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Theory of change: community engagement as an intervention to create disaster resilience

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Community resilience is a compelling problem that brings together many disciplines of study. Too often researchers wait until the end of research projects to disseminate findings, and may not include any intentional efforts toward technology translation. Convergence, and particularly the technology transfer aspects of convergence, should be a central goal for resilience research. This paper presents a theory of change proposing community engagement as the intervention needed for realizing actual community resilience. Three illustrative examples simultaneously demonstrate the need for the intervention and are used to provide guidance to researchers interested in learning how to engage. The first example illustrates investigator-driven research via post-hurricane reconnaissance coupled with experimental testing in a wind laboratory. The first example exemplifies technology transfer through regulatory changes. The second example illustrates community-based research via a post-tornado reconnaissance study, and exemplifies technology transfer through industry and outreach publications and public media. The third example illustrates community-driven research that developed a local climate plan, and incorporated the co-production of knowledge. The research translated throughout the project due to the community engaged approach leading to immediate adoption of the final research outcomes. Findings from this paper can be used to help other researchers determine the level of community involvement and navigate technology transfer options based on the goals and context of their own research.

KEYWORDS

community engagement, technology transfer, reconnaissance, multidisciplinary, building codes

Introduction

Diffusion of innovation is a theory developed over half a century ago to explain how, over time, an idea or technology diffuses through a population and into widespread adoption (Rogers, 2003). A key component to the diffusion of innovation is that people must perceive the idea or technology as innovative. The theory continues with the suggestion that different people are more inclined to be early adopters, wait for the majority, or tend to remain skeptical. A common operational use of the theory is technology transfer, which for the purposes of this paper, involves moving scientific research into practical use. While diffusion of innovation theory and the concept of technology transfer seem simple enough, the actual process can be very complicated with the need for policies, lawyers, and/or technology transfer offices in place to assist in navigating the process and measuring the impacts. Depending on the goals of technology transfer, the intended user, and the involvement of the

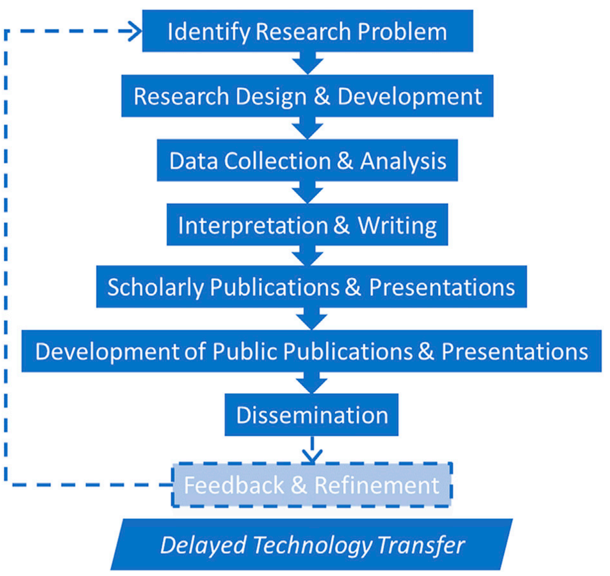

FIGURE 1
Common practice for natural hazards engineering researchers resulting in delayed technology transfer.

intended user in the research process, the investment time of the researcher, the impact, and the process can vary substantially. Research documenting these challenges, and extensive policy legislation goes back decades (Bozeman, 2000).

Academic researchers face many challenges to pursuing technology transfer (Irwin et al., 2018; Finn et al., 2022). For example, historically, academic reward structures have prioritized peer reviewed journal articles, associated citations, and annual research expenditures, as opposed to technology translation and implementation. While the number of citations may speak to impact, the metric does not measure actual translation of research findings into practice use. A primary technology transfer mechanism for civil and structural engineering hazards and disaster researchers is translation of research findings into codes and standards. Many codes and standards adopt structured consensus processes, which are intended to make the process for changing the standard fair from all relevant perspectives. Fair or not, consensus standard processes embedded in 3- to 6-year cycles of codes and standards can quickly become too time-consuming for an academic researcher (or anyone working in a volunteer capacity). This is especially true when funding is hard to come by to support this portion of the research process (Bonowitz et al., 2021). Whether for these reasons or otherwise, common practice is (a) to wait until the research is complete to disseminate findings; (b) focus on academic outlets for dissemination; and (c) not include any intentional efforts towards technology transfer [see Bonowitz et al. (2021) and Chock et al. (2022) for examples], thereby resulting in delayed technology transfer (see Figure 1). As shown in Figure 1, feedback and refinement sometimes happen. When research projects follow the process shown in Figure 1, technology translation becomes a separate step requiring extra work at the end of the project making it more likely to not happen at all.

The motivation of this paper is to encourage hazards and disaster researchers to transcend organizational boundaries, to integrate community engagement into their research, and prioritize technology transfer. The aim of this paper is to provide a theory of change with examples and guidance for researchers to understand how to transcend organizational boundaries, integrate community engagement practices, and successfully translate their technology into practical use. The goal of applying our proposed theory of change is to move the research community into actionably enhancing community disaster resilience by implementing their science.

This paper provides new insight into how natural hazards and disaster research can be translated into practice use. Depending on the target population and degree of community involvement, the process for adoption can be very different. This paper places our aim in the context of convergence research, then introduces a theory of change considering community engagement as the intervention needed for hazards and disaster researchers striving to solve the complex problem of community resilience. This paper presents three example research projects that utilized differing levels of community involvement with different mechanisms of technology transfer. Each example concludes with a discussion on the challenges and opportunities the specific study experienced related to technology transfer framed in a way to provide insight and guidance to researchers.

A convergence research agenda for technology transfer

In 2016, "Growing Convergence Research" was named one of the National Science Foundation's *10 Big Ideas* for prioritizing future investments in science and engineering. Convergence research is "An approach to knowledge production and action that involves diverse teams working together in novel ways—transcending disciplinary and organizational boundaries—to address vexing social, economic, environmental, and technical challenges in an effort to reduce disaster losses and promote collective wellbeing" (Peek et al., 2020). Convergence research must focus on both (1) the identification of a compelling problem and (2) the implementation of solutions (Peek et al., 2020). Here we suggest, that these two characteristics of convergence research (a) require transcending organizational boundaries—beyond academic institutions, and (b) posit technology transfer as a core part of convergence. Convergent science is action-focused science (Finn et al., 2022).

Community resilience is a compelling problem that brings together many disciplines of study. Convergence, and especially technology transfer, should be a central goal for hazards and disaster and community resilience research. For nearly two decades, researchers have agreed that private-public partnerships and collaborative organizational structures can strengthen *actual* community resilience (NRC, 2005; Waugh and Streib, 2006; DHS, 2010; FEMA, 2010; NRC, 2012). While researchers have continued to agree, common practice has stayed the same (see Figure 1), and disaster losses have continued to grow substantially during this time. In these past two decades, the United States has experienced the nine most expensive years on record in terms of disaster losses (NOAA NCEI, 2023). Research teams should strive to engage community partners, including local government actors and grass roots community organizations, in the co-production of knowledge to build community resilience. Until translation is prioritized in research, disasters and the disparities exacerbated by disasters will continue to threaten our communities.

A charging paper on ethical concerns in disaster research called on the United Nations Office for Disaster Risk Reduction for an ethical code of conduct for researchers doing post-disaster field research. Gaillard and Peek (2019) suggest that an ethical code of conduct "should advance disaster research, making it scientifically rigorous as well as locally and culturally grounded" (Gaillard and Peek, 2019). But what does it mean for disaster research to be locally grounded? Resilience scholars have suggested any approach to measure or enhance community resilience cannot be one-size-fits-all (Cutter, 2016). While there is a community resilience planning guide (CRPG) (NIST, 2015), and many community resilience frameworks (e.g., Bruneau et al., 2003; Cutter et al., 2008; Renschler et al., 2010), "the devil is in the details" (NRC, 2012). And, the details of a community and its needs can be very different from one place to the next considering its unique history, geography, demography, culture, economy, governance, infrastructure, hazard risk, and capacity (NRC, 2012). Resilience requires a bottom-up approach that integrates local knowledge and the full fabric of the community, including grass roots organizations and local residents. This is why the first step in the CRPG is to form a collaborative team composed of representatives from the public, non-profit, and private domains (NIST, 2015). Because of integrating community participation in their research, Hung et al. (2016) were able to identify and measure higher adaptive capacity in areas with higher social vulnerability in their resilience assessment. Burnside-Lawry and Varvalho (2016) and Meyer et al. (2018) were able to increase risk awareness and empower and encourage collective action in climate change adaptation with the people they engaged in their research. Empowerment of residents in disaster risk reduction has been echoed in other works (Harahap, 2020), and plays an important role in improving resilience. Resilience is a shared value and responsibility, further positioning the need for community partners to be a part of the co-production of knowledge and solution implementation.

Resilience also requires a top-down approach. Olsen et al. (2020) makes a compelling case that policy implementation is the most important challenge for disaster risk reduction (DRR), and that effective DRR needs "stronger policies and implementation regimes" (Olson et al., 2020). Policy changes are the ideal way to reach the masses. Local adoption can precede federal policy changes. Perhaps a compelling way to change policy is with demonstrated effectiveness through local adoption further motivating the need for community engagement in hazards and disaster research.

Indeed, integrating community engagement in hazards and disaster research is not new. Applying tenets of diffusion of innovation theory, social and health sciences are the "early adopters" (see Wells et al., 2013; Pfefferbaum et al., 2015; Meyer et al., 2018; Singletary et al., 2022), and now it is time for "the majority" to latch on. Engineering researchers and multidisciplinary teams are already engaging too. A recent project funded by the National Science Foundation, titled *Adaptive and Resilience Infrastructures Driven by Social Equity* (ARISE) (Award No. 2148878), is integrating community engagement from the beginning. The project seeks to advance the resilience of infrastructure, including water, energy, and transportation systems, by creating tools that ensure support for underserved communities in urban and rural areas. Community partnerships are central to the approach with the goal of co-developing these tools for ensuring practical usefulness and immediate adoption. ARISE researchers are using the community toolbox, a web-based resource, to support community engagement (see Fawcett et al., 2000).

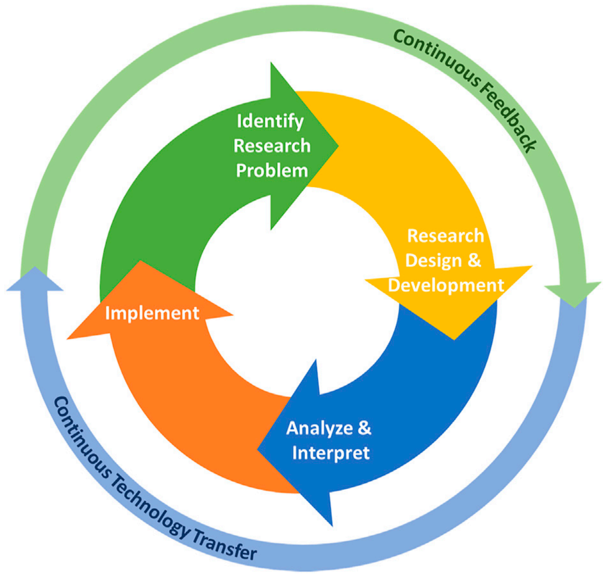

FIGURE 2
Continuous technology transfer enabled through community engaged research.

Theory of change: the community engagement intervention

This paper proposes that community engaged research can be the solution to the solution implementation problem—across disciplines. Community engagement is "the process of working collaboratively with groups of people who are affiliated by geographic proximity, special interests, or similar situations with respect to issues affecting their wellbeing" (CDC, 1997). Community engaged research "sees non-academic knowledge as not only legitimate but also necessary in the generation of new knowledge aimed at solving public problems" (Saltmarsh and Hartley, 2011). As such, the partnership recognizes and builds on the strengths of both the community partners and the researchers. A true benefit is that community engaged research enables continuous feedback and continuous technology transfer (see Figure 2) in the research process because the ideal users of the technology are part of the project team. Their perspectives are integrated throughout giving community partners an invested interest in adopting the technology they are co-producing (Chen et al., 2010). Mutual trust, respect, and commitment are key tenants of a true partnership, and can take years to establish (McDavitt et al., 2016). Partnership agreements and memorandums of understanding are also common practice for

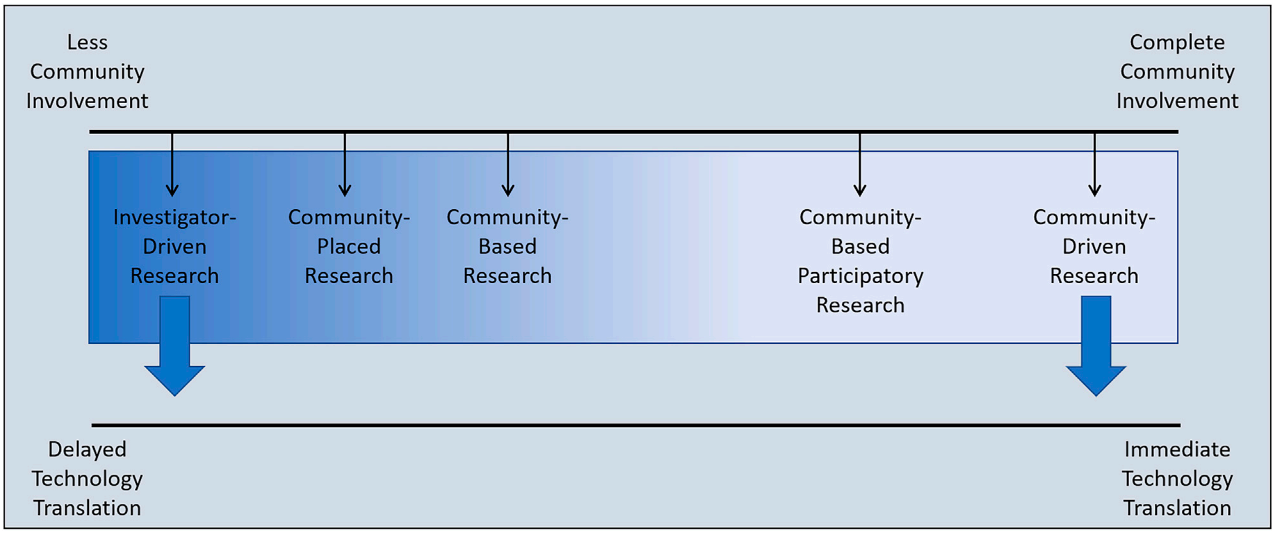

FIGURE 3
Continuum of community involvement in research with associated timeline for technology transfer (adapted and expanded from Winkler 2013).

community engaged research, especially when the level of involvement is high (CBGC, 2021).

As shown in Figure 3, there are different types of community engaged research which involve different levels of community involvement (Winkler, 2013), and thereby result in different timeframes for technology transfer. On one end of the spectrum is investigator-driven research which may not incorporate any community involvement. This style of research aligns with the common practice shown in Figure 1, which often results in delayed technology transfer. At the other end of the spectrum is community-driven research where there is complete community involvement. Community-driven research incorporates community partners at the very beginning with identifying the problem and designing the research, and throughout the dissemination process. It may even be reasonable for community partners to co-author peer reviewed manuscripts and other publications with the researchers in community-driven research (see Lyles et al., 2021 for an example; Bordeaux et al., 2007 for guidance).

When referring to community engagement, "community" does not necessarily imply any shared geographic location. Community is "a group of people who are linked by social ties, share common perspectives or interests, and may or may not share a geographic location" (MacQueen et al., 2001). For engineering researchers who may be looking to have their research translated into codes and standards, practicing engineers and those in the construction and materials industries may serve as the "community" to engage throughout their research. Advisory boards, industry panels, and community engagement studios are common mechanisms for facilitating this type of relationship. However, the degree to which the community is engaged—how frequent and involved the advisory board is—can make a big difference in the timeframe for technology translation. Similarly, human subjects research, particularly the use of survey, interview, and focus group methods, can provide critical input to the research team from a broad representative community base. However, if the community-based activities exclusively involve one-way communication, the "human subjects" are not partners and may not be as inclined to adopt findings. One-way knowledge transfer leads to community-placed and community-based research (see Figure 3). Two-way, authentic collaborations with community partners lead to immediate and continuous technology translation (see Figure 2).

Training and other educational resources are available to help researchers learn more about how to do ethical and responsible community engaged research. Three examples are shared here. First, the Collaborative Institutional Training Initiative (CITI) has multiple courses available, including *Introduction to Community Engaged Research (CEnR), Introduction to Community-Based Participatory Research (CBPR),* and *Ethical and Practical Considerations in Community Engaged Research*. CITI courses are not free, but most research-active universities have a CITI subscription, or equivalent, as part of their Institutional Review Board required training. A second resource is the Campus Compact, a national coalition of colleges and universities dedicated to civic and community engagement in higher education. The Campus Compact offers a free Community Engaged Research Knowledge Hub with curated resources and readings related to all aspects of ethical and reciprocal research with communities (Campus Compact 2021). The third resource is grounded in hazards and disaster research: CONVERGE, the National Science Foundation (NSF) supported facility that provides free training modules for researchers (Adams et al., 2023). While none of the current CONVERGE training modules are exclusively focused on the topic of community engaged research, the modules titled *Broader Ethical Considerations for Hazards and Disasters Researchers* and *Reciprocity in Hazards and Disaster Research* both incorporate the topic with the context of hazards and disaster research.

Funding agencies have also begun to see the necessity to integrate community engagement and offer support for technology transfer. The Gulf Research Program (GRP) of the National Academies of Science, Engineering, and Medicine has designated funding specifically to understand how to effectively engage communities about the impacts of climate change. At the time of this writing, two GRP requests for applications require or strongly encourage community partners, including *Thriving Communities* and *Understanding the Effects of Climate Change on Environmental Hazards in Overburdened Communities*. The GRP committee, Enhancing Community Resilience Initiative (EnCoRe), is a multi-year community engagement initiative that partners with communities in the five Gulf Coast states to build and enhance health and community resilience at the local level. While the NSF primarily supports fundamental research, programs like *Civic Innovation Challenge*, *Smart and Connected Communities*, *Coastline and People Hubs for Research and Broadening Participation*, and the new directorate, *Technology, Innovation and Partnerships*, all promote community engagement and technology translation. Thus, the timing for shifting common practice, as shown in Figure 1, to a community engaged practice, as shown in Figure 2, has never been better.

Who should be engaged in the research process, and their level of involvement, depends on the scope of the research, intended users and beneficiaries, and the desired outcomes of technology transfer. The next section provides three examples of hazards and disaster research to guide researchers in determining where along the community engagement spectrum (Figure 3) their project could lie, whom they could engage, and how to engage.

Illustrative example 1: investigator-driven research

This first example demonstrates technology transfer stemming from investigator-driven research. The project first documented hurricane wind damage to low-rise elevated residential buildings after Hurricane Michael. The field data was coupled with experimental data collected from wind tunnel tests on large scale models of elevated buildings. This illustrative example documents the 10-year process of incorporating investigator-driven research findings into a national consensus standard.

Research context

Prior to 2022, there were no building code or standard provisions specifying wind pressure coefficients or otherwise giving design engineers guidance on the underside exposed floor of elevated buildings. Existing provisions also did not account for how the aerodynamics might change on wall and roof surfaces given the size of the air gap beneath the elevated structure. This gap in design guidance was a primary motivator for this research project. The research initiated with an NSF-funded quick response field study launched in the impacted areas of the Florida Panhandle 10 days after Hurricane Michael. The goals of the field study were the on-the-ground observation and classification of damage to elevated site-built housing and manufactured housing as a result of the hurricane. Damage patterns were evident, but given the limited sample, were difficult to use for drawing strong conclusions. To supplement the field data for more specific conclusions on underside floor wind pressures and damage patterns, the results of a relevant experimental test were examined. The experimental testing was conducted using the Wall of Wind Experimental Facility (WOW EF) at Florida International University (FIU). Aerodynamic testing was conducted on a large-scale model of a single story low-rise residential building at three different elevated heights.

Both the observations from the Florida Panhandle and the wind tunnel testing show that floor underside pressures can be critically high, leading to damage to the building and its components. Improperly estimated pressures and subsequent design of components and fasteners can lead to avoidable losses during high wind events. As evidenced by the research, floor underside negative pressure coefficients can reach the same magnitudes as those on a gable roof, thus a deliberate design is necessary to limit damage. Fasteners at the edges of the building floor are of particular concern, where pressure coefficients are highest. More details about the research project and associated data are provided in Kim et al. (2020) and Sutley et al. (2019c); Sutley et al. (2020).

The technology transfer process

Technology transfer began after the experimental testing and field work were complete, and even after a peer reviewed journal paper had been accepted for publication. At that point, the authors collaborated with ASCE/SEI 7 committee members to write two change proposals. Change proposals use a specific template, and must be submitted by members of the committee. Findings from the research were incorporated into the 2022 edition of the ASCE/SEI 7 (referred to as ASCE/SEI 7-22 herein) in the wind load chapters 27 and 30. The new provisions provide guidance to design engineers on wind pressure coefficients for elevated buildings (ASCE/SEI, 2022). This change required considerable time and attention. The actual adoption of the changes into the legally enforceable building code, the 2026 edition of the International Building Code (IBC), will be a 10-year process. As shown in Figure 4, the 2022 cycle of ASCE/SEI 7 started in January 2018 and ended in December 2022. The process of writing the change proposals started in June 2020, where changes to both chapters 27 and 30 passed the final voting in March 2021.

ASCE/SEI 7-22 has been adopted into the 2026 version of the International Building Code (IBC). Upon publication of the 2026 IBC, local, county, and state jurisdictions will adopt the new code edition. Some jurisdictions adopt the most recent version of the IBC within the first 6 months of publication, whereas other jurisdictions may never adopt it [see Sutley et al. (2021) for examples of code adoption across Kansas]. Thus, from the time the experimental work started (November 2016) to the time the science will be legally enforceable anywhere (2026) will take a minimum of 10 years. At that point, new elevated buildings constructed in wind zone regions will benefit from the new provisions, and occupants of those structures will be safer during windstorms and hurricanes.

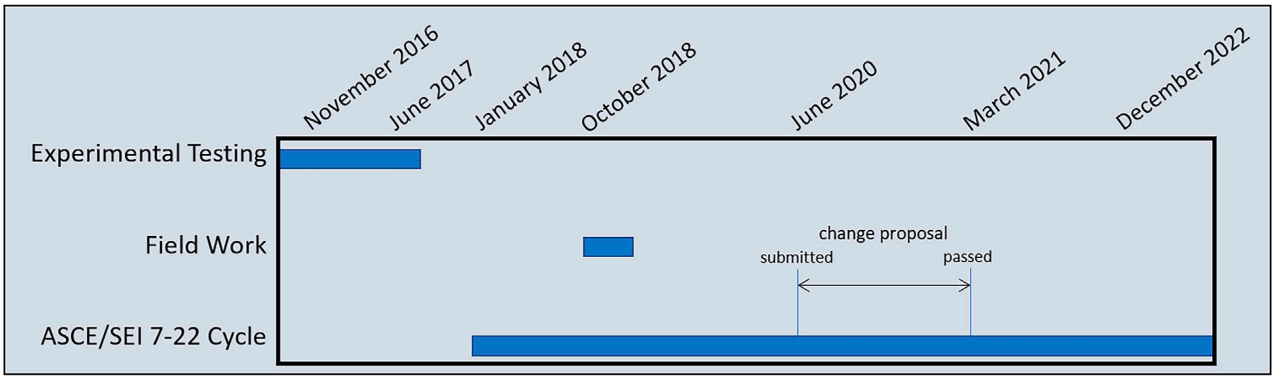

FIGURE 4
Timeline for experimental testing, field work, and technology transfer to ASCE/SEI 7.

Challenges and opportunities

The primary challenge identified in this example is the time required to see a change occur through the codes and standards process—this is both in the time commitment of an individual and the duration of the change process. Indeed, serving on the ASCE/SEI 7 committee required three trips to Washington, DC each year for 5 years, with virtual meetings and various work tasks between meetings. This is in addition to the time it took to write and revise the change proposals, and respond to the three dozen comments received on each proposal during four rounds of voting during the 9 month period.

The primary opportunity highlighted through this example is how engaging community members (e.g., standard committee members, practicing engineers, construction industry professionals and/or homebuilders and homeowners) can lead to faster technology translation. A gap in wind load provisions was a governing motivation for the research on elevated structures, and two of the team members were also members of the ASCE/SEI 7 Wind Load Subcommittee. The lead author of this paper also served as the balloteer, and thus was responsible for assembling, moving, and tracking all ballots from the system. Regardless of the level of community engagement, the consensus standard process and overall timeframe of code and standard cycles remains the same. However, engaging practitioners and codes and standards committee members in the research process could support research being adopted into codes and standards sooner in the research process and the first time it is introduced as a proposed change.

The 2022 cycle included 115 change proposals to the wind load provisions, with an 81% success rate. Although most proposals did end up passing, successful proposals were, on average, included on four ballots and took five and a half months to pass all voting requirements at the subcommittee and main committee levels. Of the proposals that did pass, the quickest case took 2 ballots, received 4 comments, and took 6 weeks to officially be accepted. This proposal was a unique case of only changing the edition of a reference standard. Other proposals that moved quickly were generally ones proposing very minor changes and/or changes that were brought up during the previous cycle. The longest case took 9 ballots, received 76 comments, and took 14.5 months to officially be accepted. Proposals moving very slowly were either major changes or ones that the change proposal author was not revising and resubmitting in a timely manner. Thus, having someone on the committee committed to championing the work through the consensus process will help ensure the change proposal is continuously moved through ballots and revision. The Natural Hazards Engineering Research Infrastructure (NHERI) Technology Transfer Committee (TTC) is one entity that researchers can contact for consulting on technology transfer (Bonowitz et al., 2021).

In addition to codes and standards committees, engaging local government decision makers in the research could result in local adoption ahead of national adoption. Engaging beneficiaries of the research, including homebuilders and homeowners in the present example, could lead to education and empowerment. Engaging any and all of these communities could indeed lead to adoption ahead of any legal requirement.

Illustrative example 2: community-based research

This second example demonstrates technology transfer stemming from a community-based research project. The project documented damage and 1-year recovery after a tornado in Kansas that received significant local attention. Each engagement activity resulted in more opportunities to share the findings resulting in the penultimate opportunity to be part of a Public Broadcasting Station episode on tornado disasters.

Research context

On 28 May 2019, an EF4 tornado touched down in northeast Kansas causing considerable damage in Leavenworth County and surrounding areas. This research was initiated with the local tornado event. Goals of the study were to document damage along the tornado's path, and to follow up six- and 12 months later with

TABLE 1 Technology transfer mediums for the Linwood, KS tornado study.

Audience	Medium	Audience size	Estimated time to implement	Date
General audience	Social Media (Facebook)	1,000	1 h	1 June 2019
	KUToday Online News Outlet[b]	200	2 h	13 June 2019
	The Kansas City Star[c]	75,000[a]	2 h	24 June 2019
	KU Engineering's Expo for Middle Schoolers	60	4 h	24 February 2020
	Interview on PBS Terra's Weathered Series	44,271 views on YouTube[d] and 42,945 views on Facebook	15 h	Episode posted online April 2021
	Presentation to Rotary Club of Lawrence	30	2 h	20 May 2021
Practicing and professional audience	Presentation to Society of American Military Engineers of Kansas City	40	4 h	20 June 2019
	Presentation to Engineers Club of Kansas City	50	3 h	9 September 2019
	City of Leavenworth, KS Public Works	8	7 h	11 October 2019
	Continuing Education Lecture to Lawrence Homebuilders Association	50	5 h	19 November 2019
	Professional Development Lecture in Kansas City	50	5 h	2 March 2020
	Presentation to American Red Cross Kansas City Chapter	30	2 h	17 November 2021

[a]Online readership of the newspaper is reported to be between 76,853 and 3.8 million unique viewers.
[b]Lynch (2019).
[c]KC Star (2019).
[d]PBS Terra (2020).

documentation of repair progress and resident impact and recovery over time. Key findings from these investigations and contextual research include: (a) many damaged single-family wood-frame structures lacked a sufficient load path, including homes where walls used glue as their only attachment mechanism to the foundation; (b) much of Kansas has not adopted a building code, and a significant portion that has adopted any building code has adopted an outdated building code and lack enforcement protocols; (c) although a federal disaster declaration was made, no Federal Emergency Management Agency (FEMA) Individual Assistance funds came to impacted households; (d) most households experiencing home damage received an insurance claim pay out to help them with their recovery; (e) 6 months after the tornado, less than half of surveyed homes had completed repairs; and (f) more than 80% of surveyed households perceived building codes to provide residential buildings higher performance during tornadoes than what is currently prescribed in codes, and more than half indicated a willingness to pay substantially more for higher performance. More details about the research and associated data are provided in Sutley et al. (2019a), Sutley et al. (2019b), Sutley et al. (2020), Sutley et al. (2021), Sutley et al. (2021b), Sutley et al. (2021c), and Mazumder et al. (2021).

The technology transfer process

Technology transfer began after the first wave of data collection and analysis were complete, and continued for the next 2 years, during and after the second and third waves of data collection. The tornado was a significant event for the impacted area and surrounding communities. The message coming out of the study was clear: *we can and should be doing more resilient residential building construction; it is affordable, it is needed, and it would make a big difference when the next tornado strikes.* Information about the initial damage investigation was shared in various ways, which led to more local and regional groups wanting to learn about the study. Table 1 lists the mediums the study has been shared to general and professional audiences, a description of the target or actual audience and size, approximate time to schedule and implement, and the delivered date. The technology transfer started with a post on the first author's social media. Many commenters had questions on where they should shelter during the next tornado, and made notes on appreciating the information. News articles, professional presentations, and the like soon followed.

Requests for presentations and news articles about the study came to a halt when the SARS CV-2 pandemic reached Kansas. On 25 June 2020, an assistant producer from Balance Media contacted the first author via email sharing information on a short film series his team was working on for Public Broadcasting Station (PBS). The episode planned was on tornadoes. A series of email exchanges, a couple of virtual meetings, hours spent preparing talking points, and a 3-h recording session resulted in approximately 5 min of coverage in an 11-min episode viewed by over 80,000 people (see PBS Terra, 2020). The assistant producer found the first author's research online, but later shared that it was a 2017 NHERI podcast episode (Zehner, 2017) that led him to reach out. As shown in Table 1, technology transfer focused on sharing findings with the general public and industry professionals; we estimate more than 150,000 people consumed information from the study.

Challenges and opportunities

Two challenges are identified in this example: (a) technology transfer can be a significant time commitment; and (b) researchers do not always have control of exactly what information gets shared. For the first challenge, Table 1 suggests technology transfer for the first case study took more than 1 week's worth of work (52 h) over the course of 3 years. This time included time spent accepting presentation invitations, identifying availability, developing presentation slides, thinking through and practicing framing and talking points, traveling to venues, giving the presentations and interviews, etc. While many of the slides and talking points could be reused from one engagement to the next, each different audience and presentation duration needed to be considered, prepared for, and catered to.

A second challenge identified is that it is not common practice to let the researcher select or review the material to be included in the publication with a news outlet or series/episode. Here, 15 h of preparation were spent on what resulted in 5 min of recording. In this case the narrative was based on the goals of the larger episode that were in alignment with what the researcher also wanted to prioritize, but that is never guaranteed. The researcher must be especially mindful of their words in these settings. Media training is offered at many universities for the interested reader.

This example also highlights a key opportunity for other researchers: the more engagement you do and the easier you are to find online, the more opportunities for engagement you will have. Research covered in the first case study was shared on the PBS Terra series, *Weathered*. The episode is posted online on YouTube and Facebook, where each hosting location has garnered over 43,000 views at the time of this writing. During the writing of this paper, the total number of views increased by more than 3,000. The opportunity to be part of a PBS effort did not happen through existing connections or relationships—nor did any of the other engagement opportunities listed in Table 1. Rather the research and researcher were found online from the Balance Media team. As described in the previous section, as one venue hosted a presentation, audience members shared and invited the speaker to present at new venues. Simultaneously, as more content was posted online, it became easier for the assistant producer to identify the first author and the field study as a good fit for their episode. Having an online presence can go a long way for researchers who are passionate about technology transfer. Social media can also be a valuable vehicle for technology transfer. Journalists for news outlets use internet search techniques to identify experts to talk to for their upcoming stories. Importantly, news outlets are usually operating on a fast timeline, and need comments within a couple of days. Thus, the researcher must be able to respond quickly to be included.

Illustrative example 3: community-driven research

The third example demonstrates technology transfer stemming from community-driven research. The project developed a local climate plan to provide comprehensive policy on specific actions that a community will undertake to reduce greenhouse gas emissions and adaptation strategies to counter the negative effects of climate change. The process for plan development has a core focus on advancing equity through innovative community engagement. The example illustrates how the co-production of knowledge leads to immediate adoption of engagement practices. This example also exemplifies multi-way technology transfer among the professional community and the research team, as well as with the general public and future professionals currently in student roles.

Research context

In 2018, the shared Sustainability Office for Douglas County and the City of Lawrence reached out to researchers at the University of Kansas in the Urban Planning Program to help conceptualize, plan, and carry out a community engagement process to generate an equity-focused local climate plan. A partnership emerged between the Sustainability Office and the Center for Compassionate and Sustainable Communities (CCSC) (CCSC, 2023). The research involved developing a new model that explicitly incorporates the thoughts and emotions of community partners as factors that interact to enhance or constrain hazard mitigation decision-making. The research strategy included (a) a critical analysis of "A Ladder of Citizen Participation" (Arnstein, 1969), a seminal paper for community engagement in hazard mitigation planning research; (b) a systematic review of guidance and training for planners; and (c) synthesis with insights from psychology, neuroscience, and practice-oriented resources for leveraging emotional and social intelligence to overcome the emotional paradox. The partnership with the Sustainability Office opened up new pathways for incorporating equity and on-the-ground considerations and constraints.

At the outset of the collaboration, the team scanned the practice and scholarly landscape to identify attributes of equity-centered planning to reduce long-term risks from natural hazards and climate impacts, with little literature available to find. We coupled these early scoping activities with development of two public service-oriented graduate courses. The first course, *Personal Transformation for Natural Hazards and Climate Change* (Spring 2019), engaged graduate students in engineering, planning, and public administration in readings, discussions, and activities aimed at understanding and developing our individual emotional and cognitive abilities to work on equity in long-term risk reduction. The second course, *Envisioning a Compassionate and Sustainable Future During the Climate Crisis* (Spring 2020), was co-developed as a service learning course with the Sustainability Office as a partner and client. Students explored, developed, and innovated with engagement techniques like collective sustainability visioning through an online group drawing application, hosting an online

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Collective Drawing

'Board Game Basics'

Number of Players: 3 – 20

Time: 10 - 25 mins per exercise

Materials: Remote: computer or tablet, internet, web conferencing tool.
In-person: whiteboard or large poster/piece of paper and various colored markers.

Brief Activity Overview: Participants will take turns drawing images representing sustainability values or what they think of when they invasion their ideal future. For the second activity participants will create a web of barriers to reaching this vision or sources of climate change by writing words or phrases and connecting them with drawn lines.

Uses: This activity facilitates community visioning and collaboration and open discussion of values. Collaborating with other community members sparks ideas that may not be realized individually. The second exercise helps identify areas of concern and foster a better understanding of systems thinking. Both exercises build awareness and increase discussion around what the community identifies as important issues.

Requirements: If done remotely: internet access and AWWapp online. The browser is fairly mobile friendly but there is not an actual downloadable app for this particular whiteboard. If done in-person: a spacious room and large table or whiteboard access.

FIGURE 5
Instructions from innovative public engagement primer.

climate dystopia movie viewing and discussion, and developing participatory, crowd-sourced interactive storymaps that allow participants to share geo-located photos, observations, and notes about why and how areas important to their daily lives are being impacted by climate change. For more details on the research, courses, and collaborative climate plan with the interactive storymaps, see Lyles and White (2019), Lyles et al. (2021), and Climate Action Plan. (2023).

The technology transfer process

Technology transfer began nearly immediately with the co-production of a local climate plan, including investigating other local climate plans, best practices from the literature in adapting to climate change, integrating local priorities, needs, and constraints. We did not realize at the time that our work would be at the forefront of what may turn out to be a permanent transformation of conventional, constrained forms of in-person public engagement (e.g., informational meetings and public hearings) into a much wider, more versatile, and more unwieldy array of in-person, online, and hybrid forms of engagement. Indeed, the collaboration will likely result in two positive, permanent changes in the Sustainability Office: more inclusive and productive forms of engagement and a new equity-driven climate plan. The ongoing project website, which a master's in planning student helped develop as a Sustainability Office intern, is publicly available and updated regularly (Climate Action Plan, 2023). The coupling of both process and outputs increase the likelihood of sustained commitment to enhanced disaster resilience in the City of Lawrence, thus impacting tens of thousands of individuals over time. Two additional translation outcomes have resulted from the coupled research, teaching, and engagement.

First, the team adapted the hazards and climate-focused content and exercises into workshops and talks on emotions, equity, and public service. These workshops have been delivered dozens of times through the KU Public Management Center's Emerging Leadership Academy, training for members of the American Association of State Highway and Transportation Officials, and keynote speeches to FEMA, the Kansas Department of Health and Environment, and others.

Second, the team developed a publicly available primer on online public engagement methods (CCSC, 2023). Developed by students and the instructor, and vetted for usability by Sustainability Office partners, the primer presents instructions in a format similar to board game instructions (e.g., number of participants, materials needed, estimated time, ease/difficulty) for using the various engagement techniques (see Figure 5). Testimonials, tips, and examples of the products of engagement flesh out the primer.

Challenges and opportunities

The primary challenge identified in this example is how community partnerships can involve changes created by new leadership, budget priorities, staff turnover, and the like. Additionally, hazards and disasters can drastically change research plans. In this case, the pandemic put much of the climate planning work on hold for the rest of 2020 and much of

2021. When the process regained momentum in 2021 and 2022, the Sustainability Director left local government, and the Sustainability Office split into distinct County and City units.

The primary opportunity identified in this example is how building a strong partnership with trust, shared values, and lines of communication among the team enabled the research and technology transfer to continue in spite of myriad disruptions. Without investing the time up front, there is little chance the equity-centered partnership could have survived the pandemic, staff turnover, and re-organizations, perhaps even leading to the demise of the entire planning effort. One of the team mantras is to "go slow to go fast; " that is, it often takes extended time to build trusting relationships, but once established, meaningful action and impact can happen rapidly. While time investment was a key factor in building the strong partnership, it was not the only key factor. A special effort was made to direct planning funds directly into community partner's accounts, rather than external consultants. This investment has the benefits of compensating typically excluded community members for their time and insights, while also building long-term capacity and commitment for climate equity by fostering relationships and communication. Everything revolved around knowing the audience, and being intentional about ensuring the audience is representative of the community, especially those typically excluded from planning generally, and from the benefits of innovations in technology transfer in particular. By developing and maintaining shared values around authentic and equitable engagement that we then put into action by contracting with local community partners, we ensured that two-way technology development and transfer occurred in ways that prioritized the needs of marginalized communities, not researchers or even professionals. The co-production of knowledge and technology development and transfer, meant that all parties involved had a vested interest in seeing the work through. During the past 5 years, numerous forms of knowledge and technology transfer have taken place, with more to come, with a genuine commitment to centering marginalized voices to advance equity guiding the process.

Closing remarks

Community resilience is a compelling problem that requires a convergence research approach. Disaster losses will continue to climb until disaster scholars prioritize technology translation. Community engaged research is a seamless way to integrate technology translation into a research project that also opens up new ideas, directions, and opportunities for researchers to pursue. The three examples shared here illustrate different levels of community engagement and the subsequent approach to technology transfer. The first example, investigator-driven research, saved technology transfer until after all of the research was complete, and even after a peer reviewed journal article was accepted for publication. The second example, community-based research, integrated community input through human subjects research, but otherwise saved technology transfer until after the research was complete. These first two examples aligned with the common approach for technology transfer depicted in Figure 1. The third example, community-driven research, integrated community partners from the very beginning enabling continuous feedback and continuous technology transfer during the entire project.

Technology transfer does not come free; it takes time, effort, and commitment, often in the form of relationship building. A key challenge identified in the first two examples is the time required for technology translation, including the passing of time required and the commitment of time required. Research with high community involvement organically incorporates technology transfer throughout. Research with low community involvement requires distinct efforts separate from the research itself. We call on funding agencies and research institutions to further incentivize and support technology translation activities, particularly community engagement.

A key opportunity identified through the examples is how community engaged research can lead to more impactful technology translation. When starting a research project, teams should thoughtfully engage community partners and impacted communities, as well as professional end-user audiences, early and often through research design, through interpretation of findings, and through sharing and communicating the results. A community engaged approach can lead the research in directions that are more impactful, and where the positive impact is more immediately realized. There are many mechanisms for technology transfer, and research teams should pursue the mechanisms best aligned with their work, their audiences, their timeframes, and their resources at hand. Different audiences require drastically different modes of translation and associated communication.

The illustrative examples presented here focused on specific elements of technology transfer, and were not exhaustive in their coverage of the teams' efforts. Perhaps most important to mention is the translation of findings into educational courses, which all three projects did. Through the educational tools developed in all three projects, future engineers, planners, and natural hazards professionals will now be better prepared to apply lessons from these studies into their own work, continuing the impacts of the research for years.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

ES: Conceptualization, methodology, writing, reviewing and editing visualization, funding acquisition. WL: Writing, reviewing and editing visualization.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Adams, R. M., Evans, C. M., and Peek, L. (2023). CONVERGE training modules: A free online educational tool for hazards and disaster researchers and practitioners. *Front. Built Environ.* 9, 15. doi:10.3389/fbuil.2023.1096204

Arnstein, S. R. (1969). A ladder of citizen participation. *J. Am. Inst. Planners* 35 (4), 216–224. doi:10.1080/01944366908977225

ASCE/SEI (2022). *Minimum design loads for buildings and other structures*. Reston, VA: American Society of Civil Engineers/Structural Engineering Institute.

Bonowitz, D., Chock, G., Cobeen, K., Crawford, S., Holmes, W., Kim, I., et al. (2021). *State of technology transfer in the natural hazards research infrastructure (NHERI) research: 2021 annual report*. Austin, TX: DesignSafe-CI.

Bordeaux, B. C., Wiley, C., Tandon, S. D., Horowitz, C. R., Brown, P. B., and Bass, E. B. (2007). Guidelines for writing manuscripts about community-based participatory research for peer-reviewed journals. *Prog. Community Health Partnersh. Res. Educ. Action* 1 (3), 281–288. doi:10.1353/cpr.2007.0018

Bozeman, B. (2000). Technology transfer and public policy: A review of research and theory. *Res. policy* 29 (4-5), 627–655. doi:10.1016/s0048-7333(99)00093-1

Bruneau, M., Chang, S. E., Eguchi, R. T., Lee, G. C., O'Rourke, T. D., Reinhorn, A. M., et al. (2003). A framework to quantitatively assess and enhance the seismic resilience of communities. *Earthq. Spectra* 19 (4), 733–752. doi:10.1193/1.1623497

Burnside-Lawry, J., and Carvalho, L. (2016). A stakeholder approach to building community resilience: Awareness to implementation. *Int. J. Disaster Resil. Built Environ.* 7, 4–25. doi:10.1108/IJDRBE-07-2013-0028

CBGC (Community Based Research Collaborative) (2021). *In it together: Community-based research guidelines for communities and higher education*. Salt Lake City, UT: University of Utah.

CCSC (Center For Compassionate and Sustainable Communities) (2023). Center for compassionate and sustainable communities. Avaliable At: https://ipsr.ku.edu/compassion/about.shtml (Accessed February 17, 2023).

CDC (Centers for Disease Control and Prevention) (1997). *Principles of community engagement*. First Edition. Atlanta, GA: CDC/ATSDR Committee on Community Engagement.

Chen, P. G., Diaz, N., Lucas, G., and Rosenthal, M. S. (2010). Dissemination of results in community-based participatory research. *Am. J. Prev. Med.* 39 (4), 372–378. doi:10.1016/j.amepre.2010.05.021

Chock, G., Holmes, W., Kim, I., Malley, J., Bonowitz, D., Valley, M., et al. (2022). *State of technology transfer in natural hazard research infrastructure (NHERI) research: 2022 annual report*. Austin, TX: DesignSafe-CI. doi:10.17603/ds2-9as8-dt58

Climate Action Plan (2023). Community climate action. Available at: https://storymaps.arcgis.com/stories/22193694fa0544079c1f6a3de027aa90.

Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., et al. (2008). A place-based model for understanding community resilience to natural disasters. *Glob. Environ. change* 18 (4), 598–606. doi:10.1016/j.gloenvcha.2008.07.013

Cutter, S. L. (2016). The landscape of disaster resilience indicators in the USA. *Nat. hazards* 80 (2), 741–758. doi:10.1007/s11069-015-1993-2

DHS (Department of Homeland Security) (2010). Quadrennial homeland security review report: A strategic framework for a secure homeland. Available at: http://www.dhs.gov/xlibrary/assets/qhsr_report.pdf.

Fawcett, S. B., Francisco, V. T., Schultz, J. A., Berkowitz, B., Wolff, T. J., and Nagy, G. (2000). Technology. The community tool box: A web-based resource for building healthier communities. *Public health Rep.* 115 (2-3), 274–278. doi:10.1093/phr/115.2.274

FEMA (Federal Emergency Management Agency) (2010). Comprehensive preparedness guide 101: Developing and maintaining emergency operations plans. Version 2.0. Available at: http://www.fema.gov/pdf/about/divisions/npd/CPG_101_V2.pdf.

Finn, D., Mandli, K., Bukvic, A., Davis, C. A., Haacker, R., Morss, R. E., et al. (2022). Moving from interdisciplinary to convergent research across geoscience and social sciences: Challenges and strategies. *Environ. Res. Lett.* 17, 061002. doi:10.1088/1748-9326/ac7409

Gaillard, J. C., and Peek, L. (2019). Disaster-zone research needs a code of conduct. *Nature* 575 (7783), 440–442. doi:10.1038/d41586-019-03534-z

Harahap, G. Y. (2020). Instilling participatory planning in disaster resilience measures: Recovery of tsunami-affected communities in banda aceh, Indonesia. *Budapest Int. Res. Exact Sci. (BirEx) J.* 2 (3), 394–404. doi:10.33258/birex.v2i3.1085

Hung, H. C., Yang, C. Y., Chien, C. Y., and Liu, Y. C. (2016). Building resilience: Mainstreaming community participation into integrated assessment of resilience to climatic hazards in metropolitan land use management. *Land Use Pol.* 50, 48–58. doi:10.1016/j.landusepol.2015.08.029

Irwin, E. G., Culligan, P. J., Fischer-Kowalski, M., Law, K. L., Murtugudde, R., and Pfirman, S. (2018). Bridging barriers to advance global sustainability. *Nat. Sustain.* 1 (7), 324–326. doi:10.1038/s41893-018-0085-1

KC Star (2019). *Houses gutted by Linwood tornado never stood a chance*. Kansas: Kansas City Star Editorial.

Kim, J. H., Moraveg, M., Sutley, E. J., Chowdhury, A., and Dao, T. (2020). Observations and analysis of wind pressures on the floor underside of elevated buildings. *Elsevier Eng. Struct.* 221, 111101. doi:10.1016/j.engstruct.2020.111101

Lyles, W., OverstreetWu, K. Y., and Moore, J. (2021). Caring as class: Resolving the emotional paradox of climate change education journal of sustainability education. Available at: http://www.susted.com/wordpress/content/caring-as-class-resolving-the-emotional-paradox-of-climate-change-education_2021_05/.

Lyles, W., and White, S. S. (2019). Who cares? Arnstein's ladder, the emotional paradox of public engagement, and (re) imagining planning as caring. *J. Am. Plan. Assoc.* 85 (3), 287–300. doi:10.1080/01944363.2019.1612268

Lynch, B. (2019). Rapid-response damage assessment gives new insight into recent Kansas tornado. Available at: https://today.ku.edu/2019/06/10/rapid-response-damage-assessment-provides-new-insight-recent-kansas-tornado.

MacQueen, K. M., McLellan, E., Metzger, D. S., Kegeles, S., Strauss, D., Scotti, R., et al. (2001). What is community? An evidence-based definition for participatory public health. *Am. J. Public Health* 91 (12), 1929–1938. doi:10.2105/ajph.91.12.1929

Mazumder, R., Sutley, E., and Dumler, M. (2021). "Data report on household impact and recovery assessment: A longitudinal investigation after the 2019 EF4 Linwood, Kansas tornado," in *StEER – 28 may 2019 linwood, KS EF4 tornado: Field assessment structural team 1 (FAST-1)* (Austin, TX: DesignSafe-CI). doi:10.17603/ds2-87ne-d742

McDavitt, B., Bogart, L. M., Mutchler, M. G., Wagner, G. J., Green, H. D., Jr, Lawrence, S. J., et al. (2016). Dissemination as dialogue: Building trust and sharing research findings through community engagement. *Prev. Chron. Dis.* 13, 150473. doi:10.5888/pcd13.150473

Meyer, M. A., Hendricks, M., Newman, G. D., Masterson, J. H., Cooper, J. T., Sansom, G., et al. (2018). Participatory action research: Tools for disaster resilience education. *Int. J. disaster Resil. built Environ.* 9, 402–419. doi:10.1108/ijdrbe-02-2017-0015

NIST (National Institute of Standards and Technology) (2015). *Community resilience planning guide for buildings and infrastructure systems*. Gaithersburg, MD: Special Publication (NIST SP 1190), National Institute of Standards and Technology. doi:10.6028/NIST.SP.1190v1

NOAA NCEI (2023). National oceanic and atmospheric administration national centers for environmental information. Avalliable At: https://www.ncei.noaa.gov/access/billions/.

NRC (2012). *Disaster resilience: A national imperative*. Washington, DC: The National Academies Press. doi:10.17226/13457

NRC (National Research Council) (2005). *Creating a disaster resilient America: Grand challenges in science and technology—summary of a workshop*. Washington, DC: The National Academies Press.

Olson, R. S., Ganapati, E., Gawronski, V. T., Olson, R. A., Salna, E., and Pablo Sarmiento, J. (2020). From disaster risk reduction to policy studies: Bridging research communities. *Nat. hazards Rev.* 21 (2), 04020014. doi:10.1061/(ASCE)NH.1527-6996.0000365

PBS Terra (2020). Tornado warning: Survive nature's wildest winds weathered. Availabled At: https://youtube.com/watch?app=desktop&v=ji=c129HLMo.

Peek, L., Tobin, J., Adams, R. M., Wu, H., and Mathews, M. C. (2020). A framework for convergence research in the hazards and disaster field: The natural hazards engineering research infrastructure CONVERGE facility. *Front. Built Environ.* 6, 110.

Pfefferbaum, B., Pfefferbaum, R. L., and Van Horn, R. L. (2015). Community resilience interventions: Participatory, assessment-based, action-oriented processes. *Am. Behav. Sci.* 59 (2), 238–253. doi:10.1177/0002764214550298

Renschler, C., Frazier, A., Arendt, L., Cimellaro, G. P., Reinhorn, A., and Bruneau, M. (2010). "Developing the 'PEOPLES' resilience framework for defining and measuring disaster resilience at the community scale," in *Proceedings of the 9th US national and 10th Canadian conference on earthquake engineering (9USN/10CCEE)* (Toronto, New York: Free Press of Glencoe).

Rogers, E. M. (2003). *Diffusion of innovations*. 5th edn. New York, NY: Free Press of Glencoe.

Saltmarsh, J., and Hartley, M. (2011). *To serve a larger purpose": Engagement for democracy and the transformation of higher education*. Philadelphia, PA: Temple University Press.

Singletary, L., Koebele, E., Evans, W., Copp, C. J., Hockaday, S., and Rego, J. J. (2022). Evaluating stakeholder engagement in collaborative research: Co-producing knowledge for climate resilience. *Socio-Ecological Pract. Res.* 4 (3), 235–249. doi:10.1007/s42532-022-00124-8

Sutley, E., Chen, Z., Li, J., Chao, H., Daniel, L., Clements, J., et al. (2019b). "Door to door damage assessment survey," in *StEER - 28 may 2019 linwood, KS EF4 tornado: Field assessment structural team 1 (FAST-1)* (Austin, TX: DesignSafe-CI). doi:10.17603/ds2-a06x-f358

Sutley, E., Dao, T., and Kim, J. (2019c). "Rapid: Assessing the performance of elevated wood buildings, including manufactured housing," in *Florida during 2018 hurricane michael* (Austin, TX: DesignSafe-CI). doi:10.17603/ds2-85fv-n684

Sutley, E., Dumler, M., Mazumder, R., Lequesne, R., Li, J., Kirkham, W., et al. (2021c). "One-year post-tornado repair progress: Wave 3," in *StEER - 28 may 2019 linwood, KS EF4 tornado: Field assessment structural team 1 (FAST-1)* (Austin, TX: DesignSafe-CI). doi:10.17603/ds2-5ysj-a554

Sutley, E. J., Kim, J. H., Kirkham, W. J., and Lequesne, R. (2021a). Examining tornado vulnerability in Kansas with recent findings from an EF4 tornado. *J. Nat. Hazards Rev.* 22 (3). doi:10.1061/(ASCE)NH.1527-6996.0000476

Sutley, E. J., Vazquez, K., Dao, T., Kim, J., Hunt, J., and Johnston, B. (2020b). Performance of manufactured housing during hurricanes irma and michael. *J. Perform. Constr. Facil.* 34 (4). doi:10.1061/(ASCE)CF.1943-5509.0001486

Sutley, E., Lequesne, R., Gelino, B., Reed, D., Phan, N., Smith, M., et al. (2020a). "May 28, 2019 EF4 Linwood tornado: Six-month post-tornado recovery report," in *StEER - 28 may 2019 linwood, KS EF4 tornado: Field assessment structural team 1 (FAST-1)* (Austin, TX: DesignSafe-CI).

Sutley, E., Lequesne, R., Li, J., Kirkham, B., Chen, Z., Al-Sabawy, A., et al. (2019a). StEER - 28 may 2019 linwood, KS EF4 tornado: Field assessment structural team (fast) early access reconnaissance report (earr). DesignSafe-CI: Report. doi:10.17603/ds2-xz1j-nm14

Sutley, E., Reed, D., Lequesne, R., Kirkham, W., Li, J., Kim, J., et al. (2021b). "Six-month post-tornado repair progress: Wave 2," in *StEER - 28 may 2019 linwood, KS EF4 tornado: Field assessment structural team 1 (FAST-1)* (Austin, TX: DesignSafe-CI). doi:10.17603/ds2-an2v-2c39

Waugh, W. L., and Streib, G. (2006). Collaboration and leadership for effective emergency management. *Public Adm. Rev.* 66, 131–140. doi:10.1111/j.1540-6210.2006.00673.x

Wells, K. B., Tang, J., Lizaola, E., Jones, F., Brown, A., Stayton, A., et al. (2013). Applying community engagement to disaster planning: Developing the vision and design for the los angeles county community disaster resilience initiative. *Am. J. public health* 103 (7), 1172–1180. doi:10.2105/ajph.2013.301407

Winkler, T. (2013). At the Coalface: Community-univeristy engagements and planning education. *J. Plan. Educ. Res.* 33 (2), 213–227. doi:10.1177/0739456X1247431

Zehner, D. (2017). Episode 5. There Used to be buildings right there. DesignSafe Radio. Available At: https://www.stitcher.com/show/designsafe-radio/episode/eipsode-5-there-used-to-be-buildings-right-there-51320027.