Baris Salman, Syracuse University

Baris Salman is an Assistant Professor of Civil Engineering in the Department of Civil and Environmental Engineering at Syracuse University. Dr. Salman's research focuses on infrastructure asset management; particularly on improving decision making procedures for maintenance, repair, rehabilitation (MRR), and construction of physical infrastructure. Dr. Salman's research group has been focusing on management aspects of a wide variety of infrastructure systems including pavements, bridges, airports, and buried infrastructure. Dr. Salman is also interested in improving undergraduate STEM education through incorporation of newer technologies into classroom activities. Dr. Salman holds a Ph.D. from University of Cincinnati and a B.Sc. in Civil Engineering from Middle East Technical University (Turkey).

Dr. Rodolfo Valdes-Vasquez, Colorado State University

Rodolfo Valdes-Vasquez is an Associate Professor in the Department of Construction Management at Colorado State University. He is committed to advancing research and teaching in the sustainability of infrastructure projects. He believes that educating the next generation of professionals will play a pivotal role in making sustainability a standard practice.

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Abstract

COVID-19 has affected all aspects of life, including how we travel. As faculty members responsible for teaching infrastructure courses across four universities, the authors collaborated on creating a teaching module addressing this critical issue. The module focuses on the impacts of COVID-19 on different transportation systems from various stakeholder perspectives. The module was implemented in two universities (n = 25): Southern Methodist University (SMU) and New Mexico Institute of Mining and Technology (New Mexico Tech, NMT) in fall 2020 and will be implemented again at other schools in fall 2021. This paper presents the results obtained during the first implementation of the COVID-19 teaching module during the fall semester of 2020 and addresses how instructors can enhance the module for future offerings. Findings from the module's implementation demonstrate increased knowledge and understanding of the impacts of COVID-19 on different transportation systems from various stakeholder perspectives. SMU students' mean scores showed high post-evaluation scores, and NMT students' scores increased from pre to post evaluation. Additionally, the reflective writing assignment revealed students' awareness of various issues, including operational and economic impacts on operators and users. This paper offers contributions to our engineering community by focusing on lessons learned from the COVID-19 experience while providing recommendations for improving this co-create module.

Keywords: COVID-19, Infrastructure, Concept Mapping, Reflective writing

Introduction

Context of the paper (COVID) and NSF Funded Community of Practice

In the summer of 2020, the Center for Infrastructure Transformation and Education (CIT-E, an NSF-funded center to develop and implement curriculum on infrastructure) hosted the Infrastructure Education in Unprecedented Times Workshop to maintain and grow the community of practice established by this organization. The workshop allowed participants to co-create lessons on how pandemics and systemic racism affect and/or are affected by civil infrastructure. These topics were introduced through keynote speaker presentations as well as suggested readings curated by the organizing committee. During the event, participants proposed topics for possible lessons addressing the relationship between infrastructure and the two selected themes, and were divided into groups based on their level of interest in each subject. A facilitator familiar with the process and templates developed by CIT-E was assigned to each group to assist in co-creating materials. Although time was provided during the workshop for the teams to begin this effort, participants were expected to continue to meet in the following weeks to finalize their lessons.

The topic selected by the authors of this paper was the Impacts of COVID-19 on Transportation Systems, with an emphasis on different stakeholders' perspectives. The authors developed this teaching module to complement existing course material on, for example, infrastructure or transportation planning, mass transit, the interconnection of infrastructure systems, system stakeholders, social, economic, and environmental impacts, risks, risk management, sustainable design, and resilience.

COVID-19 is an abbreviation for "Coronovirus Disease 2019", which is caused by the "severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)" [1]. The virus was first detected in Wuhan, China, in late 2019, and it spread rapidly throughout the world in early 2020. Human-to-human transmission primarily occurs through droplets of saliva or discharge from the nose of an infected person [2]. In the United States, during the initial stages of the pandemic, state-level Declarations of Emergency were issued, which allowed governors of the affected states to place restrictions on group activities to slow the spread of the virus [3]. Some of these restrictions involved stay-at-home regulations, school closures, closure of non-essential businesses, social-distancing requirements, and requirements to wear face protection (masks). These restrictions had a tremendous impact on transportation and transit networks. Due to limitations on gatherings, the need for travel subsided immediately. For example, the closure of businesses, telecommuting, and remote learning largely eliminated the need for travel for business and school gatherings, which constitute many trips made in the country. According to an analysis conducted on cell-phone data of 15 million Americans, the average travel distance dropped significantly from 5 miles a day to less than a mile [4]. Busy transportation corridors, hubs, and commercial and industrial facilities were mostly deserted, which may have contributed positively to air quality for many locations worldwide [5] - [8].

Transportation agencies continue to experience drops in ridership numbers even after a full year of travel restrictions and vaccination programs' rollout. For example, the Metropolitan Transportation Authority (MTA) [9] has reported considerable drops in ridership numbers for its subway (approximately 70%), bus (about 55%), Long Island Rail Road (75%), and Metro-North Railroad (80%) services in comparison to the year before. Similarly, the Port Authority of New York and New Jersey indicated that airport travel declined by 79%, ridership in PATH train declined by 78%, and travel on PANYNJ's bridges and tunnels declined by 11% in October 2020 in comparison to October 2019 [10]. Such declines resulted in tremendous economic damages to major urban transit agencies (reaching up to billions of dollars for the cases mentioned). Meanwhile, the adoption of online shopping and e-commerce has accelerated during the pandemic [11] due to several reasons, such as stay-at-home regulations and personal preferences. In the vacuum of reduced travel through personal vehicles, air travel, and different transit modes, demand for freight transportation increased to meet consumer products' shipping demands. While the overall reduction in traffic volumes presents opportunities for long-awaited infrastructure renewal projects for many agencies, funding limitations due to reduced gas-taxes and shifts in priorities to fight pandemic-related emergencies continue to impede actions. Overall, the pandemic has created unique challenges and opportunities for riders, operators, owners and financers of transportation systems nationally and globally.

This paper presents the results obtained during the first implementation of the COVID-19 teaching module during the fall semester of 2020 and addresses how instructors can enhance the module for future offerings while highlighting any pedagogical issues that work and do not work and how these can lead to improvements in engineering education. In the sections that follow, the authors describe the teaching module, discuss the research approach or the delivery of the module, the participants, and present findings and a discussion.

Teaching Module Description

The module on the Impact of COVID-19 on Transportation Systems and Users includes an instructor's "read-me" document with suggested background reading, a description of the different activities proposed, lesson slides, and suggestions on how the module could be modified and/or customized.

Pre-class Activities

Before instructors introduce any material, students are asked to prepare a concept map on the impacts of COVID-19 on transportation. This activity allows the instructors to assess students' prior knowledge and perceptions before delivering the material. After the concept maps are submitted, students complete a short reflective writing assignment. For this pre-class activity, they read articles and/or watch videos addressing the different impacts of COVID-19 on transportation from various stakeholders' perspectives. Instructors may assign articles or videos from the suggested list provided or select their materials. In the writing assignment, students consider three different impacts; relate them to each other and their own life experiences.

In-class Activities

Slides to introduce the material and guide the in-class activities were created. As with other materials developed by CIT-E, notes are provided to assist the instructor in delivering the lecture. The first in-class activity aims to assess and describe the impacts of COVID-19 on travelers as they use different transportation modes. For this activity, small groups of students are directed to a) consider the transportation modes various stakeholders can use to travel from "Point A" to "Point B"; b) determine how each of these modes is impacted by COVID-19; c) compare and contrast these impacts, the unique challenges associated with each potential mode of travel, and make a recommendation to the stakeholders. Scenarios considered include a group of undergraduate students attending a conference, a mother traveling with a toddler and a baby to visit family, and a couple in their 60s traveling to their vacation home. Instructors are challenged to adapt scenarios as needed by selecting destinations and transportation modes applicable to their geographical context. Students can be asked to share their responses to the scenarios in small groups during class. After the small groups have a chance to share their recommendations with their peers, students are reminded that impacts can affect not only stakeholders but also the physical systems. Students are prompted to think of the different impact categories: social, environmental, cultural and the various system stakeholders. The next activity can be conducted in class, if time allows, or assigned as homework. It consists of completing an impact matrix by classifying impacts in categories – intended vs. unintended and beneficial vs. adverse.

Post-class Activities

After the lecture and discussion, students either update their concept maps from the pre-class activities or create new ones, allowing the instructors to evaluate knowledge gained and/or perception changes.

Research Approach and Participants

In the fall of 2020, two of the authors incorporated the newly-created module on the Impacts of COVID-19 on Transportation Systems and Stakeholders in their classes. The students involved in this study included 11 students (2 undergraduate seniors and nine graduate master's students) from Southern Methodist University (SMU), a medium-sized private research university. Both undergraduate students were enrolled in the bachelor of science program in civil and environmental engineering. Master's degree students were enrolled in various degree programs, including the master of science in civil engineering, master of science in environmental engineering, and the master's of arts in sustainability and development (MASD). An additional 14 students enrolled in the bachelor of science in Civil Engineering Program at the New Mexico Institute of Mining and Technology (NMT), a small STEM dominant four-year public state school, also participated in the study: one sophomore, one junior, and 12 seniors.

The two instructors had to adapt the module to fit their existing schedules because it was not completed until the beginning of October 2020. As expected, these instructors had already prepared their syllabi and assignments for the semester. Thus, one instructor delivered the module as an ungraded activity while the other provided the module as an extra-credit activity. Both instructors assigned the concept-map activity before and after the lecture, but the reflective writing activity was adapted as a post-class assignment. The video selected for this activity was "*The Future of Transportation in the Era of COVID-19*" [12]. This video features former Secretaries of Transportation, Ray LaHood, now co-chair of Building America's Future, and Anthony Foxx, currently Lyft Chief Policy Officer; Commissioner of the Chicago Department of Transportation Gia Biagi, and League of Cities CEO Clarence Anthony, discussing pressing needs, opportunities and challenges for the future of transportation given the COVID-19 crisis.

Two slightly different approaches were used for the post-class reflective writing activity. The instructor at SMU asked students to a) identify three impacts on stakeholders from the readings, video, or class discussion, b) discuss possible relationships between these impacts and topics covered in class, such as sustainability and resilience, and c) relate the impacts to their own life experiences. The instructor at NMT instructed students to a) identify in the video three COVID-19 related impacts to stakeholders or to transportation systems they were unaware of, b) describe the relationship between these impacts, c) connect them to their own life experiences, and d) identify a concept or impact they either did not understand or would like to investigate further.

Analysis Approach and Results

The analysis of student deliverables included two steps 1) concept map analysis and 2) reflective writing analysis.

Concept Maps

The concept maps on the impacts of COVID-19 on transportation created prior to the lesson were compared to those produced as homework after the module was completed. Figure 1 shows one of the students' preliminary concept maps, while Figure 2 presents one of the concept maps created after exposure to the module material.

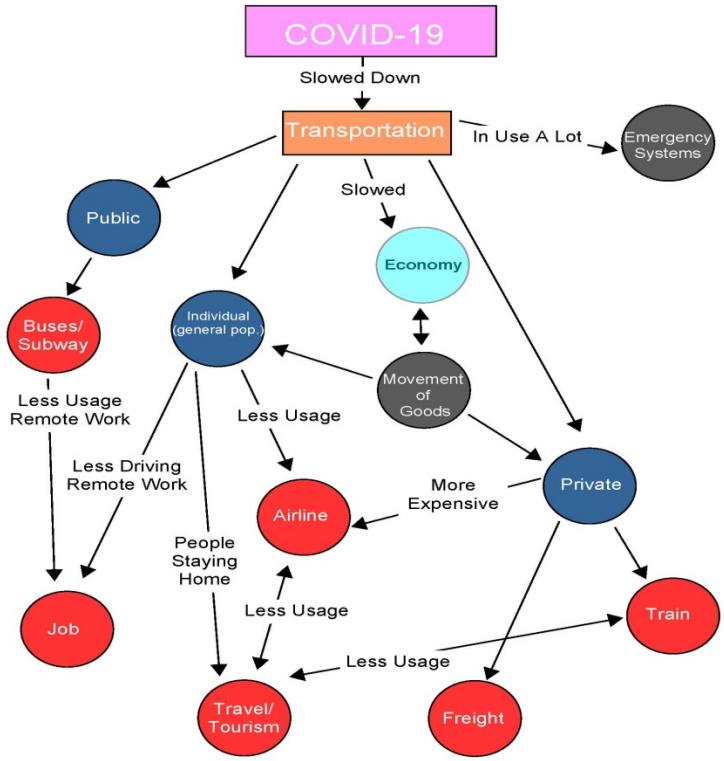

Figure 1. Example of concept map before the lecture.

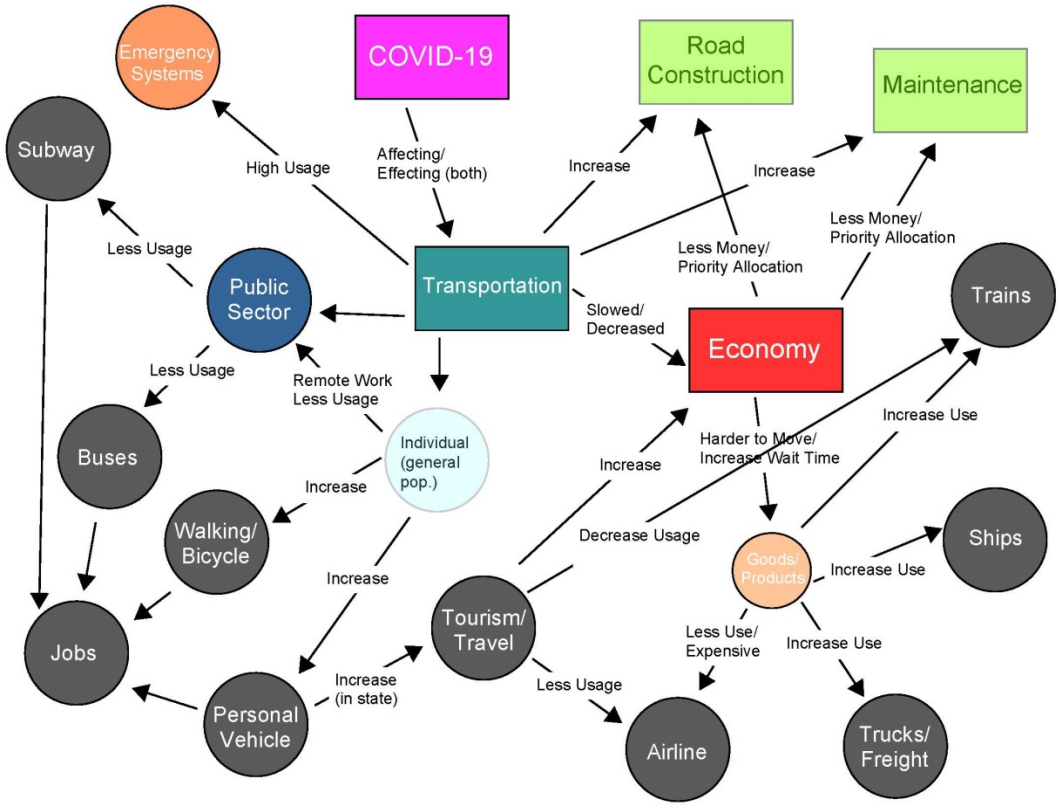

Figure 2. Example of concept map after lecture.

Appendix A shows the grading matrix used for assessing these concept maps, which was adapted from Besterfield-Sacre et al. [13] and Valdes-Vasquez, and Klotz [14]. The rubric allows instructors to assign scores in terms of "content," "relationships," and "organization." A 4-point scale from 1 (poor) to 4 (excellent) was used while assessing student performance. In evaluating concept maps, authors paid attention to the following:

- Organization: Concept maps should feature feedback loops and cross-connections between concepts. The maps should not consist solely of linear connections.
- Relationships: Relationships between concepts should be shown and labeled explicitly.
- Content: Maps should feature concepts that collectively represent a comprehensive and hierarchical structure.

Since one concern when using rubrics as an assessment tool is validation, two faculty members (also co-authors of this paper) were asked to independently assess the concept maps, discuss their assessments, and reach an agreement. Each faculty member participated in the development of the teaching module and has taught sustainable infrastructure courses. Concept maps were given to the evaluators without students' names. These concept maps were randomly arranged to eliminate individual bias. Evaluators met twice to talk about their assessments and to come to an agreement on final scores. Table 1 summarizes results from SMU and NMT (pre-class and post-class) pilot applications. Scores reflect the mean for each evaluation category (i.e., content, relationships, organization) for each university group. Numbers in parentheses show the standard deviation values for the observations.

Table 1. Concept Map Evaluation Scores

	Content	Relationships	Organization
SMU* n = 11	2.50 (0.39)	1.27 (0.26)	1.18 (0.34)
NMT (pre-class) n = 14	1.68 (0.64)	1.50 (0.52)	1.07 (0.27)
NMT (post-class) n = 14	2.36 (0.53)	1.86 (0.74)	1.5 (0.76)

* Only one set of scores available for SMU.

Results indicate that students from these two cohorts performed similarly in all three criteria. Table 2 summarizes the mean change in pre-class and post-class assessments for students at NMT. Students showed a considerable improvement in terms of "content" and "organization." The most substantial improvement (i.e., a jump of 2 points) was recorded in two students' organization scores.

Table 2. Change in Evaluation Results

	Content	Relationships	Organization
Δ NMT (post-class - pre-class)	0.68 (0.49)	0.36 (0.44)	0.43 (0.73)

* Numbers in parentheses indicate the standard deviation values for these observations.

Reflective Writing

The two instructors who integrated the module into their courses assessed the reflective writing assignment. Reflective writing was evaluated by identifying themes in student responses and analyzing students' connections to their own experience and/or relevant course material. This approach was preferred over a quantitative analysis of the results because it provided more information on the module's value to the students. Because the requirements for these assignments were slightly different, they were first analyzed separately.

Impacts of COVID-19 on transportation most commonly identified by SMU students were: (1) increased inequity, (2) increased sanitation and regulations on the use of masks and social distancing, (3) decreased revenues due to the reduced ridership, (4) reduction in routes available, and (5) increased exposure of operators to COVID-19. Impacts most commonly identified by NMT students were: (1) increased inequity, (2) decreased revenues due to reduced ridership, (3) lack of public transit access and tradeoffs between ridership and coverage, (4) inadequate government funding for transit and (5) implications for micro-mobility travel.

As shown by the lists above, several students at both universities cited increased inequity and decreased revenues due to reduced ridership as impacts of COVID-19 on transportation and stakeholders. Some students learned about new impacts from taking the module, while others students gained a deeper understanding of already known impacts and learned more about the reasons for these impacts (see quotes):

> *"[o]ne impact of COVID-19 that I had not considered was the effect public transportation had on essential workers. Many people that have essential jobs do not own cars, and as a result, they heavily rely on public transit,"*

> *"[t]hough I was aware that COVID-19 disproportionately affect BIPOC, I did not consider that part of the reason for this is that in many communities, these individuals rely heavily on public transit and rideshare options, where they are much more likely to be exposed to the virus."*

It should be noted that at NMT, inequity and social justice in transportation were not covered in this Infrastructure course. These topics were addressed in a separate class: Introduction to Transportation, but only a few of the students registered in the Infrastructure class had already completed the Transportation course. At SMU, concepts of social justice in transportation were not addressed directly in this course which was primarily focused on resilient infrastructure and adaptation in the face of climate change. However, several of the graduate students had taken Sustainable Transportation in the preceding semester which addressed social sustainability and transportation. Additionally, the MASD curriculum at SMU, of which many of the graduate students were enrolled, has a core focus on issues of sustainability, development, and justice across built environment and design.

There were apparent differences observed in the types of experiences communicated in the reflective writing based on geographical location, absence of transit in the community, and family status. For example, while students living in urban areas (SMU) identified impacts related

to the use of public transportation - increased sanitation, regulations on using masks and social distancing, reduced route availability, and bus operator exposure to COVID-19, students living in rural areas (NMT) where public transportation is practically nonexistent, did not identify such impacts. Instead, these students focused their attention on transit funding, tradeoffs between ridership and coverage, inadequate government funding, and alternative transportation systems such as micro-mobility. Additionally, graduate students from SMU related experiences of maneuvering transportation with children and spouses and other family members.

Responses to the reflective writing assignment showed that students took this opportunity to explore the impacts of COVID-19 on different stakeholders and the transportation system itself more extensively. Some related the impacts to concepts covered in class, such as:

- Resilience: *"Early in this class, we discussed the concept of resilient infrastructure. One of the things that our infrastructure is not resilient to is rapid changes in demand,"*
- Complete Streets: *"[cities] redefined the concept of a street, reducing the number of cars and creating a friendlier environment for pedestrians and cyclists,"*
- Adaptive infrastructure*: "[t]his isn't a personal experience, but I remember that during the pandemic the entire NBA season was played in a "bubble" in Orlando, Florida. The NBA "bubble" is a great example of facilities being used for different purposes than originally intended, Adaptive Infrastructure."*

Student responses also showed some understanding of how COVID-19 has impacted the operation of transportation systems, ridership and revenue, and their interconnections, as demonstrated by the following reactions:

> *"The same factor that is decreasing ridership of public transportation is increasing car sales, record levels as of September of this year. Prices will eventually catch up, potentially pricing people out that cannot afford new cars or the rising prices of the upkeep and fees of their existing cars. For me, it was this cycle of unaffordability; I couldn't afford the transportation to work to afford the transportation. That is very much the case for many people who now find themselves without a job,"*
>
> *"I am very concerned about how the negative economic impacts to taxpayers and general public will have a cascading effect for local governments and system owners. The reduced revenue from taxes and ridership will likely have a long-term effect on our infrastructure systems which we may not be able to see right now."*

Also interesting were the reflections on the future implications of the pandemic and potential impacts on future transit ridership:

> *"[i]t seems that as lockdowns are lifted, people might be less inclined to go back to taking buses and ride sharing. The fear of another wave of cases would likely be in the back of their minds. Furthermore, as more and more people and businesses see the appeal for remote workers, the need for a workday commute will likely forever be reduced."*

Finally, some students shared that they could not relate to the stories in the readings or videos of COVID-19 impacts on transportation and specifically on transit, either because they did not have

access to transit or had never taken transit. Despite this reality, these same students expressed an interest in learning more about the lack of transportation in low-income communities. They were able to make connections between access to transportation and access to economic opportunity, showing empathy towards these particular stakeholders and an ability to understand the consequences of transportation inequity.

> *"I am going to be honest and say that I have no relation with these impacts."*
> *"...if this is fixed, then the people in these areas would have more opportunities to leave, find work, or get a better education."*

Discussion

Findings from this module's implementation demonstrated increased knowledge and understanding of the impacts of COVID-19 on different transportation systems from various stakeholder perspectives. NMT's mean scores showed an increase from pre- to post-evaluation, and SMU students showed similar post-evaluation scores. Additionally, the reflective writing assignment revealed awareness of various issues, including operational impacts, economic impacts to transportation operations and users. Apparent differences in the issues that resonated with students based on geography (urban vs. rural) and family status (i.e., income availability, child-care responsibilities) were also noted and were of interest to the authors. Students showed an ability to connect the module to their personal experiences. When students felt unable to do so, they still demonstrated empathy for those they recognized have most likely been impacted by COVID-19 disruptions to transportation, including the low income, zero-car households, essential workers, and the transit-dependent.

Though proving impactful, many improvements to the delivery of the teaching module are suggested. First and foremost, the authors advise that other instructors plan to implement the module when developing their initial syllabus. The module uses many forms of content delivery to ensure learning amongst individuals with diverse learning styles. Appropriate scheduling of module lectures and assignments will be necessary to ensure success. Most important is avoiding the perception that “more work is being added” at the last minute by a late introduction of the module. In addition, if this module is being delivered in multiple classrooms by multiple instructors, special attention should be taken to ensure that instruction delivery is consistent, mainly if an in-depth measurement of impact is of interest. Instructor expectations should be agreed upon and delivered to students uniformly. Other considerations include the grade-level of students (graduate vs. undergraduate) and students' prior knowledge and environmental experiences—these differences made for notable yet interesting differences in student responses. Although a difference in responses was observed based on students’ geographical location, absence of transit in the community, and family status, the authors do not recommend modifying the module based on these demographics. Instead, if different perspectives are lacking due to a lack of diversity in students’ backgrounds, the authors suggest the instructors encourage the students to consider other stakeholders’ perspectives through questions and discussions. An in-depth consideration of diverse opinions is strongly encouraged and viewed as a curricular contribution to justice, equity, diversity and inclusion goals.

Concept mapping can be a useful learning tool. However, practice is often needed for students to design an impactful concept map. We recommend that students be allowed to practice creating a concept map before the implementation of the module. The use of concept mapping to respond to questions such as "Who am I ?" at the beginning of the course provides the opportunity for such practice. We also recommend that students critique each other's concept maps. The opportunity to offer peer feedback further exposes students to the rules and expectations for concept mapping. This scaffolding approach is expected to improve the quality of the pre- and post-evaluation of the concept maps during module implementation.

Furthermore, reflective writing is a useful tool for having students reflect on their personal experiences while surprisingly teaching students empathy. The act of looking beyond their own experiences to the experiences of various stakeholders appears to have created opportunities for students to consider broader social and economic impacts on transportation systems and people. This welcomed finding is significant as the civil engineering disciplines continue to seek meaningful ways to connect students with themes such as equity and social justice. Similar to what was found in the implementation of the concept mapping activity, if students have limited exposure to reflective writing, we recommend that samples and practice be provided with clear expectations for content, structure, and grading of the reflective writing deliverable.

In terms of limitations, the unprecedented conditions and times, in fact, hindered the implementation of this module and assessing students' knowledge about the impacts of COVID-19. First, two of the courses scheduled to participate in the study were canceled due to low enrollment. The findings presented are thus limited by a small sample size and limited participation. Second, fall 2020 was, for many, the first full semester of remote instruction. Student engagement, therefore, proved more challenging than expected. Finally, because of the ongoing disruptions to the transportation system, many students had limited contact with their local transportation systems, and in many cases, usage was already quite limited. Therefore, students had to draw on a retrospective view to characterize potential impacts of COVID-19 on transportation systems and stakeholders, as well as media reports, rather than current or ongoing experiences.

Conclusions

This paper outlines the process used to co-create a teaching module on the impacts of COVID-19 on various transportation systems and stakeholders for implementation in the civil engineering classroom. The module uses multiple content delivery modes to meet its learning objectives - videos, readings, a PowerPoint presentation, small group discussions, and individual work that includes reflective writing and concept mapping. Though somewhat demanding in its delivery, the use of multiple learning strategies is intended to encourage learning among diverse learners. Learning is assessed by using pre- and post-evaluations of student work. Findings from the module's implementation demonstrate increased knowledge and understanding of the impacts of COVID-19 on different transportation systems from various stakeholder perspectives. As is to be expected, not all students engaged fully in the module requirements. Not all students took the time to reflect in a meaningful way on their own experiences, and as is to be expected, not all students produced a high-quality concept map. Yet, in the end, it does appear that each student gained a better understanding of the critical themes communicated via the module content.

In engineering education, instructors are challenged to engage students directly with their built, social, and natural environments. Yet as educators, we often struggle to communicate social and built environment interactions. This module offers a framework for delivering this content, facilitating student engagement and reflection, and assessing learning impacts. The focus on "diverse stakeholder perspectives" challenges students to think about the social, economic, and natural environment impacts and interconnections between these impacts. This approach allows instructors to emphasize the importance of systems thinking in analyzing a problem, which is a focus on the whole rather than a small part. Finally, through the selected content, this module offers instructors material that can begin the conversation around transportation and social justice. Research shows that students from marginalized communities respond well to instruction grounded in personal experience and real-world problems. This content is by no means intended to offer a detailed treatment of topics such as transport poverty, social exclusion, or transportation equity. Still, the authors challenge instructors and students to begin to recognize the uneven ways in which disruptions in travel impact transportation stakeholders.

Opportunities for future research exist. First, students' sociodemographic characteristics can be examined and related to the ideas captured in concept maps and reflective writing. With a larger sample of students, it would be interesting to investigate how students' socioeconomic backgrounds and experiences impact their concept map development and experiences drawn upon. Second, this approach to content delivery and implementation can be adapted and used to communicate impacts from other disasters and events or draw attention to non-traditional groups of stakeholders. Finally, as we explore opportunities to further develop and expand this module, we are challenged to identify additional ways to connect infrastructure education with a broader social justice agenda.

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References

[1] CDC, "COVID-19 Overview and Infection Prevention and Control Priorities in non-US Healthcare Settings," Feb. 26, 2021. [Online]. Available: https://www.cdc.gov/coronavirus/2019-ncov/hcp/non-us-settings/overview/index.html [Accessed March 6, 2021].

[2] WHO, “Coronovirus,” 2021. [Online]. Available: https://www.who.int/health-topics/coronavirus#tab=tab_1 [Accessed March 1, 2021].

[3] S., Parr, B. Wolshon, P. Murray-Tuite, and T. Lomax, "Multistate Assessment of Roadway Travel, Social Separation, and COVID-19 Cases," *Journal of Transportation Engineering, Part A: Systems*, *147*(5), 04021012. 2021.

[4] J. Glanz, B. Carey, J. Holder, D. Watkins, J. Valentino-DeVries, R. Rojas, and L. Leatherby, "Where America didn't stay home even as the virus spread," *The New York Times*, April

2, 2020. Online. Available: https://www.nytimes.com/interactive/2020/04/02/us/coronavirus-social-distancing.html [Accessed March 1, 2021].
[5] Z. S. Venter, K. Aunan, S. Chowdhury, and J. Lelieveld, "COVID-19 lockdowns cause global air pollution declines," *Proceedings of the National Academy of Sciences*, *117*(32), 18984-18990. 2020.
[6] X. Shi, and G. P. Brasseur, "The response in air quality to the reduction of Chinese economic activities during the COVID-19 outbreak," *Geophysical Research Letters*, *47*(11), e2020GL088070. 2020.
[7] L. Y. K. Nakada, and R. C. Urban, "COVID-19 pandemic: Impacts on the air quality during the partial lockdown in São Paulo state, Brazil," *Science of the Total Environment*, *730*, 139087. 2020.
[8] A. Sharifi, and A. R. Khavarian-Garmsir, "The COVID-19 pandemic: Impacts on cities and major lessons for urban planning, design, and management," *Science of the Total Environment,* 142391. 2020.
[9] MTA, "Day-by-day ridership numbers," March 1, 2021. Online. Available: https://new.mta.info/coronavirus/ridership [Accessed March 1, 2021].
[10] PANYNJ, "Volume at Port Authority Facilities Continued Decline Through October 2020 Due To Covid-19 Pandemic," Dec. 4, 2020. Online. Available: https://www.panynj.gov/port-authority/en/press-room/press-release-archives/2020-press-releases/volume-at-port-authority-facilities-continued-decline-through-oc.html [Accessed March 1, 2021].
[11] R. Y. Kim, "The Impact of COVID-19 on Consumers: Preparing for Digital Sales," in *IEEE Engineering Management Review*, vol. 48, no. 3, pp. 212-218, doi: 10.1109/EMR.2020.2990115. 2020.
[12] Axios Events, "The future of transportation in the era of COVID-19," Aug. 28, 2020.Online. Available: https://www.axios.com/axios-event-future-transportation-f12e504d-09da-4ba9-8f27-b7bbbcd2bce3.html [Accessed March 6, 2021].
[13] M. Besterfield-Sacre, J. Gerchak, M. Lyons, L. Shuman, and H. Wolfe, "Scoring concept maps: An integrated rubric for assessing engineering education," *J. Engineering Education,* 93 (2), 105–115. 2004.
[14] R. Valdes-Vasquez, and L. Klotz, "Incorporating the social dimension of sustainability into civil engineering education," *J. Prof. Issues in Eng. Educ. Pract.*, 10.1061/(ASCE)EI.1943-5541.0000066, 189–197. 2011.

Appendix A. Concept Mapping Grading Matrix adapted from Besterfield-Sacre et al. [13] and Valdes-Vasquez, and Klotz [14]

Score	Content	Relationships	Organization
1	Some understanding can be gained from the concepts presented on the map. However, the map is naïve and contains misconceptions about the subject matter; inappropriate ideas or terms are used.	Relationships are somewhat clear but lacking; the importance is evident but not very distinctive.	Concepts are not well integrated. The map is arranged with concepts only linearly connected. There are few or no connections within/between the branches.
2	The concepts presented show definitive thinking among them. However, the map has several subject matter inaccuracies.	Relationships are indicated; the relative importance of ideas is shown for the most part.	A few feedback loops exist. The map has a linear organization with few within/between branch connections.
3	The concepts presented show effective and integrated thinking. However, the map has a few subject matter inaccuracies.	Relationships are effectively indicated, and relative importance of ideas is indicated.	Several feedback loops exist. The map has a linear organization with several within/between branch connections.
4	The map reflects an accurate understanding of the subject matter, meaning few or no misconceptions are presented; it also provides new information.	Both simple and complex relationships are effectively indicated; the relative importance of ideas is clearly indicated.	The map is non-linearly organized with concept integration and the use of feedback loops providing a complete picture of ideas.