

Capacity-Building to Support Safer Housing through Appropriate Hurricane Strap Use

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Abstract: Amid rising global disaster risks, governmental and nongovernmental organizations have called for increased technical assistance to build capacity within communities to build safer housing. However, limited research has evaluated these approaches to building technical construction capacity. This study discusses the process of collaboratively designing an approach to build construction capacity for safer housing, evaluating this process through measures of builders' self-efficacy and knowledge of mitigation measure efficacy. The capacity-building focuses particularly on the appropriate use of hurricane straps in wood roof construction in Puerto Rico, which was identified as an area where engineering recommendations did not align with many builders' perceptions of safety. Three phases were used to design, implement, and assess this capacity-building approach. First, we interviewed staff in local nongovernmental organizations (NGOs) to identify propositions for building technical construction capacity in Puerto Rico. We then used these propositions as a framework to design the capacity-building approach. Finally, we piloted and evaluated this approach with existing trainers and community members who are building and repairing housing in Puerto Rico, interviewing them after implementation to analyze shifts in self-efficacy and knowledge of mitigation measure efficacy. The results reveal interviewees' increased perceived self-efficacy and knowledge of mitigation measure efficacy following capacity-building, leading them to express increased willingness to mitigate hurricane risks to housing with appropriately installed hurricane straps. Overall, this study provides evidence that centering people's perspectives is needed in technical construction capacity-building to influence builders' self-efficacy and knowledge of mitigation measure efficacy and promote safer housing construction and suggests an approach that can be used to center these perspectives. **DOI: 10.1061/NHREFO.NHENG-1708.** *This work is made available under the terms of the Creative Commons Attribution 4.0 International license, <https://creativecommons.org/licenses/by/4.0/>.*

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Introduction

Disasters are growing more frequent and severe (Dinan 2017), threatening communities and their housing. In many hazard-prone regions, most housing is constructed informally, whereby residents hire builders or self-build with the help of friends and family to address their needs and concerns, given their available resources (Feliciano et al. 2022). The local knowledge and other resources applied to build this housing can result in affordable structures that respond well to common structural loads (Langenbach 2015). Yet, postdisaster studies and reconnaissance reports have revealed

that informally constructed housing often possesses structural vulnerabilities, leading it to be more heavily damaged in disasters than housing constructed through more formal building and regulatory processes (FEMA 2018; Miranda et al. 2020). Thus, understanding how informal construction processes occur can provide critical insight into how to increase the safety of most of the world's housing.

In the informal construction context, builders' and residents' housing safety perceptions ultimately determine how things are built and, thus, whether housing is safe from future hazards. Researchers have documented examples of builders inadvertently constructing unsafe infrastructure when their perceptions of safety do not align with an engineering understanding of structural safety (Audefroy 2011; Rodgers 2012). In a survey of builders and hardware store employees across Puerto Rico, Goldwyn et al. (2022a) found that builders' perceptions of hurricane-safe roof construction led to both a lack of hurricane mitigation and problems with hurricane strap installation (both in the location and methods of installing these straps).

There is wide recognition of the need to build capacity for constructing safer housing (Clinton 2006; Wisner et al. 2014) and mitigate hazards, as well as the need for communities to be active participants in their disaster risk reduction (FEMA 2011; Sarzynski and Cavaliere 2018). At its core, capacity-building involves working with communities to build their capabilities so they can identify their needs and address their priorities (Eade 1997). Yet, common approaches to building technical construction capacity for informal construction, such as pamphlets or reports with safer construction recommendations, rely primarily on one-way information dissemination from technical experts to the general public. These one-way approaches presume that

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information alone can change construction practices and do not effectively interrogate misalignments between this information and builders' perceptions of safety or communicate with builders to ensure they can prioritize or recall technical recommendations (Opdyke et al. 2018; Zerio et al. 2016).

Based on what we understand about housing safety perceptions, the misalignments between these perceptions and engineering understanding, and the factors prompting hazard preparedness, we posit that effective technical construction capacity-building should involve active collaboration with communities to learn their perspectives and then center and address their needs and concerns given their available resources and alternatives. This research investigates and assesses a capacity-building program design that is centered around local builders' perspectives, addressing the research question: *How can a technical construction capacity-building approach be collaboratively designed to encourage hazard mitigation in building construction?* In doing so, this study contributes to the limited existing research on capacity-building for safer housing and methods of communicating technical recommendations to interrupt common one-way information dissemination approaches through increased dialogue to increase self-efficacy and knowledge of mitigation measure efficacy, which we argue to be appropriate constructs for building technical construction capacity.

In this study, we collaboratively design, pilot, and evaluate a technical construction capacity-building approach focused on housing in Puerto Rico, a US Caribbean island. Our approach began in prior work that learned from builders' perceptions of housing safety in hurricanes and earthquakes (Goldwyn et al. 2022b) and conducted engineering performance assessments of housing safety in wind and seismic events (Lochhead et al. 2022; Murray et al. 2022). Through comparison of perceptions and these engineering assessments, we identified areas for technical construction capacity-building, where perceptions of housing safety and recommendations from engineering assessments did not align (Goldwyn et al. 2022a). Here, we focus on one area that emerged as a concern for builders and residents—the appropriate use of hurricane straps for mitigation of roof and housing damage in hurricanes in houses with wood-frame roofs. Our engineering studies showed that the installation of appropriately designed hurricane straps (in terms of specified quantity, fasteners, and locations) could significantly improve outcomes in hurricanes (Lochhead et al. 2022). However, many builders do not expect damage to key roof connections where hurricane straps can help, instead perceiving that it is more important to strengthen the connections between metal roof panels and the roof. Thus, in this study, we design and investigate a capacity-building approach to communicate technical recommendations on hurricane strap application and effectiveness, assessing how and if the capacity-building approach can encourage hazard mitigation.

Background

Despite the recognized need to build capabilities for safer housing construction (Clinton 2006; Wisner et al. 2014), there is limited research on how to effectively engage with communities of builders to communicate technical recommendations and build technical construction capacity for safer housing. This section describes the evidence that centering people's perspectives is needed in developing solutions in cooperation with communities and ultimately building construction capacity and the lack of existing research in this area, and, through reference to the literature, identifies measures of self-efficacy and knowledge of hazard mitigation efficacy

as appropriate constructs for evaluating approaches for building technical construction capacity.

Centering Peoples' Perspectives to Address Misalignments and Build Capacity

The limitations of traditional, one-way approaches to sharing technical construction recommendations or unfamiliar technology with those building housing informally highlight the need to collaborate with communities for capacity-building. Approaches to sharing technical construction recommendations have traditionally taken a deficit model (Suldovsky 2017), where information is assumed to flow from experts to the general public through one-way information dissemination without engaging with communities to discuss their perspectives or realistic challenges. This one-way information dissemination can also assume that technological advancements and recommendations are applicable to everyone, without listening to users to investigate their available resources, alternative approaches, societal priorities, and needs. For example, researchers investigating pamphlets that were widely distributed about typhoon mitigation for housing in the Philippines found they did not convey the recommendations in a way that allowed builders to prioritize or recall them (Opdyke et al. 2018; Zerio et al. 2016). Scholars have noted similar challenges with other top-down efforts to share information on disaster risk and preparedness. For instance, strategies to share disaster warning information with simplified mobile alerts are confusing, uninformative, and fear-inducing (Bean et al. 2016) and such that they can end up reducing versus increasing self-efficacy for hazards (Duval and Mulilis 1999).

Recognizing the role of public participation in hazard mitigation (Sarzynski and Cavaliere 2018), scholars have argued for the importance of opening dialogue and listening to community perspectives to ensure that technical recommendations are shared in a way that resonates with the community (Tanner et al. 2020). Importantly, centering and engaging with communities encourages community ownership of the process and ensures that the recommendations address their needs, perspectives, and capacities. Scholarly and policy literature on people-centered approaches focus on methods of engaging with and centering peoples' perspectives during the phases of community hazard preparedness planning and recovery (FEMA 2011; Schilderman and Lyons 2011), but studies have not evaluated how increasing dialogue within training approaches that address technical construction recommendations elucidates people-centered concerns and influences self-efficacy.

Nevertheless, researchers studying building code compliance provide insight into ways of engaging with communities informally constructing housing to develop technical recommendations and change practices. For example, scholars have argued for the value of eliciting public perspectives around societal expectations for building codes (Mieler et al. 2013; Tanner et al. 2020), while recommending that the technical details of how these expectations are met to technical committees. For instance, technical recommendations can then focus on structural components or systems that most align with community safety objectives. Other studies have demonstrated the need to show the benefits of code compliance and hazard-resistant design (e.g., FEMA 2020). By listening to and incorporating public perspectives into capacity-building, the focus shifts away from simply sharing technically correct engineering solutions toward communicating technical recommendations in a way that resonates with the public's concerns (i.e., the hurricane damage homeowners are the most worried about) and realistic challenges (i.e., limited resources and complex information). Yet, there is

limited applied engineering and social science research on methods of promoting dialogue to understand and incorporate peoples' perspectives into approaches aimed to build technical construction capacity in a way that emphasizes dialogue to address their concerns.

Evaluating Capacity-Building Approach Influence on Future Hazard Mitigation

There is limited research on the design of technical capacity-building approaches for the construction sector. Fortunately, scholars studying whether individuals take action to prepare for hazards and reduce their disaster risk provide insight into measuring whether capacity-building influences hazard preparedness. In particular, research has shown preparedness actions can be predicted by *self-efficacy* and *perceived mitigation measure efficacy*.

Self-efficacy is one's perceived ability to complete preparedness activities given their resources and existing challenges (Bandura 1977; van Valkengoed and Steg 2019). Leading theories in hazard preparedness, including the protection motivation theory (PMT) (Rogers 1975; Rogers and Prentice-Dunn 1997), discuss the role of one's perceived ability to protect themselves from or mitigate disaster risks. The PMT considers self-efficacy in the context of perceived threats and the ability to cope with such threats (Rogers and Prentice-Dunn 1997). This study relies on the PMT's interpretation of self-efficacy as related to a particular person's knowledge and skills (Rogers and Prentice-Dunn 1997). Other studies have built on these theories and found self-efficacy to be a leading driver of protective actions against hazards (Bubeck et al. 2012; van Valkengoed and Steg 2019). In addition, studies have found several barriers to self-efficacy, including the perceived complexity of preparedness actions such as choosing flood insurance (Seebauer and Babicky 2020). Individuals' concerns related to cost (Weinstein 1993) and whether they perceive the mitigation measure as realistic for them (Fothergill and Peek 2004) can also act as barriers to self-efficacy. Hendriks and Opdyke (2022) recently investigated how technical assistance modalities influenced housing safety perceptions in Nepal, finding that the technical training raised awareness of unsafe practices and structural vulnerabilities but was unable to increase capabilities to address those risks. This technical assistance did not consider the cost barriers preventing builders from feeling capable of implementing the recommendations and, thus, did not build self-efficacy and capacity (Hendriks and Opdyke 2022).

Perceived mitigation measure efficacy is the perception that preparedness activities effectively reduce disaster risk (Terpstra and Lindell 2013). This perception influences whether an individual takes preparedness actions. PMT's definition of coping appraisal includes response efficacy or the belief that the action will effectively reduce expected damage (Rogers and Prentice-Dunn 1997). The protective action decision model (PADM) extends beyond PMT's idea of response efficacy to focus on the preparedness action's efficacy for increasing the safety of people and property as well as its utility for other purposes (Lindell and Perry 1992; Terpstra and Lindell 2013). According to these theories, people are likely to take protective actions to prepare for hazards if they perceive themselves at risk and believe that they have access to mitigation options that will effectively mitigate that risk (Seebauer and Babicky 2020). Other studies of hazard mitigation and preparedness behaviors have noted examples of households not mitigating hazards in part due to perceptions of mitigation measures not being efficacious (López-Marrero 2010). In contrast to this perceived mitigation measure efficacy, fatalism, or feelings of hopelessness about opportunities to prepare for disasters, discourages

people from mitigation (McClure et al. 2001, 2007; Turner et al. 1986). Thus, this study investigates perceptions of both self-efficacy and knowledge of mitigation measure efficacy and appropriate use to measure whether the designed capacity-building approach has empowered builders to take action to mitigate disaster risk.

Context

Given that most people build and rebuild their housing after disasters without external assistance through the informal construction sector after disasters, there is a widely recognized need to mitigate future disaster risk by training builders on safer housing construction (Clinton 2006; Jha et al. 2010). Thus, our study discusses a technical construction capacity-building approach in Puerto Rico, a US Caribbean island where most housing is constructed informally (Hinojosa and Meléndez 2018). Like much of the Caribbean, Puerto Rico's complex colonial history, multihazard environment, and weak regulatory enforcement and supervision of housing construction have contributed to individuals building and living in housing that is vulnerable to the hazards affecting the island. Hurricanes Irma and Maria devastated Puerto Rico in September 2017, damaging or destroying over a third of all housing stock (Habitat for Humanity International, n.d.). Then, the 2019–2020 earthquakes also damaged or destroyed approximately 10,000 houses across Puerto Rico's southwestern region (Miranda et al. 2020).

Housing Construction in Puerto Rico and State of Construction Training

Informally constructed housing has been the only form of affordable and accessible housing in Puerto Rico for those without land tenure, with low incomes, or who cannot wait for lengthy permitting processes (Clancy et al. 2020; Shrestha et al. 2021). Much of Puerto Rico's housing stock is built on land that has been informally subdivided among family members over generations without any official land title, restricting residents from accessing formal housing construction processes (Acevedo and Pacheco 2018; Clancy et al. 2020).

Housing in Puerto Rico is generally built with reinforced concrete/masonry, wood, or a combination of reinforced concrete/masonry and wood. However, there is widespread fatalism about the safety of wood housing in hurricanes in Puerto Rico, with many residents perceiving it as impossible to build a wood house that can withstand a hurricane (Goldwyn et al. 2021, 2022b). Perceptions of the relative safety of reinforced concrete/masonry housing in Puerto Rico can be traced to modernization efforts in Puerto Rico that focused on "hurricane-proof" concrete construction (Burrows 2014) and the shared experience of relatively good performance of this construction in frequent, devastating hurricanes. Now, despite construction advancements such as hurricane straps that can substantially strengthen wood-frame roof connections, the distrust in the safety of wood housing in Puerto Rico persists, leading many higher-income families to build concrete rather than wood housing types. Residents cannot easily finance or insure wood housing in Puerto Rico. On their website, Puerto Rico's Department of Housing Homebuyer Assistance Program lists, "*The living area must be built entirely out of concrete. In case the chosen property has a section made of wood or metal, it cannot be in a living area*" (CDBG-DR Department of Housing, n.d.). Yet, wood housing is still common because, as one builder we talked to put it, "*people build wood houses here because they don't have the time or money for concrete.*" There are no available comprehensive estimates of the prevalence of informally constructed wood-frame roofs or

wood-frame roofs secured with any or appropriate hurricane straps. However, before 2017's Hurricanes Irma and Maria, Puerto Rico's housing stock of 1.1 million one- and two-family structures was reported to be approximately 76% all concrete construction, 13% mixed wood and concrete construction (most commonly reinforced concrete and masonry walls with wood-frame roofs), and 11% all wood construction (Clancy et al. 2020).

Moreover, formal construction training options are limited and hard for many people to access in Puerto Rico. Most of those working in construction in Puerto Rico have not been formally trained, but rather informally apprenticed. Construction wages in Puerto Rico are about half of that of the United States on average (BLS 2019), and the cost of living in Puerto Rico is also high due to a myriad of factors like the Jones Act (Yglesias 2017), spurring an outmigration of skilled labor to the states. Trade schools in Puerto Rico do not teach construction trades, and apprenticeships take several years to complete at a low wage.

Government agencies like the US Department of Housing and Urban Development have provided additional funding for programs directed at training to address these needs, with several running over the past year. After Hurricanes Irma and Maria and before this study, FEMA hosted or funded workshops on wood-frame housing construction and hurricane straps. For example, FEMA collaborated with JZ Engineering to develop workshops on safer housing construction starting in 2018 (JZ Engineering, n.d.). While no case studies have evaluated the quality or effectiveness of these workshops at building technical construction capacity, anecdotal evidence gathered by the authors through this study revealed that these hands-on, multiday workshops were more effective at reaching populations of builders informally constructing housing than other approaches taken by organizations in Puerto Rico to disseminate information through pamphlets or guidebooks filled with construction recommendations because dialogue with affected appeared essential for uptake.

However, these programs have taken years to start after Hurricanes Irma and Maria and the 2019–2020 earthquakes in Puerto Rico. Grassroots and community-based organizations have stepped in to address the gaps in need left by the federal government and the absence of international aid organizations, hosting hazard preparedness trainings and rebuilding housing. To date, trainings have focused on construction basics, including masonry and carpentry, rather than extending to the details of hazard-resistant design. In addition, to date, these have been somewhat limited in reach and mostly not focused on hurricane mitigation for wood-frame housing.

Rationale for the Focus on Hurricane Straps: Drawing from Community Perspectives

This study draws from prior work by the authors that found builders, hardware store employees, and other experts across Puerto Rico were concerned about wood housing safety in hurricanes (Goldwyn et al. 2021, 2022b). Hurricane straps, referred to locally as “anchors,” are a common hurricane mitigation measure for wood-frame roofs and a housing safety technology of interest to residents and builders. Reconnaissance and wind performance assessments in the Caribbean have documented the importance of hurricane strap use for hurricane mitigation of wood-frame roofs. However, studies have revealed that common nailed and toe-nailed wood-frame roof connections cannot withstand uplift and shear wind forces in hurricanes (FEMA 2018; Kijewski-Correa et al. 2019; Lochhead et al. 2022). This lack of secure roof construction increases the risk of loss of the entire roof in a storm (Lochhead et al. 2022).

Our prior work showed that builders and residents might not be prioritizing hurricane straps at key roof connections due to technical construction capacity limitations (Goldwyn et al. 2022b). For example, in a survey of over 300 builders and hardware store employees, Goldwyn et al. (2022b) found that fewer than half of all respondents viewed hurricane straps as important hurricane mitigation measures for wood housing. One reason builders may not be including hurricane straps in their housing construction is that they are prioritizing measures of securing their metal roof panels, which they know based on experience will fail first, rather than strengthening these critical interior roof connections (Goldwyn et al. 2022b). However, panel-fastener interface connection failure is less costly and catastrophic than purlin-to-truss and truss-to-wall connection failures that can lead to the loss of the entire roof. Respondents may not have a structural systems perspective of failure, leading them to attribute the panel failure they have observed in prior hurricanes to the panel-fastener interface alone rather than to both the panel-fastener and purlin-to-truss connections. The uncertainty about the importance of these roof connections and the potential for hurricane straps to strengthen these connections provides opportunities for technical construction capacity-building (Goldwyn et al. 2022a).

Hurricane straps are widely available in Puerto Rico and have grown increasingly common since Hurricane Hugo in 1986 and even more popular after Hurricanes Irma and Maria in 2017. These straps are a relatively affordable and accessible mitigation measure when considering their role in reducing costly, catastrophic structural failures that are common in housing built with toe-nailed connections in the wood roof system rather than hurricane straps. We estimated the material cost of hurricane straps in a 16-ft by 24-ft house with ideal purlin spacing (one purlin every two feet) and truss or rafter spacing (one truss or rafter every four feet) to be roughly \$50–100 (Lochhead et al. 2022) because each recommended hurricane strap costs between \$0.75 and \$1.50. This price point is accessible to many but not all (the most common alternative to connections strengthened by hurricane straps, toe-nailed connections, solely require the purchase of nails). Labor is more significant with hurricane straps, but the cost of this is unclear.

Despite being widely available, there is significant uncertainty on how to use and install hurricane straps. In prior work by the authors, interviewees explained that they did not know how or where to install hurricane straps to increase their housing safety and wanted more information (Goldwyn et al. 2022a). Lacking formal training for builders or robust regulatory processes, it is up to builders, residents, and grassroots organizations to learn and develop guidance on hurricane strap importance and installation to ensure wood housing is safe in future hurricanes.

Organization of this Paper

This study is organized into three phases, each with specific results supporting the subsequent phase. Fig. 1 illustrates each phase of this research and the relationships among research outcomes generated from each phase.

In *Phase 1: Listening and characterizing*, we interviewed staff from locally-based NGOs and others involved in community hazard-related planning and then qualitatively analyzed responses to identify themes for successful capacity-building approaches in Puerto Rico. This phase helped us identify several propositions to guide our initial capacity-building approach, which we aligned with applied communication literature. Next, in *Phase 2: Designing*, we used the propositions established in Phase 1 as a framework

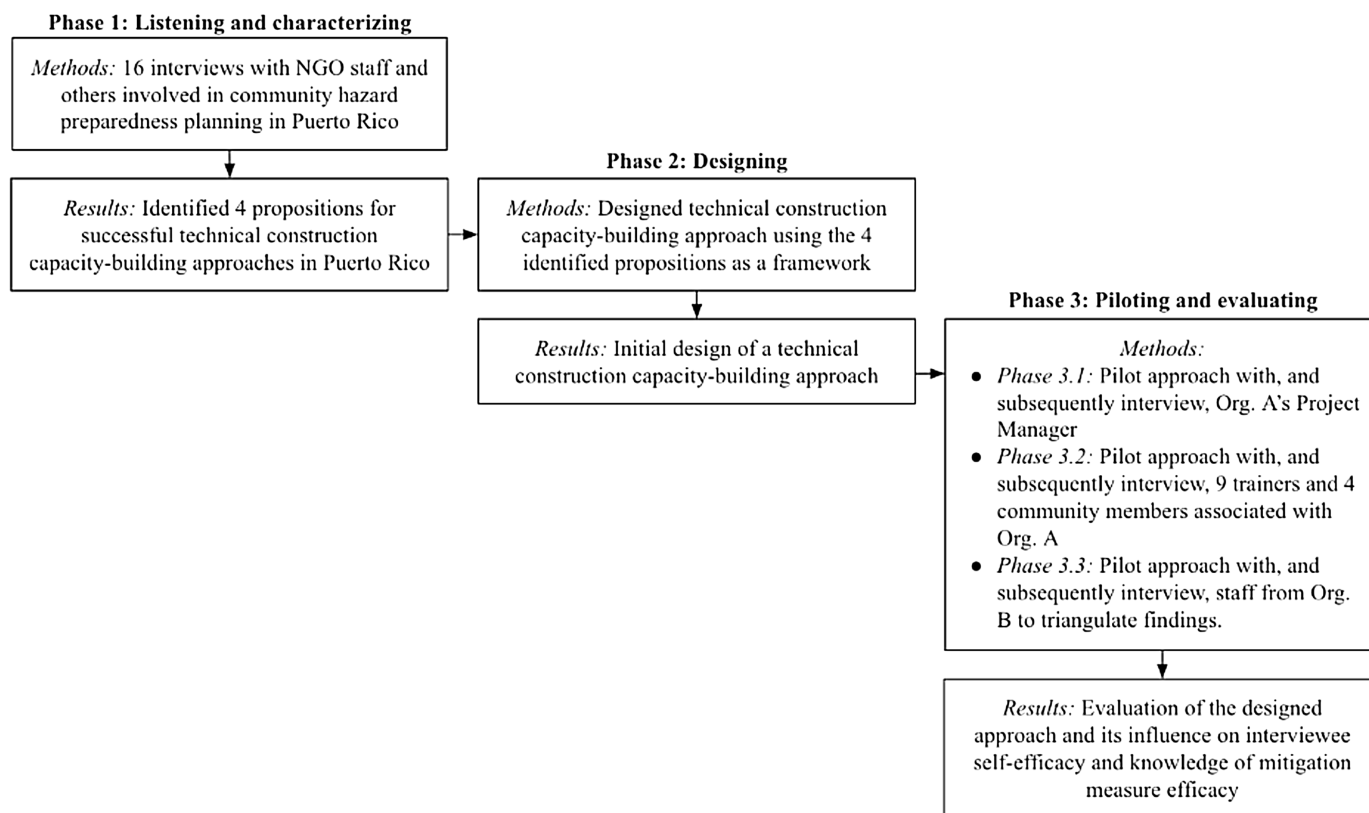


Fig. 1. Research process.

to design the capacity-building approach focused on hurricane strap application and effectiveness. Finally, in *Phase 3: Piloting and evaluating* the design, we worked alongside locally-based organizations to pilot and evaluate the design, interviewing participants to understand their perceived self-efficacy and mitigation measure efficacy. This final stage presents results of how the capacity-building approach influences self-efficacy and knowledge of mitigation measure application and efficacy to answer this study's research question.

Phase 1: Listening and Characterizing

We consulted Puerto Rican community-based organization staff and others involved in community planning to investigate how to communicate technical recommendations about wood-frame roof mitigation to community members. These groups are familiar with community engagement and sharing technical recommendations in a way that resonates with Puerto Rican communities.

Phase 1 Methods

In *Phase 1* (Fig. 1), we conducted 16 interviews over Zoom in English and Spanish, each taking approximately 60 min. In these interviews, we began by asking questions about communicating technical recommendations in Puerto Rico. For this phase, we asked questions like, “*Could you describe the aspects of your community-based organization’s training programs that you believe made it successful?*” We also asked about building technical construction capacity, specifically, with questions like, “*Who do you believe makes the decisions about whether to use hurricane straps? What do they consider?*” We then transcribed and qualitatively analyzed interview transcripts using Trint and QSR NVivo,

respectively, to compile a list of propositions for capacity-building approaches in Puerto Rico and determine realistic challenges and concerns of people making decisions about hurricane straps. We concluded the interviews after reaching saturation, or the point when we no longer received new responses to the interview questions.

With this information, we developed propositions related to the design of a training program in Puerto Rico. With this information, we developed propositions related to the design of a training program in Puerto Rico. To do so, we transcribed and qualitatively analyzed interview transcripts using Trint and QSR NVivo, respectively. We concluded the interviews after reaching saturation, or the point when we no longer received new responses to the interview questions. We used a combination of inductive and deductive coding for this analysis. For instance, we began with deductive codes from literature, such as a code for the importance of demonstrations (Dearing 2009). Then, we inductively coded for themes as they emerged throughout interviews, such as interviews discussing the valuable role dialogue plays in community empowerment. We then analyzed the relative frequency of each code, finding the percentage of interviewees discussing each theme to identify four propositions.

Phase 1 Results

Overall, interviewees discussed recommendations for communicating technical recommendations in Puerto Rico and emphasized the positive value of a capacity-building approach focused on hurricane straps. For example, one interviewee explained the need for training on hurricane straps saying, “*I think people are interested in learning how to use hurricane straps properly. People don’t want to go through another hurricane like Maria destroying their houses*

again . . . we have to bring this knowledge to every corner because self-construction is going to continue to be the way most people in Puerto Rico build.” The propositions resulting from Phase 1, which are well aligned with existing literature, are intended to increase capacity-building success.

Proposition 1: Share Recommendations and Engage Communities Alongside Trusted Local Groups

Almost all (94%) interviewees described the importance of working through local, trusted groups. As one interviewee stated, “it’s always a delicate thing to come in as an outsider, so it’s just about having that community trust or having it come from within the community rather than just coming from outside.” Another interviewee emphasized the importance of working with community-based organizations that are already well-established and trusted, saying, “I think that the drivers for success are having close communication with community leaders and establishing a connection with the community directly.” These trusted groups can also ensure that the recommendations are repeated over time and shared with harder-to-reach populations. In Puerto Rico, where most residents and builders never received formal recovery support for their informally constructed housing, grassroots and community-based organizations step in to support those in need (Allen 2019). As one interviewee elaborated, “grassroots workshops are the closest thing we have to building codes for wood houses here in Puerto Rico.” In other words, many people in Puerto Rico cannot access formal technical guidance on housing construction and, thus, rely on workshops and other training events hosted by grassroots and community-based organizations.

Proposition 2: Hands-On Learning with Lectures

Half of those interviewed for this study emphasized the importance of combined lectures and hands-on training to promote learning, particularly in populations with low literacy rates. As one interviewee stated, this form of learning “gives people a hands-on exposure to the building and having an idea of where everything goes and how the pieces fit together to incorporate different styles of learning and getting to practice with the tools that we’re going to use in real-life scenarios.” For example, staff from the two training programs focused on housing construction explained that the lectures provide theoretical information on the reasons for specific topics, such as using PowerPoint slides to explain the different types of wind forces that affect a house in a hurricane. Then, this is paired with hands-on training such as practicing using a hammer at different angles. Another interviewee explained, “I think the combination of brief lectures and hands-on learning is really important . . . hands-on training helps with the span of attention.” Researchers have noted the success of programs implemented to train local builders through a combination of formal lectures and hands-on training, in which they can ask questions and learn by physically experimenting with safer building practices (Bartolini and Schacher 2017). The combination of lectures and hands-on learning can incorporate demonstrations, showing evidence of changing practices under real-world conditions and influencing behaviors (Dearing 2009).

Proposition 3: Empower through Dialogue

Two-thirds of the interviewees emphasized the importance of discussion and taking time to answer questions during training programs. As one trainee said, “I would say there’s a sense of not just being lectured at, but a sense of conversation. It was explicitly said by one of the [training supervisors]s to feel free to chime in at any point.” One interviewee explained their community-based organization’s efforts to promote empowerment, saying, “We are kind of arranged in the space as a circle to have more equal

representation.” It emerged clearly that it is critical to create a space where all participants are equals during capacity-building by engaging in discussion, listening, and learning about their needs. Communication scholars have argued for the need to tailor messages through information exchange processes (Mokros and Aakhus 2002), where these messages are a tool in a dialogue. One-way information dissemination about disaster risks, such as television programs, does not play a large role in longer-term disaster preparedness efforts (Dunwoody and Neuwirth 1991). Instead, two-way discussions with people can raise risk awareness and support preparedness activities (Becker et al. 2012) because people generally trust the information shared through interpersonal communication rather than mass media dissemination (Arlikatti et al. 2006).

Proposition 4: Incentivize Attendance

In addition to the first three propositions discussed by most interviewees, we included a fourth proposition that was mentioned by staff from the organization we collaboratively designed, piloted, and evaluated the approach with the need to incentivize attendance. Studies have noted problems recruiting working men to attend training events and workshops due to the common traditional and cultural expectations to prioritize immediate obligations to provide for their families or communities rather than preparing for future events (Saizen and Chakkalathundiyl Sasi 2015). Each of the community-based organizations offering training programs on safer housing construction paid their trainees, and, thus, each of the interviewees affiliated with those programs expressed that it was important for capacity-building approaches to incentivize attendance.

Phase 2: Designing

In Phase 2 (Fig. 1), our design began with prior work learning from homeowners, builders, hardware store employees and organization staff perspectives on safer housing construction in Puerto Rico, which revealed that many individuals were interested in capacity-building related to hurricane strap use (Goldwyn et al. 2022b). Based on these perspectives and existing literature, as discussed in the Background, we established the goal of this approach as increasing self-efficacy and knowledge of mitigation measure efficacy, focusing on the understanding of the application and effectiveness of hurricane straps as wood-frame roof hurricane mitigation. Then, we applied the four propositions identified in Phase 1 to design a capacity-building approach.

First, adhering to Proposition 1, we shared recommendations and engaged communities alongside trusted locally-based organizations. We piloted the approach alongside a group we refer to as Organization A. This is a community-based organization focused on training individuals to build and repair wood-frame roofs that were damaged in Hurricanes Irma and Maria. Organization A pays trainees as they learn and work on housing construction and addresses the importance of hurricane straps through a combination of lectures and hands-on learning, showing where and how to install the hurricane straps. However, Organization A’s construction methods do not align with the practices recommended by the hurricane strap manufacturer. We also used interviews with local builders working with Organization B, a locally-based NGO that has repaired and rebuilt housing in response to Hurricanes Irma and Maria, to validate the key themes that emerged from discussions with Organization A (Carter et al. 2014). At the time of the pilot training, each organization had already repaired or rebuilt over one hundred roofs across over 20 communities, with Organization A graduating almost 50 apprentices. Building technical construction

capacity alongside Organization A was critical to the design because of how trusted they were by community members. As one member of the neighboring community said in a preliminary interview, “*If it’s built by [Organization A] I trust it.*”

Next, we adhered to *Proposition 2* by incorporating a combination of slides in Spanish (shown in Supplemental Materials) with discussion prompts and hands-on learning with demonstration materials. For the initial design of the presentation, we emphasized the expected order of failure of structural components and systems in a wood-frame roof, which had emerged as areas of misalignment between perception and engineering assessments of housing safety (Goldwyn et al. 2022a). We conveyed methods of reducing catastrophic failure by emphasizing the need to strengthen a continuous load path in a house with recommended hurricane straps (shown in Supplemental Materials, Slide 19). Finally, we outlined common mis-installations of the hurricane straps in the presentation, based on conversations with the hurricane strap manufacturer, which included builders bending and using insufficient fasteners.

Demonstration materials and hands-on learning used two model (6-in. by 4-in.) houses we built, one showing the truss roof systems common on the island and analyzed in Lochhead et al. (2022) and the other showing the house that Organization A uses as a baseline in their design, with rafters rather than trusses. We showed the connections that would fail in wind loads. When discussing methods of strengthening the houses and improving vulnerable connections, we passed around materials and discussed differences in cost and expected performance. For instance, when explaining the catastrophic failure of losing the connection between the trusses and walls, we passed around a demonstration house and broke another in that location to practically show the relevant connection. Then, when we discussed the methods to strengthen this connection with the recommended hurricane strap, we passed around both those hurricane straps and specified fasteners to install them with.

We aligned our design with *Proposition 3* by encouraging dialogue using the prepared material as conversation guides. It was critical for the capacity-building approach to be conducted in Spanish to promote dialogue. We encouraged individuals to ask questions and make comments, emphasizing that we intended to have a discussion that could help us understand their perspectives and work with them to find realistic solutions. While explaining concepts to each other or asking questions, individuals used the demonstration materials to illustrate their points. Importantly, this dialogue also enabled us to combat the perceived complexity of hurricane straps to empower individuals to incorporate and share the recommendations. For example, when one interviewee asked, “*If I am limited on money, can I use two screws and two nails rather than four screws?*” we took the opportunity to explain the details of hurricane strap fasteners and assure her that using four nails, rather than any screws, was the cheapest fastener option that would also enable the hurricane straps to withstand their specified loading. When another interviewee asked, “*How am I supposed to know which one to use at this unusual house I’m working on right now?*” we asked to see photos of the house and then discussed the tradeoffs between different hurricane strap options together.

Finally, following *Proposition 4*, we incentivized attendance with meals for all attendees and \$10 gift cards for a major hardware store for all individuals who consented to participate in interviews. These \$10 gift cards represent an hour of pay for a trained apprentice at Organization A and could be used to purchase the recommended materials.

Phase 3: Piloting and Evaluating Design

In *Phase 3* (Fig. 1), we piloted and re-designed this capacity-building approach in three stages involving 20 people to ensure that we were designing an approach that acknowledged people’s realistic challenges and empowered their opinions. In each of the three stages of *Phase 3*, shown in Fig. 1, we piloted the approach and subsequently interviewed individuals to evaluate their general perceptions of the capacity-building approach format and content, self-efficacy, and knowledge of mitigation measure efficacy.

Phase 3 Methods

First (*Phase 3.1*), we piloted the approach with, and subsequently interviewed, Organization A’s project manager. Second (*Phase 3.2*), we piloted the approach with, and then interviewed, four members of Organization A’s neighboring community and nine construction apprentices affiliated or working with Organization A. Third (*Phase 3.3*), we triangulated our data sources by interviewing six of Organization B’s contractors and other staff. None of the 20 total interviewees involved in *Phase 3* were involved in prior phases of the study. In *Phase 3*, we considered only interviewees who were affiliated with Organization A or B and who engaged in rebuilding informally constructed housing after Hurricanes Irma and Maria. We did not inquire about interviewee construction experience prior to the hurricanes, but Organization A and B’s builders repair and reconstruct informally constructing housing in both urban and rural areas. While most of these interviewees were paid formally by the organizations, most reported external construction experience that was not formally paid. Each of the capacity-building approach workshops lasted approximately one hour and was followed by additional time for 45-min interviews. We incentivized attendance by providing meals for attendees and US\$10 gift cards for a hardware store for each interviewee.

After piloting the approach in each stage of *Phase 3*, we subsequently interviewed all attendees using the same interview questions in Spanish or English, depending on interviewee preference. To capture general feedback on the capacity-building approach in these interviews, we asked questions like, “*Can you describe anything you would add to or remove from the materials we used, including the slides and demonstrations?*” We investigated self-efficacy by asking respondents about their perceived ability to mitigate hurricane risk with hurricane straps. For instance, we asked interviewees, “*Can you describe if or how you will change practices after today’s discussion?*” We evaluated the understanding of mitigation measure installation and efficacy by applying Bloom’s revised taxonomy to interrogate the effect of the approach on six cognitive processes: remembering, understanding, applying, analyzing, evaluating, and creating (Armstrong 2010). To do so, our questions ranged from interrogating memory of key facts to questions exploring abstract thinking such as creating new ideas. For example, to capture understanding, we asked respondents questions such as, “*How would you explain how many nails need to be used in a hurricane strap to someone else?*” We also asked interviewees about how they would apply their understanding of the recommendations to new situations, asking questions like, “*If your neighbor only had money to buy four hurricane straps, which would you tell them to buy and where would you tell them to put them?*” Due to the cocreation process, we also asked interviewees about changes they would make to the creation of the capacity-building approach. For instance, we invited respondents to provide ideas for videos or changes to the presentation, sample materials, and model houses. Finally, we recorded, transcribed, and qualitatively analyzed this interview data using deductive and inductive

coding to investigate themes from literature (i.e., self-efficacy) and general themes that emerged across interviews, such as the problem with information complexity.

To evaluate this pilot approach and answer this study's research question, we have organized the results from Phase 3 into three sections. First, we discuss the results of the codesign process and how the capacity-building approach evolved over the piloting process. Then, we discuss observed changes to self-efficacy and knowledge of mitigation measure application and efficacy.

Results from the Collaborative Design Process and How the Approach Evolved

From the first *Phase 3.1* pilot approach, hurricane strap installation emerged as an area that interviewees wanted to focus their attention on. Organization A's project manager explained that they realized during our pilot approach that they had been teaching their trainees to install hurricane straps incorrectly, installing the straps with unspecified screws and without filling all the required holes. We also discovered that Organization A was using hurricane straps that were both weaker and more expensive than those recommended. Thus, we added information to our presentation to compare the difference between the recommended types of hurricane straps and those the organization was using.

Nails, unlike screws, can withstand shear loads and are intended for hurricane strap installation (Garrison 2012; Simpson Strong-Tie, n.d.). Conventional screws are best for pullout forces and will fail under shear stress (Garrison 2012), although proprietary or "specified" screw products can be used for shear loads. Moreover, hurricane straps are designed for a specific number of nails, and without using all the nails, the strap will fail prematurely. However, it was clear that there were practical barriers to installing the hurricane straps with nails rather than screws. We adapted our design based on this interview data to ensure that individuals understood the value of using nails in each hole of the hurricane straps rather than using screws in half of the required holes. We also discussed the force that hurricane straps can withstand if installed with all the specified nails. Then, in *Phase 3.2*, all of the participants asked questions about this part of the discussion, and all of the 15 interviewees were surprised to learn that they should install hurricane straps with nails rather than unspecified screws.

Participants were also interested to learn about the possibility of adding hurricane straps to strengthen connections in an existing roof structure. For instance, one interviewee asked, "Well, let's say someone built the roof without the hurricane straps. You could come in afterward and add them, right?" To respond, we explained the ease of adding recommended straps in already constructed roofs at the roof-to-wall connections. In addition, the interviewees proposed new ways to share the recommendations with others in their communities, such as simplified handbooks on the five hurricane straps commonly used in Puerto Rico and videos showing the difference between using nails and screws. Interviewees also emphasized the need to train builders and residents on appropriate anchoring systems to connect reinforced concrete/masonry walls with wood-frame roofs, a topic that was not covered in our pilot approach.

Finally, in *Phase 3.3*, we triangulated our data sources by piloting the capacity-building approach with Organization B, a locally-based NGO that has repaired and rebuilt housing in response to Hurricanes Irma and Maria. Organization B does not offer training on hurricane straps, yet welcomed the opportunity to codesign the capacity-building approach with their repair and reconstruction quality assurance team. We used interview transcriptions from Organization B to validate the key themes that emerged from

discussions with Organization A. For example, if an interviewee with Organization A mentioned a particular barrier to using hurricane straps, such as the added labor of installing the straps with nails rather than screws, we looked to the themes that emerged in Organization B's interviews to triangulate data sources (Carter et al. 2014).

Participants from Organization B emphasized the complexity of existing guidance on hurricane straps, which aligned with the interview findings in prior pilot stages. Despite repairing and reconstructing housing per engineering designs, these organizations were overwhelmed by the number of hurricane straps detailed in catalogs and the lack of guidance on selecting and installing them correctly. In fact, despite working on formal housing construction projects with Organization B, one contractor discussed how they had been misinstalling hurricane steps with unspecified screws even on supervised job sites. Again, this aligned with the findings from the prior stages.

We changed the approach throughout the pilot process after eliciting interviewee perspectives to address their needs and realistic challenges. For instance, we shifted to capture topics that interviewees indicated they wanted to learn more about. When people asked questions during or after a pilot capacity-building approach, we noted the questions and adapted the approach to cover that topic moving forward. For example, during an initial pilot, a community member asked, "What is the difference between the specified screws and the screws we already use?" In response, we explained the heat treatment process of the specified screws that allow them to act as nails under shear loading (Simpson Strong-Tie, n.d.). Then, we brought in demonstrations of specified and nonspecified screws and added additional information to our presentation that covered the topic for the next design iteration.

Interviewees also expressed positive feedback on the approach design. For instance, in response to questions about the general format of the approach, one interviewee explained that they "liked how we just flowed through a conversation, and you had slides to show more information when we asked questions." Interviewees frequently pointed to different parts of the models and the different types of hurricane straps when asking questions or explaining ideas to each other, facilitating conversation and learning. This helped to facilitate discussion and collaboration because interviewees did not need to know the technical name or details of any components in order to articulate their questions.

Evaluating and Navigating Barriers to Increase Self-Efficacy

After pilot capacity-building approaches, interviewees expressed positive changes to their self-efficacy. For example, all 15 interviewees with Organization A expressed surprise at the recommendations but stated they were invigorated to adopt the guidance when asked whether they would change their practices. Thirteen (87%) interviewees remarked that they would readily adopt changes to their practices with one builder calculating expected costs in his head and making the statement, "it is \$35 to make sure your roof doesn't blow away."

However, interviewees also noted several barriers to self-efficacy that may limit the adoption of the recommendations. Among these challenges, interviewees mentioned labor time (and, thus, cost), actual and perceived material cost, complexity, and information inaccessibility. These conversations revealed important obstacles with the laborious nature of installing hurricane straps with nails rather than screws. Indeed, the only interviewee who did not remark on changes they would personally make was a builder in charge of procuring the materials, who continued to be

skeptical about the increased labor time and costs of installing nails rather than screws. The labor -and associated cost and time- required to install hurricane straps with nails is a barrier to mitigating hurricane risk in hazard-prone regions with weak regulatory enforcement over housing construction. The added labor of using nails rather than screws, especially at the angles often required during construction, reduced interviewee self-efficacy and perceptions of others' self-efficacy. As one training program's project manager said, *"using a hammer is a learned skill, especially at all of the weird angles we always have to work with."* One apprentice also emphasized the added labor time of using nails, saying, *"It will take three days on that roof to install the hurricane straps with nails; it takes one day with screws."* This provides a measure of the increase in labor costs associated with installing hurricane straps with nails rather than screws. Several respondents discussed their concerns about the tradeoffs between increased safety and labor, with some asking how much using half of the required nails reduces the connection strength.

In addition, over half of the interviewees mentioned actual and perceived costs as barriers to adopting the recommendations, stating that perceived cost was generally higher than the actual costs. One interviewee explained their belief that residents' and builders' perceptions about hurricane strap cost are incorrect, saying, *"it is a common myth that hurricane straps are too expensive."* Interviewees mentioned several examples of the need for more training focused on hurricane straps to convey the cost-to-benefit ratio of implementing them and challenge perceptions of their high cost.

From the interviews, it was clear that the complexity of the existing hurricane strap information was a barrier to adoption, particularly for older builders and residents, which aligns with studies showing that the perceived complexity of preparedness measures, such as purchasing flood insurance, can reduce preparedness activities (Seebauer and Babicky 2020). Currently, the most accessible guidance on hurricane straps is the several hundred-page catalogs that hang in the hurricane strap section in most of Puerto Rico's large hardware stores. The complexity of this catalog of hundreds of materials and options overwhelms individuals as they decide between the four or five types of hurricane straps sold in the store. Describing the complexity of the available catalogs, interviewees made statements like *"it's more complicated than it should be"* and *"it's not accessible to people."* Interviewees continuously emphasized the need for a simplified manual to guide safer construction practices in Puerto Rico.

Some interviewees indicated that it might be challenging to promote others' self-efficacy by teaching older builders how to use hurricane straps because they are a relatively new technology that appears complex. For example, one interviewee explained, *"People in the construction trades are very sensitive. They will be like 'Oh you can't come tell me how to do my job! I've been doing this for so long.' ... it's about education, educating them about what it does and how helpful it is. Explain it's going to keep the house together."* Bartolini and Schacher (2017) also discuss the importance of approaching communicating technical construction recommendations sensitively to respect the professionalism of the industry while encouraging safer practices.

Yet, interviewees discussed methods they plan to personally take to increase other builders' self-efficacy and share the recommendations with builders they saw not using them, such as clearly explaining their installation process and their effectiveness when installed correctly. For example, one interviewee explained that they would approach someone they saw using unspecified screws to install hurricane straps and *"start by explaining that a screw versus a nail reacts differently to different stresses. So your nail stress ... it's like a shear strength that you can bend like this*

[demonstrates with nail]. Whereas a screw under shear pressure will more likely crack." In other words, the interviewee would explain the difference between nails and screws in a way that resonated with them during the capacity-building approach to intervene in unsafe construction practices.

Evaluating Understanding of Hurricane Strap Application and Efficacy

In response to the capacity-building approach, interviewees widely indicated their increased knowledge of hurricane strap installation and its mitigation efficacy. Nearly all interviewees (87%) explained they felt invigorated to share the importance of using and correctly installing hurricane straps at critical roof connections to reduce costly, catastrophic failure. Interviewees believed more accessible information on hurricane strap importance, application, and installation would help combat fatalist perspectives about wood housing. As one interviewee said, *"people here in Puerto Rico are used to wood houses that are not sturdy. They are comfortable that way because it's the type of house they grew up in. They are used to their house getting damaged in every hurricane. The information isn't accessible on how to make your house strong."* This interviewee explained that capacity-building must combat fatalism by empowering residents to believe they can have a safe house for the first time.

Applying the principles of Bloom's revised taxonomy (Armstrong 2010), our results reveal interviewees' enhanced knowledge of this mitigation measure efficacy, including an ability to apply their new understanding to complex situations. For instance, when asked how they would explain the ideas or concepts to someone who did not attend the training, they demonstrated their recollection and understanding (the first two levels of Bloom's revised taxonomy). In response to the interview question asking interviewees to demonstrate their ability to apply their understanding to the new situation of seeing a neighbor installing hurricane straps with insufficient nails, one interviewee explained, *"I would say ... these people ... told me something I didn't know so I'm going to tell you. You have to fill all of the holes. All of them. And it works. Your house won't fly away."* When we asked the trainees what they would recommend in the complex scenario of a neighbor only having access to four hurricane straps when building a roof, each of the interviewees applied their knowledge by emphasizing that the hurricane straps should be used to strengthen the recommended connections between rafters or trusses and the top of the wall.

Trainees also explained the main takeaways that surprised them, emphasizing the added efficacy of using nails rather than screws when installing hurricane straps. Many individuals explained how their prior notions were incorrect and that nails serve a different purpose than screws, explaining that *"Nails are not just a thing of the past."* Adhering to the third level of Bloom's taxonomy, interviewees also applied this new knowledge to other situations by asking questions throughout the presentation and showing pictures of projects they had worked on. Next, aligning with the fourth and fifth levels of the revised taxonomy, they analyzed the recommendations by drawing together ideas on why they had initially installed the hurricane straps incorrectly, judging their past behaviors, and then justifying their new stance on the recommendations. During the interview, one apprentice critiqued their prior thought process by asking himself, *"Why would it have four holes if it didn't need all four nails?"*

Importantly, aligning with the highest, creation, level of Bloom's revised taxonomy, interviewees readily produced new and original ideas to share the hurricane strap recommendations

with others. For instance, nearly every interviewee mentioned the importance of Puerto Rico-specific guidance on the five to ten hurricane straps commonly used. Interviewees also mentioned the need to explain the difference in efficacy of straps installed with nails and unspecified screws to a broader audience and developed ideas for videos with the small model houses that could convey relative safety in a hurricane. As an interviewee explained, *"I think videos could show people the difference between installing them, not installing them, and not installing them correctly."* Another interviewee added, *"videos could convince people quickly that they need to change what they're doing . . . Do they want this to happen to their house?"* Researchers agree that methods like these videos proposed by interviewees can demonstrate the relative effectiveness of innovations like recommended mitigation measures compared to the alternatives (Dearing 2009). Overall, based on both direct interviewee statements and through the application of Bloom's revised taxonomy, this evaluation reveals increased knowledge of appropriate hurricane strap use for wood roof mitigation.

Limitations

The capacity-building approach was limited to the application of hurricane straps in wood-frame roofs and did not consider the connection between reinforced concrete/masonry walls and rafters or trusses, which emerged as a concerning topic to interviewees. Future work should focus on capacity-building that focuses on these connections. Future work should also investigate the longer-term changes in construction behaviors of those who participated in such capacity-building programs to investigate whether the increased self-efficacy will result in builders applying their knowledge to future construction projects. Further, there is still a need for additional investigation of methods for encouraging technical recommendations through communication with hazard-prone communities that center their perspectives as active participants in their hazard mitigation. Such capacity-building must recognize that communities have differing expectations of their infrastructure and risk tolerances (Tanner et al. 2020) that may lead them to go against technical recommendations. We recognize this approach, which aims to address technological recommendations by promoting dialogue and centering people's perspectives, is a starting point and that additional research should be done to further blend and evaluate contextualized engineering approaches that involve a deeper understanding of societal contexts and promote dialogue by listening to communities and discussing alternatives before developing solutions (Witmer 2022).

Conclusions

There is a recognized need to effectively communicate technical recommendations to promote safer informal housing construction amid rising disaster risks (Clinton 2006). Yet, in our review of literature on construction training, hazard preparedness, capacity-building, and applied communication, as well as examples of information dissemination strategies aimed at promoting safer housing construction, we found that there was a lack of evidence on approaches that center people's perspectives and promote dialogue to build technical construction capacity. To address this identified gap in knowledge, this study investigates the role of promoting dialogue to learn from and center community perspectives in designing capacity-building approaches addressing misalignments between builders' perspectives and engineering recommendations to center on the needs and concerns builders face when making their housing design and construction decisions.

This capacity-building approach focuses on one concern for builders and other stakeholders across Puerto Rico: the appropriate use of hurricane straps in wood-frame roof construction. We collaboratively and iteratively designed a technical capacity-building approach to appeal to people's concerns and needs by addressing emergent concerns with updated approach designs. While the initial capacity-building approach's design focused on the importance of installing hurricane straps at several critical roof connections, the iteration process of our design revealed a new needed area of focus: preventing hurricane strap mis-installation. When asked about changes to the topics covered and the design of the presentation and models, interviewees provided feedback on ways to add materials such as simplified videos showing the difference between the safety of housing built with and without correctly installed hurricane straps.

In this study, we also identified measures of self-efficacy and knowledge of mitigation measure efficacy as constructs with which to evaluate technical construction capacity-building approaches, through reference to the literature. To build self-efficacy and knowledge of mitigation measure efficacy, the approach simplified the perceived complexity of hurricane straps and explained the relative cost of each recommended material, lowering the barrier related to perceived cost. The approach also discussed the relative safety of housing and methods of avoiding catastrophic housing failure to ensure individuals understood the efficacy in terms of disaster risk reduction of appropriately installed hurricane straps. We applied Bloom's revised taxonomy to evaluate knowledge of mitigation measure efficacy, revealing increased knowledge of appropriate hurricane strap use for hurricane mitigation of wood roofs. Several interviewees demonstrated their knowledge of hurricane strap use by discussing new ideas for sharing the recommendations with others, including creating videos showing the difference between hurricane straps installed with nails and screws. Throughout interviews, organization staff and community members discussed methods of countering this fatalism and information inaccessibility to build technical construction capacity related to hurricane straps. Overall, interviewees expressed increased self-efficacy and knowledge of mitigation measure efficacy, indicating they were likely to put the recommendations into practice and share them with others.

Practically, this study directly addressed the need to train 20 organization staff on housing repair and reconstruction. All interviewees emphasized the value of the technical recommendations and their excitement to share the information on the importance and correct installation of hurricane straps to increase hurricane resistance of wood housing. Organization A has now incorporated the training materials, including the presentation slides and demonstration materials, into its current training class of 25 apprentices.

Taken together, we found that the approach outlined in the paper, including collaborating and iteratively designing and piloting the approach was helpful to increase self-efficacy, knowledge, and willingness to install hurricane-safe roof construction. Additional work is needed to assess the long-term implementation of this knowledge and to apply it to other contexts, such as flood-prone areas.

Data Availability Statement

Some or all data used during this study are proprietary and confidential in nature and may only be provided with restrictions (e.g., anonymized data). This includes interview data at a level of detail in which individuals and their responses to any interview questions can be identified. Redacted, coded data from interviews are available from the corresponding author upon request.

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Supplemental Materials

There are supplemental materials associated with this paper online in the ASCE Library (www.ascelibrary.org).

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