

Board 41: WIP – Community of Practice as a Theory of Change for Infrastructure Education

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WIP – Community of Practice as a Theory of Change for Infrastructure Education

Abstract

A national faculty Community of Practice (CoP) has created a model course for undergraduate infrastructure education as a part of its shared agenda. This CoP has collectively defined the domain of knowledge for undergraduate introductory infrastructure education; co-created and peer-reviewed more than 40 complete lessons for an introductory infrastructure course; shared best practices and resources among members; and provided mentorship to newer members adopting or adapting the materials. The Center for Infrastructure Transformation and Education (CIT-E) considers infrastructure as a system rather than a collection of unrelated structural/environmental/transportation components; even more importantly, this system is conceived of as a social-technical system that must be designed with equity and justice factors prioritized to include the diversity of users' lived experiences. To that end, CoP members have recently produced learning materials on Equity, Inclusion, and Justice (DEIJ) in infrastructure provision.

The operationalizing of CoP as a theory of change by CIT-E has emerged beyond the initial National Science Foundation (NSF) funding a decade ago, employing various change strategies. Example strategies include expanding membership and creating alternative educational practices to support change and transformation. Recent NSF funding and new membership have created opportunities for the CoP to lead change at a much broader level across civil and environmental engineering education in the U.S.

As part of this work, we conducted semi-structured interviews with seven change leaders in engineering education and DEIJ. We asked their perspectives on community of practice as a theory of change and whether it is appropriate for this work. Their responses were coded, revealing 169 codes, some of which advisors agreed upon, and many representing alternative perspectives. Processes such as considering, accepting, asking, and acknowledging are easy to overlook while executing change through mentoring, funding, and doing. The results of this work are helpful for civil and environmental engineering (CEE) faculty members interested in operationalizing change in their classroom and on their campus to meet ABET's relatively recent DEI criteria, and the process in this study is transferrable to other fields that are also mobilizing transformative practices for integrating DEIJ principles into their curricula.

Introduction

Civil infrastructure forms the physical foundation for our society. Therefore, civil engineers are ethically obligated to consider issues of diversity, equity, inclusion, and social justice (DEIJ), as acknowledged in the most recent revisions to the American Society of Civil Engineers Code of Ethics [1]. This professional responsibility is shared among those who practice engineering currently – the engineers of today – and those who educate the engineers of tomorrow. There is evidence that engineering faculty increasingly recognize the importance of educating students to approach problems through a socio-technical lens. However, institutional and professional society efforts around DEIJ continue to focus primarily on issues of representation and climate rather than promoting equity and justice through the *practice* of engineering (e.g., [2], [3]).

These efforts are important and necessary, but they are insufficient – they do not equip faculty to address issues such as systemic racism and identity-based exclusion in the academic content of infrastructure-focused courses.

Communities of practice (CoPs) are both a learning theory and a theory of change. We hypothesize that a national faculty CoP can effect change in this context – transforming infrastructure education from a focus on decontextualized technical content to a social-technical endeavor. Approximately 10 years ago, an effort to create a model course for undergraduate infrastructure education evolved into a national Community of Practice focused on improving infrastructure education more broadly. This CoP – the Center for Infrastructure Transformation and Education (CIT-E) – comprises more than 100 educators, primarily in civil engineering departments in the U.S. The CoP members collectively have defined the domain of knowledge for undergraduate introductory infrastructure education; co-created and peer-reviewed more than 40 complete lessons for the introductory infrastructure course; shared best practices and resources among members; and provided mentorship to newer members adopting or adapting the materials. As a result of CIT-E's activities, dozens of faculty members now teach differently than they otherwise would have – these faculty members teach different material and have a different approach to their teaching [4]. Most recently, faculty members across the U.S. have co-created learning materials focusing on integrating Diversity, Equity, Inclusion, and Justice (DEIJ) issues into infrastructure education. The CoP conceives of infrastructure as a system rather than a collection of unrelated structural/environmental/transportation components; even more importantly, members understand that infrastructure is a social-technical system that must be designed with equity and justice factors prioritized to include the diversity of users' lived experiences. This CoP has sustained itself beyond its initial National Science Foundation funding, growing membership and creating alternative educational practices for transformation. While these results are consistent with employing a CoP as a theory of change, more evidence is needed to scale the change.

Recent funding and new membership have created opportunities for the CoP to lead change at a much broader level across civil and environmental engineering education (CEE) in the U.S. A 2021 survey of CIT-E members suggested that civil engineering faculty members both are interested in incorporating issues of diversity, equity, inclusion, and justice into courses and curricula *and* are looking for help with how to do so effectively [4]. The survey also revealed that while the CoP is more diverse in terms of gender than the civil engineering faculty in the U.S., engaging colleagues more intentionally with greater attention to other dimensions of diversity – including, for example, race, ethnicity, disciplinary background, and leadership experience – would strengthen the CoP's capacity to address this desire and need in a meaningful way. As a result, we are building capacity in CIT-E by expanding CoP membership, documenting the existing literature related to re-contextualizing civil engineering education [5], and facilitating the collective definition of the community's vision for educating students about infrastructure in context.

To help guide our work, we have engaged with seven change leaders in higher education who have knowledge and expertise at the intersections of DEIJ theories and change theories. These change leaders were selected for their expertise in how change happens and/or their demonstrated success in effecting academic change; we are particularly interested in learning from their experiences with and suggestions for creating DEIJ-focused changes. This paper

synthesizes what we learned in a series of semi-structured interviews in which we asked about 1) their perspectives on community of practice as a theory of change and whether it is appropriate for this work, and 2) their reflections on and examples of effective DEIJ efforts as well as barriers to operationalizing change theories in practice.

The following section introduces the CIT-E CoP in the context of the literature on communities of practice as a theory of change. Then, we describe our methods and results; this is followed by a discussion of what we have learned so far regarding the pragmatic validation of community of practice as a theory of change for establishing infrastructure education that is more equitable and just. Finally, we suggest what other researchers and educators can take away from our current work.

Background

A theory of change is a “predictive assumption about the relationship between desired changes and the actions that may produce those changes” [6]. We understand that to lead the transformative change we envision, we first must understand how we expect such changes to occur. In particular, we seek to drive transformational change in CEE education and practice. Our aspiration is that graduates of CEE programs will 1) be aware of systemic racism that is quite literally built into our public infrastructure, and 2) be equipped to ensure an equitable and just infrastructure in the future. We have been actively exploring various theories of change to inform how we might most successfully drive this specific future change, with particular attention to how change can be effected through a national faculty Community of Practice.

A Community of Practice is a “group of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly” [7]. Characteristics include a shared practice, a domain of interest, and a well-developed sense of community. As introduced above, we successfully built a Community of Practice (CoP) as part of the Center for Infrastructure Transformation and Education (CIT-E). Three years after the completion of funded support from the National Science Foundation, our CoP remains impactful and cohesive. Our CoP supports ongoing interactions among practitioners in a virtual domain, leveraging a shared Canvas platform that provides access to co-created lessons and lectures. Prior to COVID-19, the CIT-E CoP supported face-to-face engagements through regular workshops and planned connections at academic conferences; since the pandemic began, we have shifted first to virtual and now to a mix of virtual and in-person interactions, providing expanded opportunities for engagement with people who would otherwise be unable to participate. As a community, CIT-E has collectively defined the domain of knowledge for undergraduate introductory infrastructure education; co-created and peer-reviewed 40 complete lessons for an introductory infrastructure course; shared best practices and resources among members; and provided mentorship to younger members adopting or adapting the materials. The entire course or portions thereof have been adopted or adapted at more than 35 colleges/universities, impacting more than 4,000 students to date [4]. The literature documents this type of activity as common in CoPs - communities of practice often result in members solving problems, sharing information, seeking and fostering expertise, or mapping knowledge.

Further, CoPs have been shown to support change at the individual faculty level and in shifting department cultures or leading to STEM reform changes at the department level [8]. Theoretical

features of CoPs inspire us to be optimistic about our ability to make change in civil infrastructure education, which is distributed broadly in higher education. Working across distance and difference, CoPs have been shown to lead to change in “non-organizationally located communities” – communities that are not located at, nor supported by, a single organization, such as a university or hospital, with human resources, financial resources, or infrastructure [8]. Evidence suggests that CoPs have been effective at diffusing teaching innovations between institutions [9].

Communities of Practice have recently taken hold in higher education, primarily related to teaching and learning networks. While they currently are popular, CoPs around teaching have not always been the norm in higher education. Research work in higher education has long espoused the need for learning networks and communities, but teaching work in higher education historically has been more in isolation [10]. Teaching and learning networks are particularly valuable in supporting innovation. Infrastructure education, like many other disciplines, is in need of innovation to remove race neutral practices which can become exclusionary, and race conscious inclusion to promote diversity, equity, inclusion, and justice.

CoPs also may be well-suited to driving change in support of DEIJ initiatives relating to curricular change. Such changes often suffer when not supported by a community [11], [12]. Relatedly, Kezar and Gherke [8] note that some benefits associated with communities of transformation are experienced more by faculty of color than by white faculty; these benefits include networking, support in pursuing new grants, and making the transition from faculty work to administration. One possible explanation is that such communities provide more support for faculty of color beyond that which may exist on their home campus.

Methods

To develop our understanding of the capacity of CoPs to effect change in integrating DEIJ context into infrastructure education, we engaged with seven change leaders with experience in academic change-making and elevating issues of diversity, equity, inclusion, and justice. These change agents agreed to be acknowledged by name and are listed at the end of this paper. We are grateful for their time, energy, expertise, and insights. We chose to invite these change leaders because of their range of experiences and perspectives, including:

- Educational backgrounds within and external to engineering;
- Making change within engineering and studying change in engineering;
- NSF grants awarded in areas related to DEIJ and/or effecting educational change;
- Administrative and leadership experience in academia and at the National Science Foundation;
- Professional history and current context;
- Personal experiences as members of minoritized groups in engineering; and
- Experience with professional engineering organizations and societies.

The data analyzed in this paper is a collection of notes from individual semi-structured interviews with these change leaders in higher education. A retroactive IRB amendment was made to the existing protocol for this study. In the initial protocol, meetings with the change leaders in this study were preparatory steps toward collecting publishable data via interviews,

web scraping, and group concept mapping. Recognizing the transferable value of the insights provided to us by these change leaders, we received their consent to amend our IRB and pursue publication.

While a recording and professional transcript would have been helpful in the data analysis process, a carefully designed interview protocol, and a collective effort to record meeting notes during and after meeting engagements, resulted in a robust dataset [13], [14]. During each meeting, one designated note-taker focused on taking notes digitally. The note-taker engaged in conversation but was not responsible for being the primary moderator of the group discussion. Multiple team members also took notes on paper during the conversation, paying critical attention to when the note taker asked questions to assist in recording as much information as possible during the conversations with the advisors. We then combined these notes to capture as much of the conversation as possible.

The interview questions for the conversations with these change leaders focused on the change-making process and integrating DEI concepts into infrastructure education curricula. The interview questions were:

- Here's our plan – to ensure that infrastructure education ensures that students consider the long-term impact, negative or positive, that their decisions as future engineers have. This will be organized/facilitated by the CIT-E Community of Practice. What capacity is needed in a Community of Practice to make this happen?
- What do you see as the biggest single barrier to change in higher education?
- What is the biggest key to success in making change in higher education?
 - Do you have any examples?
- We are considering community of transformation/community of practice as our 'theory of change' – what do you think?
- What traps might we fall into with regard to change theory in an NSF proposal?
 - Anything in particular with terminology?
- You are doing some interesting work in this area – do you see connections between your work and what we are proposing?

To improve the validity of our analysis and accurately represent the phenomena we intend to describe [15], each co-author reviewed the meeting notes for completeness and accuracy. Initially, we used descriptive coding to prepare discussion points for a team meeting focused on the next steps for developing an NSF IUSE ICT Track 2 proposal and NSF annual report. After agreeing on the richness of the description in the interview notes, we used another first cycle coding technique, process coding, to identify observable and conceptual actions in the data [16]. To reveal areas of agreement and alternative perspectives, we conducted multiple iterations of coding, focusing on identifying conceptual action that did not present itself as a gerund (“-ing” words) in the meeting notes. This early-stage analysis is foundational to providing a broad platform on which to build our future theory development. The diversity of our findings is to be expected, but evidence of how diverse and what specifically applies to the context of civil infrastructure education is needed.

Process coding is beneficial for identifying examples of “the infinite variation in the intensity, type, and timing of action/interaction/ and emotional responses” to issues, problems, situations,

goals, and events in life [17]. Issues such as systemic racism evoke many emotions and are tied to moral considerations requiring higher-order cognitive skills to process. Beyond the safety of thinking, the danger of action is real for change agents. Some civil infrastructure education change agents are in university environments where a peer reviewed document is one of their first symbolic allies when it comes to challenging the race neutral status quo.

Collaboration and communal decision-making can bring a synergistic power helpful in overcoming barriers to change. The literature discussed in the background section of this paper highlights the collaborative nature of making change in higher education by involving a diverse population of change agents. Process coding is a powerful analysis technique that is a starting point for our investigation into the alignment of change actions, and the disruption of flow and continuity in the change-making process. Even in a work in progress paper, the data analyzed describes a wide range of actions that change agents can execute. The actions for change identified in this study have logical connections that can indicate the potential for alignment, flow, discontinuity, and disruption. Figure 2 shows our initial framing of a sequence, but much more work will be done to generate transferrable theoretical framing around the processes that our community of practice actualizes and how change is sequenced.

The methods utilized in this work-in-progress paper provide strong evidence of theoretical validation and contribute to understanding the variation in the theory of change models for higher education. While conceptual actions were coded, the actual words of the change leaders that were recorded in the meeting notes are provided as examples in the results section to enhance the rigor of this study [18]. The research team will pursue further analysis and future conversations with change leaders and agents to advance the knowledge presented in this work-in-progress paper.

Results

We identified 169 process codes in our coding of the notes from the seven semi-structured interviews. Table 1 lists these codes in alphabetical order. Prioritizing including as many possible actions for making change as a CoP, we chose to share isolated verbs rather than listing them all in context. Our complete NVivo database, however, does contain examples of context for further analysis; Figure 3 shows selected words in context.

Randomizing the process codes and creating a word cloud resulted in a thought-provoking data visual shown in Figure 1. The software assigned words colors and sizes to create a word cloud that best fits the shape of two hands reaching toward each other. We used this word cloud as an initial visualization to help us think about what connections might be present among the process codes and how to analyze them. Word clouds take words out of context, meaning that a term could have been used positively or negatively. Either way though, since our focus is on *action*, the frequency matters.

Table 1. Process codes describing things people can "do" to make (or block) change in higher education

accepting	convincing	funding	needing	selling
acknowledging	counting	giving	networking	sharing
adding	covering	going	operationalizing	shifting
administrating	cracking	graduating	organizing	showing
adopting	creating	grieving	overpromising	simplifying
advising	critiquing	having	owning	solving
advocating	debating	hearing	partnering	speaking
affecting	defining	helping	poaching	struggling
aligning	developing	hiring	preaching	supporting
apologizing	dialoguing	impacting	preparing	sustaining
asking	dictating	improving	presenting	systemizing
assuming	diffusing	incorporating	problematizing	taking
being ready	digging	infiltrating	promising	talking
benchmarking	dismantling	influencing	providing	teaching
blaming	disrespecting	innovating	publishing	telescoping
blocking	disseminating	integrating	pushing	telling
bringing	documenting	interpreting	quantifying	testing
building	doing	intervening	questioning	thinking
burning out	empathizing	inviting	reacting	throwing away
capturing	empowering	involving	realizing	towing
changing	encouraging	judging	receiving	tracking
citing	erasing	keeping	recognizing	training
collaborating	exciting	knowing	refreshing	trusting
collecting	excluding	learning	remembering	underestimating
comforting	exemplifying	letting	replacing	understanding
communicating	exhibiting	leveraging	replicating	uniting
complicating	expecting	listening	resisting	unloading
conflicting	experimenting	looking	respecting	updating
connecting	fearing	making	responding	using
considering	fixing	managing	retaining	utilizing
constraining	focusing	mapping	reviewing	welcoming
contributing	following	meeting	risking	willing
converging	forcing	mentoring	scaling	working
conversing	forming	moving	seeing	



Figure 1. Randomized word cloud of process codes

Table 2 adds structure; it lists the process codes with the highest frequency considering word similarity among the process codes. Word similarity was evaluated using Windows's NVivo 11 (ver 11.4.1.1064) Plus. A word query with level 3 synonym grouping was run on the 169 process codes resulting in 15 process codes that can be connected to four or more similar process codes.

Table 2. Word frequency considering similar words among process codes

Word	Count of Similar Words	Similar Words
considering	6	considering, counting, debating, seeing, taking, thinking
accepting	5	accepting, adopting, assuming, recognizing, taking
asking	5	asking, expecting, involving, needing, taking
acknowledging	4	acknowledging, citing, knowing, recognizing
adopting	4	adopting, assuming, following, taking
affecting	4	affecting, impacting, involving, moving
bringing	4	bringing, contributing, taking, working
fixing	4	fixing, making, preparing, being ready
forming	4	forming, making, organizing, working
giving	4	giving, making, presenting, throwing
hearing	4	hearing, learning, listening, seeing
keeping	4	keeping, retaining, supporting, sustaining
learning	4	learning, seeing, taking, teaching
making	4	making, realizing, taking, working
realizing	4	realizing, recognizing, seeing, understanding

Collaborative review by the authors resulted in the selection of seven process codes to be discussed (Table 3). These codes represent diverse connections to the academic literature on change in higher education.

Table 3. Process codes discussed as connected to the literature on academic change and DEI/J

Process Code	Excerpt from interview notes	Connection to literature
doing	“Advisors doing all types of personal work that is being undocumented and unseen.”	[8]
making	“Making things complex is my superpower. And also, my super weakness!”	[12], [19]
changing	“Everyone says ‘change’ – we need to define parameters.”	[19]
funding	“don’t need to do this (sharing vision with others) after getting the funding, which can jeopardize actually achieving our vision.”	[8], [20]
hearing	“Sharing materials, wants to share, would like to hear from others who improve the materials she has shared.”	[21], [22]
understanding	“Complexity of [the location] – really spending time to understand the complexity, history, networking, who is talking to each other, redefining who an expert is (residents), understanding culture and lifeways.”	[23]
mentoring	“Bottom-up and top-down – CIT-E fills the bottom-up part, also needs administrators to be involved – how to talk to a Dean, which committees should you be on? Mentorship could be very helpful.”	[9], [20]

To move towards a second coding round, we analyzed the process codes to determine their ability to indicate sequences. Despite the limitations of the interview protocol and the lack of a recording, we found there was potential for logical sequencing of the process. The codes shown in Figure 2 provide evidence of the processes of change that can be used sequentially. For instance, shorter iterative sequences can be nested inside more extensive sequences mapping higher education's non-linear and cyclical change-making process. As we continue to collect and analyze data, focus coding and theoretical coding may be the best second cycle coding techniques to hone in on how change processes should occur and in what sequence.

Discussion

Our conversations were wide-ranging, as evidenced by the many codes shown in Table 1. The discussions centered not only on theoretical change strategies, but also on professional practices, wisdom, accomplishments, and personal experiences that have reflected the need for change in the engineering academic profession.

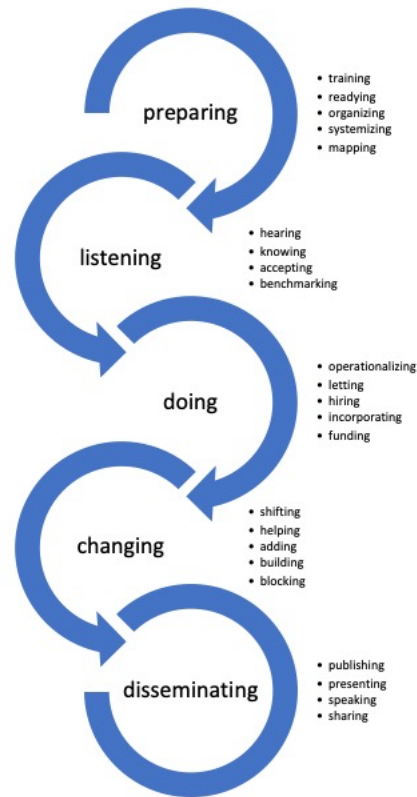


Figure 2 Cyclical sequence diagram of process codes

Looking at our notes from the conversations and the subsequent coding, the strategies that have successfully effected change in engineering education are diverse [6]. The many action verbs coded reflect different lived experiences, professional paths, and institutional contexts. Nonetheless, common themes emerged, as shown in Table 2. The words with the most similar words reflect a collaborative approach to bottom-up rather than top-down change. Words such as *asking*, *hearing*, *considering*, *acknowledging*, *collaborating*, *connecting*, and *contributing* imply an approach to change that involves planning through consensus-building and community engagement [20]. As such, these words reinforce the power of a community of practice to effect this type of change. We discussed whether CoP was better considered a change theory or strategy. Still, as reflected in our coding, there was consensus that building capacity in our CoP as a step toward making change is a reasonable approach.

Our focus on actions reflects a sense, from these interviews and our broader review of the literature, that people have been *theorizing* for years about how to incorporate issues of DEIJ into engineering education and our engineering education institutions, and it is time to focus on *actions*. Change *requires* action. The need to act at scale also is reflected in the coding with prevalent words, including *advocating*, *affecting*, *changing*, and *adopting* [8]. Our interviews revealed numerous examples of practical DEIJ efforts and barriers to change. Several of our advisors have been involved either as awardees or evaluators with NSF’s Revolutionizing Engineering Departments (RED) grants, and both the challenges and opportunities accompanying significant grant funding of this type – funding to promote academic change –

came up in multiple conversations. Further, a number of the words connect strongly to the literature on academic change, as shown in Table 3.

While literature on creating DEIJ change in the context of civil infrastructure education is in its early stages, the transferrable findings from broader DEIJ work are a strong starting point. Our interviews and coding reflect the structures and sequences for making change, beginning with asking, listening, and hearing. We had substantial discussions about effectively disseminating lessons learned from efforts to make change. Some advisors noted that those engaged in effective change-making may be less inclined or able to share their successes more broadly because they are so focused on what they are doing. Nevertheless, they suggested that there are many avenues beyond journals for sharing best practices and lessons learned. The CIT-E CoP has the ability to support change agents two-fold – by providing support for what they already do and a platform to amplify their success without getting overburdened by the dissemination process.

Finally, as mentioned previously, we began these interviews without intending to code the transcripts. We went into these conversations thinking it would be helpful guidance for us, and then we realized that the collective wisdom of these experts could be useful for everyone. The CIT-E CoP is already benefiting from considering processes we were overlooking and investing in processes that are time intensive but offer high reward. Moving forward, we will ask permission to record interviews to develop formal transcripts of future conversations. This work has also improved our case study analysis protocol and group concept mapping protocol which will provide details about how to actualize and sequence the processes documented in this paper.

Conclusion/Recommendations

This paper presents the results of a series of semi-structured interviews with seven change leaders at the intersections of DEIJ and engineering education, as part of a larger NSF-funded project to build capacity in an existing CoP to address issues of DEIJ in infrastructure education. The conversations confirmed that change can be implemented through a CoP and identified strategic actions to overcome barriers to success.

Based in part on the analysis described above, our efforts to effect change through the CIT-E CoP are grounded in the following principles:

- Change must be realistic and based on available resources;
- We must acknowledge the history of civil infrastructure as it relates to DEIJ, both positive and negative, *and* recognize the need for a different future;
- A team of faculty members can lead the change, but the agenda for the change must be jointly co-created with the broader community; and
- Faculty members are important agents of change in this domain.

This study has limitations, including small sample size and reliance on notes rather than transcripts. However, our coding revealed a range of process codes that diverge and overlap among the seven interviews. In addition, the potential for sequencing of the process codes was explored, and this paper provides a step toward understanding the change-making process executed by various stakeholders. Faculty members, students, administrators, and industry professionals are all stakeholders who are working to integrate DEIJ into engineering courses.

In the future, we plan to create a shared vision for the CoP using Group Concept Mapping (GCM) and submit a new proposal to NSF for funding to carry out the vision of transforming civil infrastructure by educating students to understand and solve socio-technical problems.

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References

- [1] American Society of Civil Engineers, "Code of Ethics," 2020.
- [2] "DEI Summit | Penn State Engineering." <https://www.engr.psu.edu/equity-inclusion/dei-summit-22.aspx> (accessed Feb. 28, 2023).
- [3] Construction Inclusion Week, "CIW - About," *About Construction Inclusion Week*, Feb. 27, 2023. <https://www.constructioninclusionweek.com/about> (accessed Feb. 27, 2023).
- [4] K. L. Sanford *et al.*, "Infrastructure Education in Unprecedented Times: Strengthening a Community of Practice," presented at the 2021 ASEE Virtual Annual Conference Content Access, Jul. 2021. Accessed: Feb. 21, 2023. [Online]. Available: <https://peer.asee.org/infrastructure-education-in-unprecedented-times-strengthening-a-community-of-practice>
- [5] K. Sanford *et al.*, "Re-contextualizing Civil Engineering Education: A Systematic Review of the Literature," presented at the 2022 ASEE Annual Conference & Exposition, Aug. 2022. Accessed: Feb. 21, 2023. [Online]. Available: <https://peer.asee.org/re-contextualizing-civil-engineering-education-a-systematic-review-of-the-literature>
- [6] M. R. Connolly and E. Seymour, "Why Theories of Change Matter. WCER Working Paper No. 2015-2," Wisconsin Center for Education Research, Jul. 2015. Accessed: May 01, 2023. [Online]. Available: <https://eric.ed.gov/?id=ED577054>
- [7] Etienne Wenger-Trayner and Beverly Wenger-Trayner, "07-Brief-introduction-to-communities-of-practice.pdf," 2015. <https://wenger-trayner.com/wp-content/uploads/2015/04/07-Brief-introduction-to-communities-of-practice.pdf> (accessed Feb. 11, 2021).

- [8] A. Kezar and S. Gehrke, “Communities of Transformation and Their Work Scaling STEM Reform,” Pullias Center for Higher Education, Dec. 2015. Accessed: May 01, 2023. [Online]. Available: <https://eric.ed.gov/?id=ED574632>
- [9] J. H. Tomkin, S. O. Beilstein, J. W. Morphew, and G. L. Herman, “Evidence that communities of practice are associated with active learning in large STEM lectures,” *Int. J. STEM Educ.*, vol. 6, no. 1, p. 1, Jan. 2019, doi: 10.1186/s40594-018-0154-z.
- [10] M. D. Cox, “Introduction to Faculty Learning Communities,” *New Dir. Teach. Learn.*, vol. 97, p. 21, 2004.
- [11] V. A. Goodyear and A. Casey, “Innovation with change: developing a community of practice to help teachers move beyond the ‘honeymoon’ of pedagogical renovation,” *Phys. Educ. Sport Pedagogy*, vol. 20, no. 2, pp. 186–203, Mar. 2015, doi: 10.1080/17408989.2013.817012.
- [12] S. Stein, “Navigating Different Theories of Change for Higher Education in Volatile Times,” *Educ. Stud.*, vol. 55, no. 6, pp. 667–688, Nov. 2019, doi: 10.1080/00131946.2019.1666717.
- [13] A. S. Clausen, “The Individually Focused Interview: Methodological Quality without Transcription of Audio Recordings,” *Qual. Rep.*, vol. 17, 2012, Accessed: Apr. 13, 2023. [Online]. Available: <https://eric.ed.gov/?id=EJ978736>
- [14] R. Rutakumwa *et al.*, “Conducting in-depth interviews with and without voice recorders: a comparative analysis,” *Qual. Res.*, vol. 20, no. 5, pp. 565–581, Oct. 2020, doi: 10.1177/1468794119884806.
- [15] M. Hammersley, “Some Notes on the Terms ‘Validity’ and ‘Reliability’[1],” *Br. Educ. Res. J.*, vol. 13, no. 1, pp. 73–82, 1987, doi: 10.1080/0141192870130107.
- [16] Johnny Saldana, *The Coding Manual for Qualitative Researchers* | SAGE Publications Inc. SAGE Publications, 2015. Accessed: Sep. 01, 2017. [Online]. Available: <https://us.sagepub.com/en-us/nam/the-coding-manual-for-qualitative-researchers/book243616%20>
- [17] J. Corbin and A. Strauss, *Basics of Qualitative Research (3rd ed.): Techniques and Procedures for Developing Grounded Theory*. 2455 Teller Road, Thousand Oaks California 91320 United States: SAGE Publications, Inc., 2008. doi: 10.4135/9781452230153.
- [18] R. F. Chiovitti and N. Piran, “Rigour and grounded theory research,” *J. Adv. Nurs.*, vol. 44, no. 4, pp. 427–435, 2003, doi: 10.1046/j.0309-2402.2003.02822.x.
- [19] G. Hefetz and D. Ben-Zvi, “How do communities of practice transform their practices?,” *Learn. Cult. Soc. Interact.*, vol. 26, p. 100410, Sep. 2020, doi: 10.1016/j.lcsi.2020.100410.
- [20] A. Kezar, S. Gehrke, and S. Bernstein-Sierra, “Communities of Transformation: Creating Changes to Deeply Entrenched Issues,” *J. High. Educ.*, vol. 89, no. 6, pp. 832–864, Jan. 2018.

- [21] L. C. Li, J. M. Grimshaw, C. Nielsen, M. Judd, P. C. Coyte, and I. D. Graham, "Evolution of Wenger's concept of community of practice," *Implement. Sci.*, vol. 4, no. 1, p. 11, Mar. 2009, doi: 10.1186/1748-5908-4-11.
- [22] W. Yu, P. Chang, S.-H. Yao, and S.-J. Liu, "KVAM: model for measuring knowledge management performance of engineering community of practice," *Constr. Manag. Econ.*, vol. 27, no. 8, pp. 733–747, Aug. 2009, doi: 10.1080/01446190903074978.
- [23] N. N. Mtawa, S. N. Fongwa, and G. Wangenge-Ouma, "The scholarship of university-community engagement: Interrogating Boyer's model," *Int. J. Educ. Dev.*, vol. 49, pp. 126–133, Jul. 2016, doi: 10.1016/j.ijedudev.2016.01.007.