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Virtually Engineering Community Engagement: Training for Undergraduate Engineers During the COVID-19 Pandemic

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Flood mitigation and adaptation measures, among other tools to improve resiliency, will be necessary to sustain coastal communities in the face of climate change. Key to successful adaptation will be engineering projects, and critical to the success of those projects will be community engagement and support. Despite the recognized importance of community engagement when addressing complex issues like coastal flooding on which engineers work, most undergraduate engineering programs offer little to no training in community engagement. In this paper, we describe our experiences working with undergraduate engineering students to develop community-driven designs to address flooding and water quality issues in the Lake Mattamuskeet watershed in eastern North Carolina. Through an interdisciplinary approach, student teams learned to engage with local stakeholders to better integrate local knowledge and address issues identified by community members in their designs. Because of the COVID-19 pandemic, all community engagement aspects of the project moved to virtual forums, and we discuss the impact this shift had on the engineering designs as well as student learning outcomes and community connections.

Key words: community engagement, engineering education, COVID-19, coastal adaptation

> *It just kind of reassured me that I chose the right career path. Because I saw the impact that engineering can have on a community. Like we could solve this big problem that's been hurting their community, hurting their crop life, has had this negative impact on them. ... And so being a part of that change, I think, has just made me even more passionate about engineering.*
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> — Capstone engineering student, 2021

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Introduction

Climate change factors, including sea level rise, increasing storm activity and severity, storm surge, and shoreline erosion are increasing the vulnerability of the world's coastlines to flooding. With their intensive human development, vulnerable coastal areas mean that coastal communities are at risk of dangerous flooding conditions and concomitant economic, human health, and environmental effects with greater frequency; the so-called once in a lifetime floods are arriving at much shorter time intervals (Bhattachan et al. 2018; Neumann et al. 2015). Flooding mitigation and adaptation measures, among other tools to improve coastal resiliency in the face of climate change, will be necessary to maintain coastal communities in their current locations.

Engineering projects, from the development of storm surge barriers to wetland creation, can help communities adapt to flooding. Anthropologists and other social scientists have long advocated for the need to include local stakeholders and community members in resource management, adaptation planning, and other environmental decision making processes (Brosius, Tsing, and Zerner 1998; Furman, Bartels, and Bolson 2018; Phillipson et al. 2012; Reed 2008; West and Brockington 2006). Such research shows that collaborative approaches, including efforts using community engagement to gather consensus before decisions are made, may help to avoid conflict, improve implementation, arrive at higher quality decisions, and build trust in the community. Overall, the field of engineering has been relatively slow to fully incorporate community engagement into design and practice, and while our review of the literature for the current article reveals an increase in scholarly papers in peer-reviewed engineering journals (e.g., *Journal of Engineering Education, Journal of Professional Issues in Engineering Education and Practice, European Journal of Engineering Education*) over the past ten years on this topic, conceptual connections between the applied anthropology and engineering disciplines continue to represent a substantial gap in the literature. In typical engineered infrastructure projects, communities have little input in the engineering design process. Community involvement in the project is often limited to public meetings that take place after a preliminary design has been created, and only minor design changes can be made (Creighton 2005; Ng, Hongyang Li, and Wong 2012). Such limited involvement means that projects are often designed with very little knowledge of the local social context and with limited understanding of the community members who will be affected by the project once implemented. This may lead to low support or even opposition to the project, or it may result in projects that are ineffective or unsustainable. The lack of understanding of community context is a major barrier to the development of engineering projects that remain effective and useful in the long term (Harsh et al. 2017; Lewis 2014). In contrast, community-driven design has the potential to bring local knowledge and opinions into the engineering design process, which can lead to both more locally appropriate design and greater support for the project (Giddings et al. 2010; Gilbert et al. 2015).

As noted above, the value of community engagement and understanding the social components of the complex issues like coastal flooding on which engineers work is being increasingly recognized, though slowly, by researchers working in the field of engineering education (Ellzey at al. 2019; Gilbert 2015). Various educational models—relatively new to engineering education but not new to education, anthropology, or social work scholars— have been proposed for how to incorporate such aspects into engineering programs, including service learning, project-based service learning, and civic engagement (Niles et al. 2018; Swan, Paterson, and Bielefeldt 2014). For our purposes, we use community engagement as an overarching term that captures these various models in engineering education. Although a full examination of the breadth of definitions of community engagement is beyond the scope of this article, here we use a definition supported by most researchers, regardless of discipline: "community engagement is a community-centered orientation based in dialogue and…its core value lies in sustaining benefits for the community" (Natarajarathinam, Qiu, and Lu 2021:1050; Taylor and Kent 2014).

Research shows that including community engagement or service learning activities across disciplines may benefit students, institutions, and communities. As summarized in Natarajarathinam, Qiu, and Lu (2021), students in courses with these kinds of activities report greater satisfaction with their courses, demonstrate higher academic performance and critical thinking skills, and show an increased ability to apply what they've learned to real-world situations (Bielefeldt and Lima 2019; Peters 2011). Community engagement also contributes to students' civic engagement and increases professional skills, such as leadership, teamwork, and cultural competence (Celio, Durlak, and Dymnicki 2011; Keshwani and Adams 2017). Research also suggests that community engagement increases the diversity of students interested in becoming engineers by increasing the recruitment of women and minority students into engineering majors and increasing student retention (Bielefeldt and Lima 2019; Swan, Paterson, and Bielefeldt 2014). Less research has focused on the benefits of community engagement for the communities involved. While, at the very least, the communities involved should benefit from the projects' deliverables, other potential benefits for the community include an increased understanding of science, engineering, and technology (Gouws, Kritzinger, and Padayachee 2011; Natarajarathinam, Qiu, and Lu 2021). Despite recurrent calls for more research geared toward better understanding community partners' experiences and perceptions of community-engaged projects (Giles and Eyler 1998; Petri 2015), this remains an understudied field.

The Accreditation Board for Engineering and Technology (ABET) Engineering Accreditation Commission (EAC), the body that accredits college and university engineering programs in the United States, recognizes the importance of training in the skills needed to effectively conduct a community-driven engineering design process. Among other outcomes, ABET (2021:para. 20) EAC requires that engineering graduates demonstrate abilities to "apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors" (Outcome 2); and "communicate effectively with a range of audiences" (Outcome 3). ABET (2021) accredited programs are also required to have a major design experience (i.e., capstone or senior design) for students at the end of the curriculum. These design experiences are an ideal opportunity for engineering students to gain skills related to community engagement, in addition to technical and professional skills (Litchfield, Javernick-Will, and Maul 2016; Mostafavi et al. 2016). They also represent a large pool of available expertise that can advance designs and solutions for resiliency challenges alongside communities that could not otherwise fund professional engineering consultancies.

Our interdisciplinary research team (made up of two social scientists, two engineers, and an interdisciplinary Ph.D. student) came together to implement a community-driven engineering design experience for three teams of students enrolled in the university's senior engineering capstone course. These student teams were assembled by the engineering faculty on our team and the instructor for the capstone course. A top environmental engineering student was selected for each team, and then three more students, each with complementary and relevant expertise, were selected for each team. These teams represented three of the only four environmental engineering teams in the capstone course that year.

Compared to contemporaneous capstone sections, for the first time at our university, these capstone projects explicitly included community engagement: the community would be involved and invested with the students from the beginning of the project and remain engaged throughout. Other capstone projects do tend to feature student interaction with two to three stakeholders, but broader engagement with the public or a community requires an amount of effort that most faculty do not have the time in which to devote. While not an initiative of the engineering department itself (though the department administration was supportive of the project for its potential to support the mission of student success while serving eastern North Carolina and developing resilience capacity in the region), the engineering faculty members on the team were inspired by their own ongoing work with the focal community to partner with the social scientists also working in the region for this effort. Combining expertise from ecological engineering, operations research, anthropology, and social ecology, our team would provide training and experience in community engagement processes and methods in addition to technical training as part of the required yearlong capstone course in the Fall 2020 and Spring 2021 semesters. Our goal was to link the knowledge embedded in a marginalized coastal community with the engineering expertise of undergraduate engineering students to design solutions that build coastal resiliency and bolster participation in adaptation planning. In support of this goal, we aimed to (1) develop a framework for engaging community members and undergraduate engineering students and facilitating a community-based engineering design process for projects to address issues caused by changing climate patterns and sea level rise; (2) document local community members' perceptions of the contributions of the framework to local resiliency; and (3) examine engineering students' expectations, perceptions, and experiences of the community-based design projects.

Building on existing relationships in the region, we began engaging with the targeted community in the Lake Mattamuskeet watershed of coastal North Carolina during the Spring 2020 semester to identify potential projects on which the students could work. However, the COVID-19 pandemic also began to emerge that semester and ultimately rendered our plans for in-depth, ongoing community engagement impossible. In this paper, we describe the engagement methodologies of the project as originally conceived and then discuss how these had to be modified (objectives 1 and 3) or jettisoned (objective 2) due to the pandemic. We present results from the analysis of semi-structured interviews conducted with the students at the completion of the project, relating these findings to the proposed outcomes of the project. Finally, we conclude with a discussion of the continuing need to educate engineering students about the importance of community engagement, train them in appropriate methodological approaches, and emphasize community perspectives in community-engaged engineering projects.

Background: The Need for Adaptation in the Lake Mattamuskeet Watershed

The Lake Mattamuskeet watershed is located in eastern North Carolina on the Albemarle-Pamlico Peninsula. The largest naturally formed, freshwater lake in the state, Lake Mattamuskeet, is no longer considered "natural" because it and the surrounding watershed have been extensively modified over the last two centuries (Forrest 1999). Like much of eastern North Carolina, the watershed sits at low elevation and has been ditched, drained, and otherwise hydrologically modified to promote land uses such as logging and farming. Water level in the lake today is controlled by gravity-fed discharge from the lake through tide gates on four canals dug in the 1800s and early 1900s that connect the lake to Pamlico Sound. Higher water level on the lake side of a gate exerts greater head pressure, opening the gate and allowing water to flow out. Extremely low vertical relief combined with rising sea/sound levels often prevents the gates from opening, contributing to flooding issues throughout the watershed. Present-day inflow to the lake has been affected by changes in land use practices, including the addition of new canals and pumps to drain farmland and an increase in private waterfowl impoundments for hunting, which can add water and associated nutrients to the lake when drained.

The lake's health and resources are critical to the economy, livelihoods, and way of life in surrounding Hyde County. Without even one stoplight, Hyde County is a rural county with an economy centered largely on resource extraction and production, including agriculture, commercial fishing, and logging. The county is among those in North Carolina with relatively high poverty rates (24%) (North Carolina Broadband Adoption Index 2019). Approximately 37 percent of households in Hyde County do not have internet access, compared to 16 percent statewide, one of the lowest access rates in the state (North Carolina Broadband Adoption Index 2019). Farming, guide services, fishing, and various recreational activities connect residents economically and socially to the lake. As part of the Mattamuskeet National Wildlife Refuge, the lake is an important stop for migratory waterfowl along the Atlantic Flyway. In recent years, however, residents and property owners have expressed concern about water levels in the lake and watershed. Due to high water levels and reduced water quality, submerged aquatic vegetation rooted at the lake bottom has disappeared, while nutrient and cyanobacteria levels have climbed, contributing to the lake's inclusion on the North Carolina 303(d) list for impaired waters (Moorman et al. 2017). The trends in water level and quality led to the creation of a partnership in 2017 among the Hyde County government, the United States Fish and Wildlife Service, and the North Carolina Wildlife Resources Commission to develop a Watershed Restoration Plan.

The restoration planning process brought together representatives of the partner organizations along with a broad group of core stakeholders identified by the County and the Hyde Soil and Water Conservation District (referred to here as the core stakeholder group). Individual core stakeholders represented interests in the watershed related to farming, waterfowl impoundments, the hospitality industry, and the residential community, in addition to the federal, state, and local agencies. The authors were also involved in the planning process. A nonprofit organization, The North Carolina Coastal Federation, facilitated the community-driven process to develop the plan. Goals and actions identified in the plan seek to protect local livelihoods, actively manage water levels, and restore water quality and clarity. Completed in 2018, the plan identifies multiple alternative solutions to the issues plaguing the watershed (NCCF 2018).

The efforts described here stemmed from the authors' involvement in the Watershed Restoration Plan. Our goal was to connect the local knowledge and perspectives of Lake Mattamuskeet watershed community members and stakeholders with the engineering expertise of East Carolina University (ECU) undergraduate students (advised by faculty). In doing so, we hoped to design solutions that build resiliency and increase the participation of marginalized communities in adaptation planning. The objectives were to: (1) develop a framework through which the interdisciplinary research team engages community members and undergraduate engineering students to facilitate a community-based engineering design process focused on generating solutions to issues caused by changing climate patterns and sea level rise (e.g., persistent flooding, poor water quality); (2) document local community members' perceptions of the contributions of the framework to local resiliency; and (3) examine engineering students' expectations, perceptions, and experiences of taking part in community-based design projects. A central priority was maintaining opportunities for community members' continued engagement with the engineering students throughout the design process. In addition to public meetings, our proposed methods included one-on-one semi-structured interviews and focus groups at all stages of the project to help identify the critical problems, determine how to balance community needs, and build support for the project. All research activities with community members and students were approved by the University and Medical Center Institutional Review Board at ECU.

Modifications for a COVID-19 Pandemic Reality

We received funding for the project in January 2020 and were beginning initial steps to recruit interviewees from the Lake Mattamuskeet watershed community when COVID-19 began to emerge globally and was declared a pandemic. Although we planned to conduct semi-structured interviews with stakeholders during the Spring and Summer of 2020, the day-to-day uncertainty and rapidly changing public health regulations in the state and county left us unsure which aspects of our proposed data collection methods we could implement. As containment efforts to prevent the spread of the virus eroded during the first weeks of the fall semester, the university moved to a primarily virtual learning format. Although we were no longer meeting with the capstone course students in person on a weekly basis, they still needed to complete their designs. In addition, this work aligned with funding received by the restoration plan partner agencies to continue planning activities, and the core stakeholders wanted the students' work to proceed. Therefore, we moved forward with our proposed work, modifying our approach and methods as best we could to still achieve our proposed objectives. Table 1 (following page) summarizes our proposed objectives and engagement methods, the actual engagement methods we employed (changed due to the pandemic), and the impacts those changes had on the project objectives and outcomes. In this section, we describe the changes and impacts in detail.

The first objective was to develop a framework through which our research team engages community members and undergraduate engineering students to facilitate a community-based engineering design process focused on generating solutions to issues caused by changing climate patterns, sea level rise, and human activities in the watershed (e.g., persistent flooding, poor water quality). Prior to the start of the academic year in August 2020, we intended to develop a list of potential engineering design projects for the students by asking members of the core stakeholder group, as well as members of the broader watershed community, about their concerns related to flooding and water quality. One of our primary goals was to broaden the perspectives of those involved in the watershed restoration activities by including a diverse group of participants in the initial interviews and focus groups, allowing us to consider the concerns and project ideas from individuals beyond the core stakeholder group. Once the student design project ideas were selected and the academic year began, we planned to hold frequent in-person meetings with the core stakeholder group and the public throughout the year-long design process to maintain transparency and to continually solicit feedback. In addition, we intended to hold small focus group discussions during the public meetings in which a few meeting attendees would be grouped together with one of the student design teams (four students) to facilitate open dialogue about the designs in a more informal setting. These focus group discussions would also increase the students' understanding of community members' goals and values, as well as the methods used to collect those data.

Due to the pandemic, we had to modify our methodology so that all tasks could be completed virtually. As a result, we could not collect project ideas from as broad a range of individuals as we hoped, and the projects that were implemented largely reflected those of the core stakeholder group. While we were able to conduct eight interviews via phone and zoom, these were with individuals we already knew, from whom we already had a certain level of buy-in, and who had access to the internet and other technology needed to do so. However, options were limited for trying to find additional interviewees during COVID. Because the students needed to begin working on the projects in August 2020, these interviews

Table 1. A Comparison of Proposed and Actual Engagement Methods, and Impacts of the Changes on Project Outcomes by Objective

Project Objective	Proposed Engagement Methodology	Actual Engagement Methodology	Impacts from Changes
Develop a framework for community-engaged engineering design process	Identification of design projects: In-person meetings with core stakeholders via watershed restoration planning team meetings In-person focus groups and one-on-one interviews with additional community members In-person public meeting	Identification of design projects: Virtual meetings with watershed restoration planning team, n=2 Phone and zoom one-on-one interview with core stakeholder group members and additional community members, n=8	Ideas for student projects largely reflected those of core stakeholder group and individuals with sufficient broadband internet connectivity or telephone service, and not the broader community and/or marginalized groups. This may have reduced the contextual detail and community values in design criteria as well as the robustness of the same.
	During the design process: In-person public meetings Large group and small focus group discussions Written feedback forms In-person meetings with students and core stakeholder group	During the design process: Virtual public meetings, n=2 Short Q&A sessions Virtual meetings with the watershed restoration planning team, n=4 Virtual small focus group meetings with key stakeholders and students, n=1 per project team, total n=3	Without opportunities to meet residents in person, speak with them informally, learn firsthand about residents' connections to the lake and their concerns, or otherwise participate in face-to-face public engagement and direct interaction with the individuals who would be impacted by their engineering designs, the students did not receive as much experience and training in community engagement as planned. Students likely learned less about community goals and values and had reduced opportunities to share project updates and receive community feedback. This also reduced the extent of community assessment and awareness of the student conceptual designs.
Document community members' perceptions of local resiliency and utility of the framework	Pre-intervention: In person focus groups and one-on-one interviews (as above) Quantitative survey at early in-person public meeting Post-intervention: Debrief in-person interviews with Focus group and one-on-one interview participants Quantitative survey at final in-person public meeting	Could not be conducted.	Could not conduct this part of the project, so could not collect and analyze community members' perceptions of resilience or learn about contributions of the framework to local resiliency.
Assess how community interactions throughout the design process affects engineering student outcomes	During the design process: Written reflections Debrief group discussions after community interactions	During the design process: Baseline written reflection, n=1/student Virtual group debrief after community interactions, n=4 Virtual debrief after small focus Group meeting with key stakeholders, n=1/student team	Student assessment related to community engagement was reduced. Debrief sessions offered good opportunities to reinforce engagement interactions and outcomes.
	After design completion: Final written reflection	After design completion: Virtual one-on-one interview, n=1/student	Qualitative analysis of interview data showed that nearly all students found the engagement training and experience useful. Rigorous statistical analysis was not attempted.

had to occur in Summer 2020, during which public health guidelines required us to remain isolated. We were unable to travel to churches, businesses, government facilities, and other public spaces in the Lake Mattamuskeet watershed area (about 100 miles from ECU's main campus, where students live) to recruit participants or establish relationships as we planned to do for the initial ethnographic and community engagement aspects of the project. COVID restrictions also meant that we could not hold an in-person public meeting during Summer 2020. The meeting could have provided an opportunity for anyone interested to attend and to learn more about the overall effort and collaboration between the engineering students and the core stakeholder group, particularly those who might have been wary of agreeing to participate in an interview. Despite these modifications, we were able to identify projects appropriate for the student teams. However, these largely reflected the concerns and goals of the core stakeholder group, not necessarily those of the broader group of Lake Mattamuskeet watershed residents, as we had hoped. While detailed descriptions are beyond the scope of this paper, two of the projects focused on redirecting water flow away from the lake to sites around the watershed where it could be treated in constructed wetlands before entering the intercoastal waterway or sound. The third project centered on restoring the four canals that act as drainage conduits from the lake to the sound. The canals have experienced substantial sedimentation and reduction in cross sectional area, essentially filling in and reducing drainage flow.

Due to continued COVID-19 restrictions, the public meetings held throughout the academic year (Fall 2020 to Spring 2021) also had to be virtual. As a result, the students did not receive experience and training in several highly important aspects of community engagement as planned. They did not have the chance to meet residents in person, speak with them informally, hear their concerns and learn about their connections to Lake Mattamuskeet and the region surrounding it, and interact directly with the individuals who would be impacted by their engineering designs. Instead, two public meetings were held virtually. Although the virtual format meant that individuals from anywhere could attend the meetings, and there were between forty and fifty attendees at each meeting, this format did not allow for the same in-depth and meaningful discussion between the students and meeting attendees as was likely to occur in person. This was further complicated because the students' presentations were sharing time on the agendas for the public meetings with other items and projects related to restoring the watershed. The virtual format also restricted meeting attendees from asking questions or making comments in response to the students' presentations, limiting the feedback students received and not giving them the opportunity to gain as much experience in responding "on the fly" to questions about their designs from members of the public, most of whom likely did not possess an engineering background.

The focus group discussions we planned to hold during the public meetings also were modified to occur virtually. While we hoped the focus group participants would be watershed residents with in-depth knowledge of the local environment and flooding and water quality issues, we had difficulty recruiting such participants without being able to conduct in-depth ethnography and establish relationships at the start of the project due to COVID-19 restrictions. We did, however, have individuals from other parts of the state contact us expressing interest in participating. Because we felt it was very important to give the students an opportunity to engage with members of the public in a small group setting, we decided to hold the focus groups and include all those who were interested in participating. As a result, the participants were from a variety of locations (e.g., the local watershed, larger cities in the central and western parts of the state) with different levels of familiarity with and connection to the watershed. This had a mixed impact—some brought a broader perspective to the discussion, which may have been beneficial, but it also meant that the discussion was not focused on local, firsthand perspectives, concerns, and advice from those who could be directly affected by the designs.

The second objective was to document local community members' perceptions of the contributions of the community engagement framework to local resiliency. We planned to collect these data via the same in-person interviews and focus groups described previously as related to the first objective. In addition, we planned to administer a brief survey at the first public meeting to collect data regarding perceptions of resilience from those attendees who did not participate in interviews or focus groups. At the end of the project, we planned to collect similar data via interviews, focus groups, and a survey, which would allow us to analyze whether and how the community-based design process influenced perceptions of resilience and the benefits and disadvantages of the framework. Because we had to switch to virtual or telephone interviews, focus groups, and public meetings, after careful consideration, we decided we could not collect high-quality, meaningful data to address this objective. We hope to assess the utility of this approach in a future study.

Objective three was to assess how community interactions throughout the design process affected engineering student outcomes, including their perceptions and experiences participating in community-based design projects. We planned to meet with the students in person each week, conducting a variety of short activities and written assignments related to community engagement. These weekly meetings would have allowed for open discussions for debriefing after any interactions the students had with community members. After one in-person meeting at the start of the fall semester, these weekly meetings moved to a virtual format, and we struggled to connect with the students because many stayed muted with their cameras off, offering only limited responses to questions or discussion prompts. This led to us presenting information and instruction about community engagement in a fairly unidirectional way, without being able to gauge student reactions to the material as it was being presented.

The exceptions to this were the debriefings we held with each student team directly after their focus group with community members. There was much more extensive participation and higher energy during these sessions, likely due to the fact that the entire preceding discussion was devoted to their particular design, so they felt there was more to talk about. In addition, because of the small number of participants in the focus groups (two to five community members plus the four-member student team), the conversations felt more personal, and the exchanges were more direct, leaving the students feeling energized by the interactions. This was reflected in how the students appraised the value of focus groups compared to the larger community meetings in subsequent one-on-one interviews (described below).

Due to the already high demands of the technical design aspects of the capstone course, we did not want to add multiple community engagement assignments, such as reflection papers, to the students' workload in order to measure student learning regarding community engagement. It was clear that during the pandemic, few of us, students and instructors alike, had the capacity to add as much to our workload as we might have during typical semesters. Knowing that stress and anxiety levels among university students were reaching very high levels, we were concerned for our students' mental health, as well as our own, and we believed it was more critical than ever to not overburden the students. While these advanced engineering students should be challenged to do high-level, high-quality work, as educators, we had to think about their development as people, not just as engineers, and we recognized that limits on demands and expectations were not only appropriate but vital. We limited our assessment to a one-on-one interview with each student to gain an understanding of their perspectives on the community engagement aspects of the capstone course. We present the findings from the analysis of these interview data next.

Student Perspectives on Community Engagement

The transition to virtual meetings reduced both the community engagement training the students received and the amount of actual community engagement they experienced. Therefore, when it came to assessing what the students learned and experienced regarding community engagement, there was less to assess. One key piece of assessment and evaluation that we did conduct was a one-on-one interview with eleven of the twelve students at the end of the academic year. (We were unable to connect with one of the students during this time.) These short (less than thirty minutes) interviews allowed us to gather individual perspectives on the community engagement and feedback elements of the design process. During the interviews, we asked students to reflect on what the community meetings and focus groups were like for them, what they gained from and valued about incorporating community engagement into the engineering design process, and what they learned about people's connections to the lake. We recorded and transcribed these virtual interviews and then analyzed the transcripts for themes. While students were informed that we would only share information from the interviews with their engineering professors, our colleagues on this project, without attribution to particular students and only after final grades were submitted to encourage honest responses, we recognize that our role as instructors may have led to a positive bias in responses.

During the interviews, nearly all the students indicated they found the community engagement training and experience useful and valuable, both for the engineering design process and their future careers as engineers. One of the core benefits of community engagement that the students recognized was the capacity to arrive at higher quality decisions, more creative solutions, and solutions better suited to specific circumstances of a given locale. Students talked about how gathering local expertise and ideas during community meetings and focus groups led to additional considerations they would otherwise not have incorporated into their designs:

> I remember that there were some interesting points that were made and some perspectives that we hadn't considered before…something that, apart from that meeting, we never would have considered….I think it was good for whenever we got a little bit like laser focused in on what our project objective was…it kind of helped to bring it to a broader perspective and to how maybe we could integrate other goals that the community had while we're doing our specific design.

Like many of her classmates, this student believed that her team's engineering design benefited from engaging with community members. Her team's design process improved when they learned about local perspectives and could include those needs and goals in the final design. For example, one team learned that community members hoped created wetlands could be designed with specific slope, water level, and other parameters to support habitat for specific bird species.

The students recognized that knowledge about the lake and how the watershed behaves revealed by community members was critical information they would not otherwise have had access to without direct engagement. While the students noticed wide variation in technical expertise among community members, which is typical and expected, they remarked on how, through these experiences, they realized the need to give community members more credit for their knowledge and the value this added to their designs. This included questions the community members asked the teams, such as the potential for flooding on neighboring properties due to the design of constructed wetlands.

Students felt that additional opportunities for discussion with small groups of community members, specifically earlier in the design process, would have further improved the quality of their designs. Focus groups can be challenging to convene in the best of times. As described above, since we were forced to interact at a virtual distance from both the students and the rural community at the center of the designs, the process of convening focus groups during the pandemic was even more difficult.

Another key value of community engagement, according to the students, was a deeper understanding of the larger context for their work:

> Even though people had different interests in the lake, whether it was fishing or hunting or there was their farmland or they just like to go there to visit with their families, at the end of the day, that all stems from the welfare of the lake. So that's something that's absolutely paramount and, you know, no matter what we propose to be constructed and whatever design solution we have, at the end of the day, this does matter to a lot of people, and it does serve a really huge ecological purpose. So yeah, I would say that that's what was really emphasized to me…after the whole year, honestly.

For this student and several others, community engagement increased their awareness of the larger setting of the lake watershed, to understand the broader role their designs could play if implemented. Moving beyond a classroom design exercise to one that intersected with the real lives of real people helped the students make connections between their work and the broader lake ecology.

Beyond the ecology of the region, directly engaging with community members underscored for the students that the health of the lake and watershed was personal to the community:

> It's serious for them. It really is. From an outside perspective, it's just about controlling water, …but to some of them, it's their livelihood. Their lives depend on that lake. And the whole community revolves around it, fishing, camping, tourists. So it's really personal for them. It was just a lot of the people that we talked to talked about restoring it to how they remember it as children, how it was twenty, thirty years ago. The water was clear and fish everywhere. … It's their home pretty much, and we were hired to help fix that.

The students could discern the deep connections community members felt for the lake in what they chose to share during the focus group meetings. Given its sheer size, we could expect that the lake plays an important role in the life of the community and in individual residents' lives. But hearing about those connections from community members themselves, in their own words, was impactful for the students and their designs. One student remarked how she did not expect to hear how important the lake is to daily life in the watershed. In fact, some students commented on how understanding those connections spurred them to do their best work:

> I guess it, for us, it showed us how much these people care about the conditions of the canals. And I guess made us a little more passionate about our project and that these are real, real lives this is affecting. …Capstone is usually you build something, and you design a tangible product. And ours is just a proposal. Like, this is kind of not really cool. …But hearing how many people this would impact if they actually do go through with it, I think it was really cool. And just hearing people on board with our plan and just further iterating to us that there's a need for this, I think it gave us a little more drive to actually do this project. It made it a little more important to us. So I thought the focus groups were really beneficial.

By centering community perspectives, the focus groups affected student outcomes by shifting how they saw their own work. Their behavior was influenced by engaging with the community. Community engagement led the students to see their own work through another lens, a community lens, that helped them to see its importance and potential in a new and deeper way.

In addition to shifting perspectives on the design projects, nearly all the students felt the community engagement experience helped them develop key skills they otherwise would not have and that they will draw on in their future careers as engineers. In particular, a majority of the students described increased confidence in their public speaking skills:

> I feel like I got a lot more comfortable talking to an audience in general because we haven't really done much of that in our classes. It's mostly just presenting to an audience of our peers. But this is a lot more interesting because we got a chance to present to a bunch of people that we don't really know. And we had to know what we were talking about, which was something in and of itself, which was kind of something we had to learn.

Students presented their draft designs at virtual community meetings and focus groups multiple times during the yearlong course. In advance of each community meeting, they practiced their presentations with the faculty. These repeated experiences helped the students learn how to communicate technical information to varied audiences, and their confidence in doing so grew noticeably. Many commented in the interviews about the value of this real-world experience they were getting as compared to their peers working on other capstone projects.

Beyond describing greater comfort with their communication skills in general, the students also reported that the community engagement experiences improved their ability to take and address feedback and critique in real time:

> But I think when I am working, I know that this entire experience, especially the community engagement aspect of it, I can really use that to promote as a skill. Some people, I feel like if they were to present their solution in front of people and if they were to really react negatively to your solution, that you worked hard on, some people could, I don't know, fall apart from that. Some people would not do well in that situation. So the ability to say that you have experience with that, presenting your solution to the public and then they can react however they want to, I think that is very valuable. And that's something that I'll be able to kind of market when I'm looking for a job.

As educators, we know students can be sensitive to receiving critique in public fora. Yet, as working professionals, that is something they will likely experience. Replicating those situations during training provided opportunities to introduce students to the sting of this kind of criticism and help them develop the composure to find the actionable items within the feedback.

Students also noted that community engagement during the pandemic taught them how interacting online differs from interacting with people in person. While also vitally important to in-person focus groups and other community interactions, the virtual nature of the focus groups underscored the importance of certain behaviors, specifically letting pauses in discussions play out and waiting to speak until stakeholders had finished their thoughts on a topic. Still, the students voiced a desire to have conducted the community engagement in person:

> The only thing I wish we got to do, and this is out of everyone's control because of COVID, I wish we got to meet all in person. It would have been, I think, more intimate if I got to see these people face-to-face, and have discussion with them and build that connection. I think that would have been really cool. But I understand with COVID, that's not a possibility right now.

Students like this one recognized that part of the power of community engagement comes from our ability to connect with other people. This tends to be stronger in person than through screens.

One student commented on how the technology used in virtual meetings can create barriers for some to interact fully:

> I do think we probably could have gotten just better conversation if we did it in person because a lot of people also don't want to type out a whole question or sometimes things don't make sense when you ask it via chat.

Relying on the chat functionality of a virtual meeting platform can introduce an added layer of awkwardness, particularly around technical questions and exchanges. Meeting participants who do not use these platforms frequently may also have trouble navigating the interfaces to find chat boxes and end up getting shut out of discussions that occur via chat. At the same time, meeting participants who use virtual platforms often may fall back on behaviors adopted for other settings that are less appropriate for community meetings. One student explained how this was something she noticed among her peers:

> I think the only thing that really I noticed from a lot of my peers overall was that fear factor in a lot of meetings, but I don't even want to say that that was a fear factor. I think that was also just a subliminal thing that we did after an entire semester of online classes, where our cameras and mics were always supposed to be off. It's just something that we got comfortable doing in meetings, even if it wasn't the right thing to do in community engagement meetings. Because in our classes, if we have our mics and cameras off, it's considered respectful because you're not disrespecting or you're not interrupting the professor if you're obviously looking off to the side doing something else. But in a community engagement meeting, it can make you look very absent and like you aren't paying attention.

After we instructed the students to have their cameras on for the focus groups and those portions of the core stakeholder group and public meetings related to their designs, students like this one demonstrated a clear understanding of why doing so matters. The visuals afforded by our computer cameras, however limited compared to in-person interactions, offer vital connections and demonstrate our engagement with others. Despite the limitations of virtual engagement, a few students noted a preference for participating in virtual meetings because it felt less like public speaking to them and thereby felt less stressful.

Although our efforts to incorporate community engagement opportunities and training into an undergraduate engineering capstone course were more limited than we had planned due to the COVID-19 pandemic, students reported several beneficial outcomes. Analysis across all transcripts of one-on-one interviews with the students revealed: (1) recognition of the power of local knowledge to improve solutions, (2) greater awareness of the broader ecological context of their work, (3) deeper understanding of local meanings about the lake, (4) improved communication skills, (5) experience receiving and acting on public critique, and (6) enhanced utility of virtual engagement methods. In terms of the designs themselves, given the limited experience of the students and the time constraint of needing to complete designs within one academic year, our research team decided a reasonable set of goals for the students was to complete a conceptual design, perform preliminary analysis using analytical models, and communicate those findings. There are still many details to work through before their designs can be implemented, including permitting processes, and local decision makers will be the ones to decide whether or not to seek funding to implement any of the designs. Still, the students' efforts have advanced the engineering design process for addressing flooding in the Lake Mattamuskeet watershed, and participating in a community-engaged design process has enhanced the students' capacities for incorporating community perspectives into their engineering work.

Conclusions

Adapting to climate change and reducing its effects on coastal communities will require complex solutions, and it is increasingly recognized that incorporating the knowledge and goals of local communities into these efforts, including engineered adaptation designs, will increase their acceptance and success. Community engagement training, however, is often not included in undergraduate engineering programs. As we have described, the overarching goal of this project was to connect the knowledge of Lake Mattamuskeet watershed community members with the engineering expertise of undergraduate students to design solutions that increase coastal resiliency by broadening community participation and incorporating community engagement opportunities and training into an undergraduate engineering capstone course. Just as it has impacted nearly every aspect of people's lives worldwide, the COVID-19 pandemic dramatically affected our plans to do so.

Our plans to expand participation in the community beyond the core stakeholders and others who participated in the watershed restoration planning process were limited by the transition to virtual work during the pandemic. Without the opportunity to conduct ethnographic activities as originally planned, the design projects selected for the students reflected the goals of the core stakeholder group without a deeper consideration of those of the broader watershed community. The lack of in-person public meetings and focus groups meant that there were fewer opportunities for community engagement throughout the design process. As a result, the students received less experience directly interacting with community members than originally planned and received less feedback on their designs.

While we expected that the sustained engagement practices of our planned framework would lead to greater community support of the resulting designs and an improved state of readiness to adapt to sea level rise, we were not able to work towards or assess these intended outcomes. Given the modifications we made, we were not able to document community perceptions of resilience, assess the impact the framework had on those perceptions, or examine community perceptions of the utility of the community-engaged design process. It remains unknown whether the members of the community feel that such a method is effective in building resiliency and engaging them in the engineering design process.

The switch to virtual instruction for the capstone course also meant that the amount and type of training the students received related to community engagement changed. The training was not as comprehensive and in-depth as originally planned. In addition, the stress of the ongoing pandemic felt by students and instructors alike led us to limit the number of assignments and assessments we used in the course.

Many of the students expressed disappointment at not being able to interact and engage with community members in person. We shared that disappointment. Funded by a federal program to conduct our research as proposed, it was incredibly difficult to accept that we had to reduce our expectations of ourselves and our students. We found ourselves needing to find a balance between the typical researcher mindset to push through difficulties and get the research done no matter what and our educator selves who recognized that student capacities were limited by the stress of the events unfolding around them. And our own capacities were reduced as well. Our "decisions"—in some cases, we had no choice but to modify in particular ways—highlight the realities of being educators during a global pandemic and the trade-offs we needed to make to balance instructional goals with student well-being.

As we reflect on providing community engagement training in an engineering capstone design course during a major disruption like the COVID-19 pandemic, we recognize the key commitments that facilitated such a project. The first of these was a commitment to essentializing tasks and requirements. For the course in general and specifically for each task, we asked ourselves to identify what was truly essential to the students' development and to focus on those elements. By stripping back to these core elements in a deliberate way, we could find some sense of control in a situation that was beyond our control and present a set of clear objectives for our students to focus on. The other was a commitment to maintaining flexibility. By providing ourselves the space to evolve our plans as circumstances changed through a shared prioritization of open communication and dialogue among the project faculty team, we were better able to meet the needs of the moment.

Despite the necessary modifications and limitations, the students successfully developed engineering designs that incorporated feedback from the core stakeholder group. They gained important skills related to communicating with stakeholders and presenting highly technical engineering designs to members of the core stakeholder group and the general public. Students reported feeling more connected to their projects and more motivated to develop a solution as a result of even their limited engagement with the community. In addition, as expected, the students valued the community engagement experiences and felt better prepared to communicate their engineering design ideas to people with varying levels of expertise in the future.

Although the COVID-19 pandemic meant we had no choice but to modify project objectives and limit the extent of in-person activities, the fact that the students still found value in their interactions with community members for their engineering designs as well as for their futures as engineers highlights the critical need for and importance of including community engagement training and activities in engineering education. The successful development of student designs also highlights the potential of frameworks that connect engineering students and their faculty advisors to marginalized coastal communities with limited capacity and resources to draw upon in the face of continued threats from sea level rise, flooding, and other impacts from climate change. While further research is needed to continue to assess the benefits to engineering students, the perceptions of community members on the utility of this approach, and the extent to which such approaches effectively include local perceptions and knowledge into engineering designs, findings indicate this project could be used as a model at other sites to provide training and experience for students and to provide marginalized communities with limited resources engineering designs at a reduced cost.

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