International Journal of Mass Emergencies and Disasters
March 2019, Vol. 37, No. 1, pp. 6-24.

Interdisciplinary Citizen Science and Design Projects for Hazard and Disaster Education

Jaimie Hicks Masterson
Michelle Annette Meyer*
Nasir Ghariabeh
Texas A&M University
Marccus Hendricks
University of Maryland
Ryun Jung Lee
Saima Musharrat
Galen Newman
Garett Sansom
and
Shannon Van Zandt
Texas A&M University

Email: mmeyer@arch.tamu.edu

Disaster science is increasingly incorporating interdisciplinary methods and participatory research techniques. Yet, traditional higher education programs remain focused on lecture. More examples of educational efforts that meet the needs of future researchers and practitioners to foster collaboration across disciplines and with communities are needed. This paper describes one such effort that included three projects co-designed and co-led by university students, faculty, and community residents to address flooding challenges in socially vulnerable neighborhoods. This paper provides an overview of the educational programs, the three projects, and the feedback from graduate and undergraduate students who helped initiate these efforts, and discusses the benefits and challenges for similar interdisciplinary and participatory educational programs. Benefits for students include increased interdisciplinary dialogue, improved science communication, increased research participation, real-world research experience, and awareness of resident perspectives and knowledge. Challenges include a lack of cultural competency among students, time needed to earn resident trust, and mismatched community, academic, and student schedules.

Keywords: Disaster, interdisciplinary research, citizen science, education, service learning, hazard, flooding.

Interdisciplinary Citizen Science and Design Projects for Hazard and Disaster Education

The increasing frequency and magnitude of disasters along with population growth in hazardous areas, such as along coastlines, emphasizes the need for appropriate education and training in disaster science for numerous disciplines. Furthermore, disaster scholars emphasize that physical disaster risks are not equally distributed across population groups. The most socially vulnerable populations, who have the least resources to prepare for, respond to and recover from a disaster individually, often face the most disaster risk and have the slowest rates of disaster recoveries (Van Zandt et al. 2012; Cutter, Boruff, and Shirley 2003). Emergency and disaster management professionals skilled in multiple scholarly disciplines—from social science to engineering to urban planning—have an advantage in addressing the complex physical and social nature of disaster resilience. Yet, few higher education programs tackle disaster science outside of disciplinary silos. This paper provides an example of one educational program that included three projects designed to be academically interdisciplinary *and* community-driven, where the by-product was more engaged, and knowledgeable students who will be future hazard scholars and practitioners.

Tackling and teaching societal problems that span disciplinary boundaries, like disaster resilience, cannot be addressed in silos and require interdisciplinary approaches (Frank 2015; Silka et al. 2013; Rittel and Webber 1973). An interdisciplinary approach particularly emphasizes critical thinking. Research on interdisciplinary projects shows how critical thinking skills that cross disciplinary boundaries or integrate across various disciplines are valued by employers more than specific, individual degree programs (Hart Research Associates 2015; Morin, Jaeger, and O'Meara 2016). In relation to environmental issues specifically, over 40 years ago, in 1977, the Tbilisi Declaration called for interdisciplinary approaches to environmental education (Rowe and Johnston 2012); and now many interdisciplinary education programs focus on sustainability-related issues (Johnston 2012). The Association for the Advancement of Sustainability in Higher Education (AASHE), for example, led cross-disciplinary workshops to foster problem-based approaches to environmental education (AASHE 2010). While disaster researchers have discussed interdisciplinary research methods for addressing vulnerability and resilience (e.g., Fuchs, Kuhlicke, and Meyer 2011), there is less focus on interdisciplinary *educational* approaches to disaster resilience.

Interdisciplinary education is only one of multiple necessities for higher education in disaster resilience; community participation in the research is another initiative that is gaining prominence in the disaster field (Berke et al. 2011). Instead of scholars and university educators dictating problems and solutions *to* and *for* communities, universities could co-create projects *alongside* communities (Frank 2015; Stoecker 2016; Ward and Wolf-Wendel 2000). The problem-based environmental learning can be enhanced when grounded in local community context and driven in pursuit of community outcomes. Furthermore, student learning outcomes, achievement, engagement, and cultural competency increase when immersed in service learning projects (Lockeman and Pelco 2013; Hatcher 1997; Kilgo 2015; Carson and Domangue 2013; Miller, Rycoek, Fritson 2011; Reising, Allen, and Hall 2006). National organizations and foundations along with scholars have called for community impact and reciprocity in educational and research programs (Boyer 1996; Bryne 2006; National Academy of Sciences 2004; Carnegie 2006), but this is difficult to implement. Researchers, including community-engaged researchers, are still often mistrusted, at least at first, by over-studied and fatigued community members (Ross and Stoecker 2016), and researchers continue to struggle to make successful bottom-up, community-led science that contrasts traditional top-down science (Silka et al. 2013). Furthermore, whether communities benefit when students and researchers focus on interdisciplinary, problem-based projects remains unclear (Stoecker 2016; Stoecker and Tyron 2009; Stoecker, Beckman, and Min 2010). Thus, we argue that interdisciplinary *and* participatory projects can enhance disaster education while supporting community resilience and equity goals if purposefully designed and managed.

Citizen science, in particular, is one tool for researchers, students, and residents to co-create projects that transcend traditional disciplinary silos. Citizen science is a process by which volunteer members of the public, who commonly lack advanced or technical training in science, engage in scientific activities (e.g., data collection or analyses) that might otherwise be beyond the reach (financially or otherwise) of professional researchers or practitioners (Conrad and Hilchey 2011). Citizen science projects are increasing across the world (Bonney et al. 2014). Yet, very few address disasters or hazards (Crowdsourcing and Citizen Science 2018). Preliminary research studies indicate that trained residents and students can collect valid and reliable disaster data, such as damage assessments or risk information (Lue, Wilson, and Curtis 2014; Bonney et al. 2014; Méheux, Dominey-Howes, and Lloyd 2010). Citizen science, especially within a framework of community-based participation, can foster accountability, trust, transparency, and legitimacy in government and nongovernmental responses to resident needs, highlight low-cost and effective solutions to community problems, and raise previously overlooked distributive justice issues (Corburn 2005; Cutts, White, and Kinzig 2011; McCall 2003), all of which are central to promoting disaster resilience, especially in socially vulnerable communities.

We argue that the integration of university and high school students into citizen science research projects for hazards and disasters addresses several of these challenges. Educational programs such as those described below are designed to be interdisciplinary, to support cultural competence of students (Amerson 2010; Alexandrowicz 2001), to foster co-learning between residents, researchers, and students, and to promote further understanding of the intersection between physical vulnerability and social vulnerability through future urban planners, engineers, social scientists, and emergency managers. This paper provides an overview of executing this program, the three citizen science projects, and student feedback on their experiences. We conclude with an honest discussion of key challenges and opportunities for these educational programs.

BACKGROUND

The Institute for Sustainable Communities, established at Texas A&M University, aims to embed a bottom-up, community-based approach into research and university coursework. The Institute involves faculty from urban planning, engineering, sociology, public health, and political science, among others, in building collaborative research designs. Since 2014, the Institute has worked with community-based organizations and high schools in the Manchester/Harrisburg, South Park, and Sunnyside neighborhoods of Houston, Texas. The neighborhoods are highly socially vulnerable, based on common social vulnerability indices (e.g., Van Zandt et al. 2012). These neighborhoods have higher minority populations than most other Houston neighborhoods—95%-99% racial minority, according to the City of Houston (2012)—and have median incomes that are one-third of Houston's overall median income. Social vulnerability intersects with disaster vulnerability in these neighborhoods as large portions of the neighborhoods fall into the 100-year and 500-year floodplains, with frequent ponding issues after heavy rainfall or storm events (Texas Organizing Project 2016). Additionally, Manchester/Harrisburg residents live near over 20 toxic or hazardous facilities such as petrochemical operations (DHHS 2009; EPA 2015; Linder, Marko, and Sexton 2008). Years of infrastructure and housing neglect and disinvestment have resulted in inadequate and aging drainage infrastructure and vacant parcels, along with abandoned toxic facilities (Newman et al. 2017). Together these risks make the low-income, minority residents vulnerable to both natural and technological disasters.

The research team conducted physical vulnerability (such as the percentage of property damage) and social vulnerability (such as poverty, race/ethnicity, age, and gender of households) analyses of watersheds in the Houston-Galveston metropolitan statistical area (see Muñoz et al. 2018). Based on the vulnerability analyses, the Institute reached out through our social network of key informants in Houston, with an interest in hazard-related issues and a track record of trusted community engagement and local knowledge of community concerns. Two community-based organizations with decades of experience in neighborhood advocacy emerged as willing participants because of a shared goal—reducing hazard risk to people. Texas Environmental Justice Advocacy Services (TEJAS) and Charity Productions are nonprofits that engage community members in addressing various environmental and social inequities and the persisting problems that have come from city neglect and disinvestment resulting in physical vulnerability. The Institute was invited to explore project possibilities in two neighborhoods identified by the community-based organizations, Manchester/Harrisburg and Sunnyside. Additionally, these organizations connected the Institute to local high schools near the neighborhoods with their own track record of project-based learning and community projects: E.L. Furr High School (FHS) and Jones Futures Academy (JFA) within the Houston Independent School District.

The partners organized a community meeting where the Institute discussed hazard vulnerabilities and other data, and residents identified disaster resilience related needs and gaps. Specifically, partners and residents described two hazards as priority concerns—environmental toxins and flooding. The partners and the Institute developed a community covenant, or an agreement of how each party would work and interact together, before proceeding. This covenant described protocols for communication, publishing results, and the duration and commitment of the Institute in the community, among others. After developing a community covenant, the team identified an interdisciplinary set of projects to be incorporated into secondary and higher education classrooms. Because there are significant limits on local scaled data that constrain community capabilities, students and partners took to the streets to collect and understand pertinent data. The Institute's pedagogical approach marries invaluable residents' local knowledge required to address needs with local data gathering co-led by community members and students of higher education.

As trust was developed and the covenant written, faculty and graduate students met bi-monthly as an interdisciplinary team to discuss the program as a whole and review data collection protocols and results. Each faculty member assigned at least one graduate student to the team. The number of people involved in this group fluctuated with graduations and new inclusions over the life of the program, but generally ranged from 12 to 20 people. Graduate students presented their disciplines' research questions, protocols, and results at the bi-monthly meetings. We, as a team, specifically decided to have graduate student presentations form the basis of each meeting to foster the next generation of scholars with interdisciplinary skills. These discussions provided space to debate disciplinary terminology, as well as validity and reliability assumptions of the data. Each graduate student project fed into another, for example, climate change models were used to predict future floodplains, which were applied to urban planning assessments of social vulnerability at the Census block group level, which informed public health predictions for future disease potential.

Importantly, in these meetings, graduate students learned about research ethics when working with human subjects. The citizen science projects described below (including the participation of high school students) were reviewed and approved by the university's Institutional Review Board (IRB) and all graduate students and faculty, including those from non-social science disciplines, completed human subjects ethics training. IRB approval was complicated due to the lack of familiarity of IRB reviewers with citizen science projects compared to traditional human subjects research. Questions included whether citizen science projects gather human subjects data or just use human subjects as data collectors, and whether human subject participation in improving the educational components of the projects falls within exempt or other status. We did end with expedited review and approval to conduct focus groups, informal interviews, and short surveys with student and residents who participated. Browne and Peek (2014) indicate that IRB approval may not fully address all the ethical challenges researchers face in the field or ensure that research is conducted in the most culturally appropriate manner. As our program expanded to include more undergraduates at our predominately white institution, the project team required cultural competency training for undergraduates since many had never worked in neighborhoods or organizations that were majority minority or low-income.

INTERDISCIPLINARY AND PARTICIPATORY HAZARD EDUCATION RESEARCH PROJECTS

Community partners worked with the researchers and students to design three participatory research projects that incorporate citizen science or public participation into infrastructure planning, public health, and landscape architecture. Each project draws from the expertise of hazard and disaster social scientists with training in urban planning and sociology. Below, we briefly overview each of the three projects—1) stormwater infrastructure assessment, 2) surface water quality, and 3) green infrastructure design—then provide views from former students and discuss challenges and opportunities.[1]

Stormwater Infrastructure Assessment

Knowledge about the continued capacity of installed stormwater infrastructure is a challenge across communities (Hendricks et al. 2018). Communities require timely and complete data to understand potential flooding risks from damaged or missing stormwater infrastructure components. These risks may vary across neighborhoods, placing further physical risks in neighborhoods with concentrations of socially vulnerable populations (Van Zandt et al. 2012).

Our community partners wanted to document poor neighborhood infrastructure. Thus, graduate students from urban planning and engineering adapted an existing professional engineering-based assessment technique (Gharaibeh and Lindholm 2014) into a citizen scientist data collection technique that includes visual descriptors of the engineering performance standards that measure the quality and capacity of the stormwater

[1] Details of the methodology and specific research results of each of these three projects are provided in separate publications. See (Hendricks et al. 2018) for stormwater infrastructure assessment, (Sansom et al. 2016) for surface water quality, and (Newman et al. 2016) for green infrastructure designs.

infrastructure assets. Graduate students used focus groups, informal interviews, and classroom lecture activities under the supervision of planning and sociology faculty members to ensure the tool was comprehensive and comprehensible to the high school students and local residents who participated. Multiple iterative field trials of the assessment technique tested whether the data collected were useful for the task at hand (i.e., informing stormwater infrastructure management decisions) and at the same time not overwhelming in its quantity and technicality to the volunteer collectors (i.e., high school students). The reproducibility of the same responses to a given sample unit by multiple people provided a test of reliability, and assessments by engineering scholars confirmed the validity of the data. The final assessment technique consists of a protocol with statements that require a pass or fail response.

Immediately following each field trial, the high school students participated in a focus group providing feedback on the layout, language, structure, and set up of the technique and the strengths and weaknesses of the technique as well as what they learned during the activity. The high school students often expressed accurate understanding of complex stormwater management issues and consequences of poor drainage (e.g., vector-borne illnesses, chemical concentrations, etc.) and to disaster risk, environmental injustice, and neighborhood inequalities as it relates to stormwater infrastructure. For example, they described how stormwater infrastructure varied across neighborhoods based on social characteristics (e.g., "rich" versus "poor" and "all white" versus "mixed or minority" neighborhoods in their words). Furthermore, students described scenarios of infrastructure failure by way of quality and condition that link to flood risks in ways that are congruent with scholars' descriptions of these issues. Students ended the project stating they had more knowledge about specifics that affected stormwater drainage, including when ditches are obstructed, damaged or blocked culverts, and broken or blocked drains.

Surface Water Quality

Manchester/Harrisburg residents also raised concerns about toxic and biological contaminants in the local surface water that is exacerbated by the poor stormwater infrastructure quality. Using student and community partner knowledge about neighborhood areas where pooling and standing water commonly occur, graduate students trained high school students on water sampling and how to interpret water quality lab assessments. Then, students sampled surface water to assess the presence and concentration of select heavy metals. They followed this sampling with a community-wide health survey in Manchester/Harrisburg to determine the composite physical and mental health scores of residents.

The health survey that accompanied the water sampling included the 12 item Short Form Health Survey version 2 (SF12v2) to assess the general mental and physical health of the community (Ware, Kosinski, and Keller 1996). High school students, teachers, and representatives from the community partner organizations, received one-hour training about door-to-door surveying from one faculty member and one graduate student knowledgeable in public health surveying techniques. The training for citizen scientists mimicked programs used to train public health practitioners in surge assessments (e.g., EpiAssist). This group then attempted to complete a census of the neighborhood and received an overall response rate of 72.7% for houses in which an eligible respondent answered the door.

The findings of the water sampling confirmed community members' fears and indicated that there were concentrations of barium in every location sampled. The findings also confirmed that arsenic was present in eight locations, chromium in ten, lead in twelve, and mercury in two (Sansom et al. 2016). The survey results showed a neighborhood population with reduced physical composite health scores compared to national averages.

Previous research shows that marginalized communities offer unique challenges in collecting data, including low participation rates (Knight, Roosa, and Umana-Taylor 2009; Yancey, Ortega, and Kumanyika 2006). This project, which included door-to-door surveys, was enhanced by the purposeful relationship with TEJAS and the local students and teachers. Many survey respondents remarked that the only reason they were willing to complete the survey was due to the presence of local high school students and community organizations, indicating that the high response rate was partly due to our ongoing participatory research efforts. More importantly, the local citizen scientists pinpointed problematic locations, which allowed for surface water sampling to occur in known pooling water areas and provided data on areas that the community already wanted tested.

Green Infrastructure Designs

Citizens and community-based organizations worked with landscape architecture and planning faculty to develop green infrastructure design solutions to mitigate flooding and environmental toxins in both neighborhoods. Both Manchester/Harrisburg and Sunnyside suffer from inadequate flood and stormwater infrastructure, but Sunnyside community partners also identified a significant amount of vacant parcels as a community concern and potential resilience opportunity (Newman et al. 2016). Population loss between 2000 and 2010 and home ownership decline of 23% over the last twenty years increased vacant land amounts in Sunnyside; 346 tax delinquent vacant parcels occupying 461 acres of land comprise 22% of the neighborhood's total area (H-GAC 2016). Community partners discussed and identified a 202-acre site in the southeast portion of the neighborhood as the design/research study area to serve as a model for future development within the neighborhood. This project expanded traditional urban planning and landscape architecture public participation practices (Innes and Booher 2004) and involved both the development and application of an innovative system of feedback loops from community members and university students and faculty (Figure 1). Community partner organization representatives assisted with coordinating all site visits and presentations and encouraging meeting attendance.

The entire design process followed a structured framework which relied on the production and analysis of evidence for making design decisions. The timeline of this process is as follows: 1) university graduate and undergraduate students were given tours through the neighborhoods, 2) students discussed existing issues with members and stakeholders, 3) a Geographic Information Systems (GIS) geo-database was developed, 4) students performed an inventory/analysis of existing conditions, and 5) undergraduate students presented scenarios of visualized design solutions.

In all, landscape architecture faculty and undergraduate students met with community members five times over a seven-month period (Figure 1). The first two meetings occurred in the community so an inventory of resources and analysis of conditions could be completed. The introductory meeting allowed residents to discuss community problems, initiating a discussion to identify flood vulnerable areas. At this meeting, faculty and university students worked with community members and high school students to identify prominent issues within the neighborhood. At a second meeting, students presented site analyses to residents; feedback on this presentation provided insight, identified unseen conditions, and generated ideas for future urban growth strategies. The final three meetings were held at the university where students presented their analyses and design scenarios. The third and fourth meeting involved feedback loops between community members and students in which a series of design scenarios were presented to residents and critiqued by neighborhood members and stakeholders. Graduate landscape architecture students then condensed each scenario into one singular master plan based on the community feedback.

The final design had three goals: 1) Improve the local economy, 2) Create a healthier and more active neighborhood and 3) Strengthen resilience to flood. The research site has 16% vacant parcels/abandoned structures, much of which was redesigned as green infrastructure that addressed stormwater and flooding concerns. At the community's request during the meetings, PhD and master students worked together to develop design impact projections using landscape performance tools. The Landscape Architecture Foundation (LAF) has a series of Landscape Performance tools that measure the effectiveness of existing or designed/planned solutions to fulfill their intended purpose (Yang et al. 2016). These tools help estimate construction and maintenance costs of green infrastructure provision, calculate stormwater runoff impacts, analyze land use changes, and project potential community employment opportunities. Our final designs address potential flooding in the neighborhood. Houston receives 49.7 inches of rainfall per year and has days of extreme rainfall such as Hurricane Harvey in 2017. The new design would increase water infiltration by up to an additional 20 million gallons of water per year, at maximum capacity.

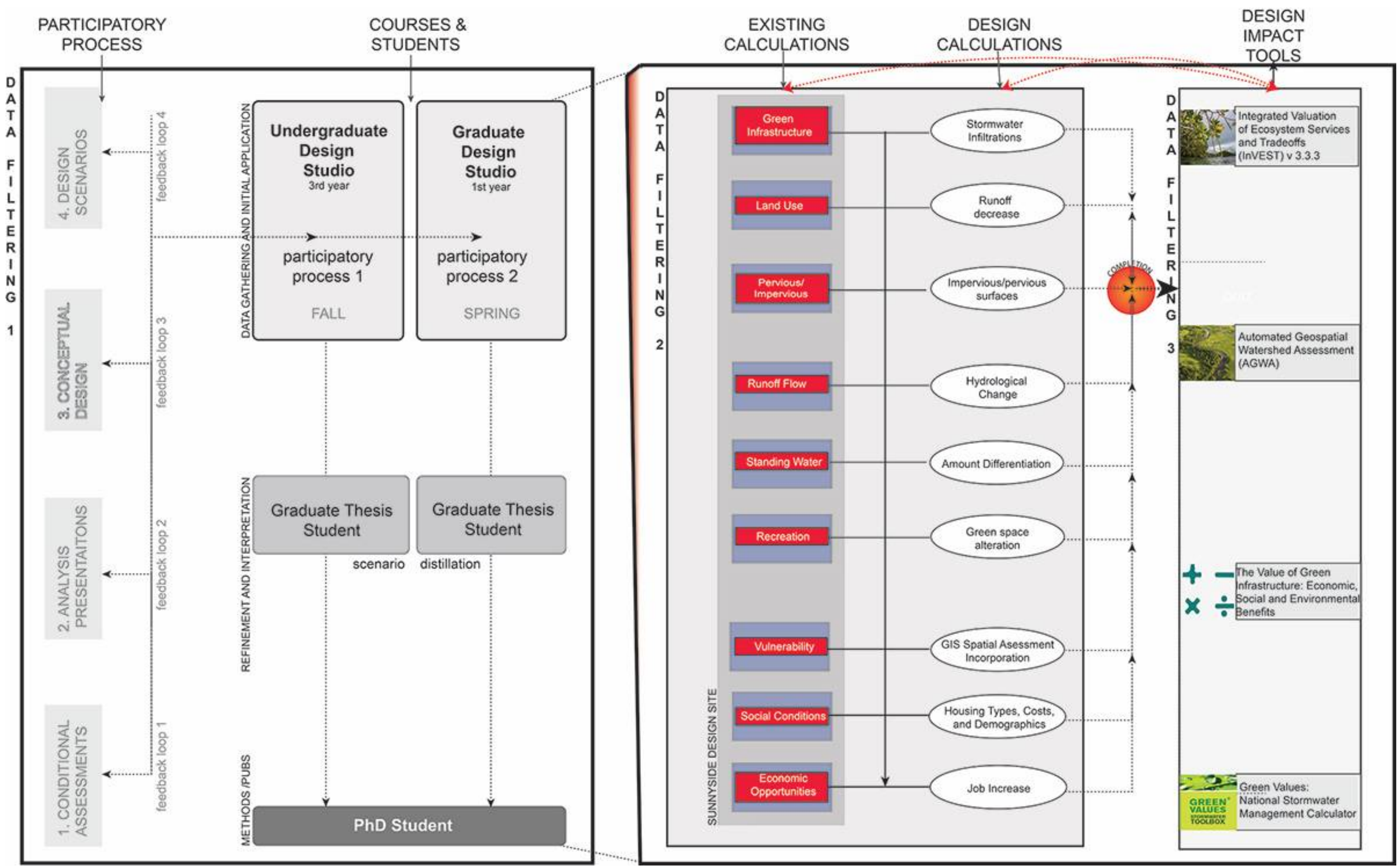

Figure 1. Feedback Loops for Community Engagement in Learning Outcomes

DISCUSSION: STUDENT FEEDBACK ON INTERDISCIPLINARY CITIZEN SCIENCE PROJECTS

This interdisciplinary citizen science program focused on the intersection between physical and social vulnerability to disasters, especially flooding. Incorporating high school student and local resident participation through citizen science and participatory feedback loops gave university students and residents access to greater experience and knowledge about flooding risks and resilience. For example, resident feedback provided information as to specific functions and land uses wanted by the community and those which merited removal. Relatedly, resident knowledge on existing conditions such as stormwater ponding areas during flooding supported targeted research design and data collection. This information (and much more) would not have been exposed without a participatory process.

Diverse Perspectives

Based on feedback from graduate and undergraduate students who have since graduated and moved into practice or faculty positions, interdisciplinary and community perspectives (Figure 2) are valuable inputs to inform transformational learning and community outcomes. Students offered their thoughts on the following questions: 1) What did you gain from working on an interdisciplinary hazards related project that supports your development as a scholar and/or career trajectory? 2) What did you gain for your career and/or scholarship from working on a community-engagement project? 3) What was challenging about interdisciplinary research as a graduate student? 4) What was challenging about community engagement as a graduate student? 5) What did you learn about collaborative research from participating in the Institute?

First, the interdisciplinary approach engaged students with fields they might not normally encounter, providing first-hand experience working with researchers across disciplines. Students expressed improved recognition of interdisciplinary research questions, understanding of other disciplines' methods for addressing those questions, and improved communication skills across disciplinary divides. One former graduate student from engineering stated what many of the students agreed with,

> The interdisciplinary nature forced me to get out of my comfort zone and created a great development opportunity for me. It made me think about my research from different perspectives and draw connections to research in other disciplines I would not have realized otherwise, which required delving into and understanding other

> disciplines' work. I was also challenged in communicating highly technical information to those of other backgrounds. I essentially was able to learn how to present my work to those outside of my discipline.

Next, a community-engaged approach, as described by former students, demonstrated the importance of understanding community perspectives, which can impact the development of strategies to address complex hazards issues. For example, in speaking with community members, one public health student became aware that community members have an understanding of the issues in their communities. Some researchers, even those trained in social and behavioral sciences, often overlook resident knowledge, assume that residents are blind to community problems, or that they would not understand science (Davies 2008). In hazards and disaster practice, risk assessments are often viewed as highly technical procedures beyond the capacity of local resident comprehension (Davies et al. 2015). Thus students received foundational experience of co-learning with residents, which has been called for to generate more useful resilience projects, as expressed in this example quote:

> The ability of local members to correctly identify and diagnose certain issues within their neighborhood was truly eye-opening. My current research and projects revolve around community engagement precisely because I saw how beneficial it could be for the researchers, the community, and scholarship as a whole.

We must add that students who were less surprised by the knowledge of residents were those students who themselves were first-generation college students or grew up in similar low-income or minority neighborhoods.

Principles of Practice

The project revealed "principles of practice" for community-engaged, interdisciplinary learning where students and communities co-design, co-produce, and co-learn (Figure 2). First, university faculty, students, and community-based organizations co-designed projects. In fact, research ideas and projects evolved and grew as more time was spent in the community and with residents. The community-based organizations had a long history of understanding and addressing community concerns and needs, while university students and faculty held knowledge related to scientific methods and best practices for data collection and strategies. Each held specific knowledge about hazards and were able to combine knowledge to create locally viable research projects.

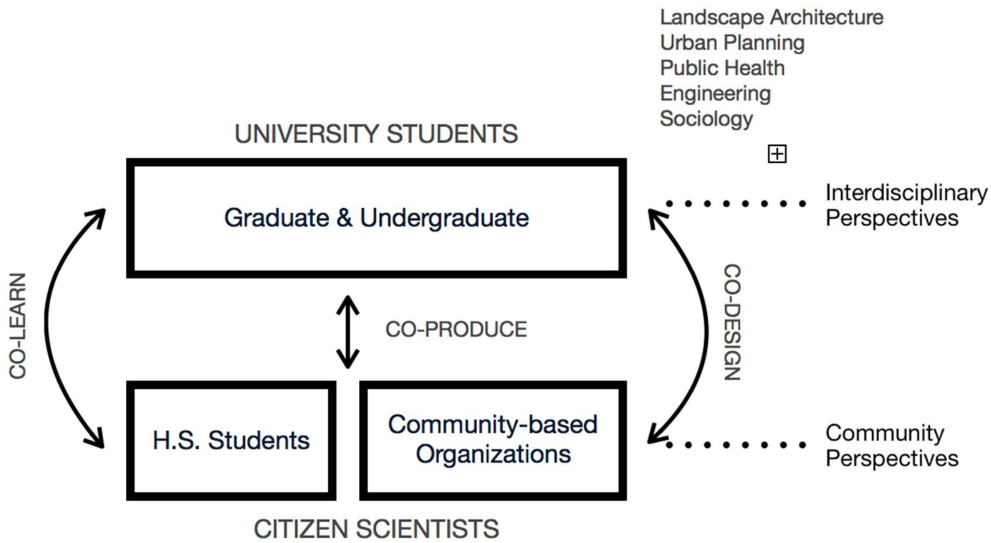

Figure 2. Incorporating Interdisciplinary Perspectives and Community Perspectives for Student Learning

Second, university students and citizen scientists, in this case community-based organizations and high school students, can co-produce data and information together. Feedback from classroom surveys of undergraduate student participants in planning and landscape architecture courses showed that many students wanted *even more* resident involvement than a typical client-centered design studio. Students understood the diverse opinions and experiences of residents provided invaluable information not available through typical analyses used for design and research decision-making. Many students also commented that working within teams for the courses, having frequent resident and stakeholder involvement, and also trying to respond to faculty feedback forced them to compromise some of their own original ideas, but that this resulted in a more real-world experience of the research process.

Third, university students and high school students as citizen scientists can co-learn together. Students worked alongside one another in a feedback loop of knowledge transfer. Specifically, university students were also able to take leadership roles in research projects by training, educating, and mentoring high school students, an experience not always available in traditional research projects. Different levels of students took on more complicated tasks allowing each academic level to be effectively challenged. High school students were able to speak to localized knowledge. Additionally, high school students of marginalized communities expressed that they feel more connected with a Research University and expressed that they could see themselves as not only undergraduate students but also as graduate students after participating in this project. The high school students even traveled to the university for school tours and spoke with enrollment and admissions staff during those visits.

This feedback is preliminary, but it highlights several future research needs to fully assess the educational outcomes for these types of programs. This feedback provides some starting points for future research such as measuring students' interdisciplinary "growth" around definitions and science communication, changes in students' assumptions about public knowledge (particularly cultural assumptions about the capacity of socially vulnerably residents to participate in science), and students' understanding of real-world research projects.

CHALLENGES

Several factors affected the success of these projects and required flexibility and dedication to project-based learning. First, university students must be prepared to go into communities and work with diverse stakeholders. The project team required undergraduate students to complete cultural competency training focused on breaking down assumptions and stereotypes. Staff with experience working in similar neighborhoods also spoke to common missteps, emphasizing the importance of strong and healthy community relationships. In hindsight, all university students and faculty, even social science faculty, would benefit from cultural competency training to work in communities that are demographically and culturally different than their own. This is a step we have initiated.

Second, these projects need long-term engagement with sustained and persistent communication between the community leaders and the professors and students. Residents and partners indicated to us that they were hesitant to work on short-term or one-off projects due to past experiences with researchers who collect data and never return. This raises challenges and opportunities. We are exploring additional opportunities for oral history projects that engage local high school English students and graduate students to understand the daily lived experiences in socially and physically vulnerable populations under the threat of environmental hazards. We are also working with high school teachers on developing curriculum for other classes, such as math classes, that incorporate these projects regularly into the school year. The challenge, though, is that the trust required to gain access to such stories and complete the projects described above requires time. Committed long-term staff and senior faculty (who are not under the pressure of achieving tenure) were crucial to maintaining the momentum, communication, and coordination with the community throughout our program. Having project managers or other research staff who communicated quickly and warmly with residents was crucial.

Third, and relatedly, residents and community organizations do not think in semesters and have other priorities pulling on their time. Engineering and public health students faced the challenges that urban planners and social scientists know well: community members are not always available to participate in research when needed. University students need back-up plans in case the community research projects are not completed in time for their course or thesis schedules or with the necessary data to meet sampling requirements. Some of our graduate students collected data independently from the citizen science data collection to ensure that they had enough data points to complete their theses or dissertations in the timeframe they had established. Other graduate students used their experience with residents to inform the questions they asked, but did not use citizen science data for their dissertations due to the incompatible timetables. Students also had to become flexible and able to rearrange work, including data collection days and community meeting times, as resident schedules ebbed and flowed, which varies dramatically from many traditional data collection techniques.

CONCLUSION

This collaborative experience presented numerous opportunities to enhance undergraduate and graduate student learning by engaging across disciplines and with local residents on disaster-related projects. Most student participants stated the process was a great challenge to perform but one in which their passion and knowledge grew. The project shows how higher education can effectively incorporate project-based learning and community-engaged learning into interdisciplinary hazards programs. Most notably, educators can incorporate community-centered curriculum as a mechanism to achieve student-centered learning at each academic level. With growing climate change impacts, students of higher education must be trained to listen to and work alongside physically and socially vulnerable communities to co-collect local scaled data to fully understand heightened risks and be prepared for the "new normal" of hazards and disasters.

References

Alexandrowicz, Viviana 2001. "Community Service Learning in Culturally Diverse Settings as a Springboard for Student Constructed Case Studies." *Education* 121(4): 761-67.

Amerson, Roxanne. 2010. "The Impact of Service-Learning on Cultural Competence." *Nursing Education Research* 31(1):18-22.

Association for the Advancement of Sustainability in Higher Education (AASHE). 2010. *Sustainability Curriculum in Higher Education: A Call to Action.* Denver, CO: AASHE.

Berke, Philip, John Cooper, David Salvesen, Danielle Spurlock, and Christina Rausch. 2011. "Building Capacity for Disaster Resiliency in Six Disadvantaged Communities." *Sustainability* 3(1):1-20.

Bonney, Rick, Jennifer L. Shirk, Tina B. Phillips, Andrea Wiggins, Heidi L. Ballard, Abraham J. Miller-Rushing, Julia K. Parrish. 2014. "Next Steps for Citizen Science." *Science* 343(6178):1436-37.

Boyer, Ernest L. 1996. "Scholarship of Engagement." *Journal of Public Service and Outreach* 1(1): 11-20.

Browne, Katherine E. and Lori Peek. 2014. "Beyond the IRB: An Ethical Toolkit for Long-Term Disaster Research." *International Journal of Mass Emergencies and Disasters* 32(1):82-120.

Bryne, JohnV. 2006. *Public Higher Education Reform Five Years after the Kellogg Commission on the Future of State and Land-grant Universities*. National Association of State Universities and Land-grant Colleges, Washington D.C. and the W.K. Kellogg Foundation, Battle Creek, MI. Retrieved March 12, 2019 (https://files.eric.ed.gov/fulltext/ED519711.pdf).

Carnegie Foundation for the Advancement of Teaching and CIRCLE (The Center for Information and Research on Civic Learning and Engagement). 2006. *Higher Education: Civic Mission and Civic Efforts.* Carnegie Foundation, Princeton, NJ. Retrieved March 12, 2019 (https://civicyouth.org/PopUps/higher_ed_civic_mission_and_civic_effects.pdf).

Carson, Russell L. and Elizabeth A. Domangue. 2013. "The Emotional Component of Service-Learning." *Journal of Experiential Education* 36(2): 139-54.

City of Houston. 2012. *Super Neighborhood Demographics*. US Census Bureau. Retrieved July 20, 2018. (http://www.houstontx.gov/planning/Demographics/docs_pdfs/SN/sn_coh_race_ethn.pdf)

Crowdsourcing and Citizen Science (CCS). 2018. *Federal Crowdsourcing and Citizen Science Catalog*. Retrieved September 1, 2018 (https://ccsinventory.wilsoncenter.org)

Conrad, C. Cathy and Krista G. Hilchey. 2011. "A Review of Citizen Science and Community-Based Environmental Monitoring: Issues and Opportunities." *Environmental Monitoring and Assessment* 176(1-4):273-91.

Corburn, Jason. 2005. *Street Science: Community Knowledge and Environmental Health Justice*. Cambridge, MA: The MIT Press.

Cutter, Susan L., Bryan J. Boruff, and W. Lynn Shirley. 2003. "Social Vulnerability to Environmental Hazards." *Social Science Quarterly* 84(2):242-61.

Cutts, Bethany B., Dave D. White, and Ann P. Kinzig. 2011. "Participatory Geographic Information Systems for the Co-production of Science and Policy in an Emerging Boundary Organization." *Environmental Science & Policy* 14(8), 977-85.

Davies, Sarah R. 2008. "Constructing Communication: Talking to Scientists about Talking to the Public." *Science Communication* 29(4):413-34.

Davies, Tim, Sarah Beaven, David Conradson, Alex Densmore, J.C. Gaillard, David Johnston, Dave Milledge, Katie Oven, Dave Petley, Jonathan Rigg, Tom Robinson, Nick Rosser, and Tom Wilson. 2015. "Towards Disaster Resilience: A Scenario-Based Approach to Co-producing and Integrating Hazard and Risk Knowledge." *International Journal of Disaster Risk Reduction* 13:242-47.

Department of Health and Human Services (DHHS). 2009. *Community Health Profiles 1999-2003: Harrisburg/Manchester Super Neighborhood*. Houston, TX: Department of Health and Human Services. Retrieved March 12, 2019 (https://www.houstontx.gov/health/chs/Harrisburg-Manchester.pdf).

Frank, Andrea. 2015. "Reaching the summit: explorations in meaningful learning through community engagement." Presentation at the 2015 International Higher Education Teaching and Learning (hetl)--Scholarship of Teaching and Engagement (SoTE) Conference, Utah Valley University, Orem, UT, January.

Fuchs, Sven, Christian Kuhlicke, and Volker Meyer. 2011. "Editorial for the Special Issue Vulnerability to Natural Hazards—the Challenge of Integration." *Natural Hazards* 58(2):609-19.

Gharaibeh, Nasir G. and Debora Lindholm. 2014. "A Condition Assessment Method for Roadside Assets." *Structure and Infrastructure Engineering* 10(3):409-18.

Hatcher, Julie. 1997. "The Moral Dimensions of John Dewey's Philosophy: Implications for Undergraduate Education. Michigan Journal of Community Service Learning." *Michigan Journal of Community Service Learning* 4(1):22-9.

Hendricks, Marccus D., Michelle A. Meyer, Nasir G. Gharaibeh, Shannon Van Zandt, Jaimie Masterson, John T. Cooper, Jr., Jennifer A. Horney, Philip Berke**.** "The Development of a Participatory Infrastructure Assessment Tool towards Sustainable and Resilient Communities." *Sustainable Cities and Society.* 38: 265-74.

Houston-Galveston Area Council (H-GAC). 2016. "GIS Datasets." Retrieved March 1, 2016 (http://www.h-gac.com/gis-applications-and-data/datasets.aspx).

Innes, Judith E., and David E. Booher. 2004. "Reframing Public Participation: Strategies for the 21st Century." *Planning Theory & Practice* 5(4):419-36.

Johnston, Lucas F., ed. 2012. *Higher Education for Sustainability: Cases, Challenges, and Opportunities*. Milton Park, UK: Taylor and Francis Group.

Knight, George P., Mark W. Roosa, and Adriana J. Umaña-Taylor. 2009. *Studying Ethnic Minority and Economically Disadvantaged Populations: Methodological Challenges and Best Practices*. Washington, DC: American Psychological Association.

Kilgo, Cindy A. 2015. "The Estimated Effects of Service Leanring on Students' Intercultural Effectiveness." *Journal of College Student Development* 56(8):867-71.

Linder, Stephen H., Dritana Marko, and Ken Sexton. 2008. "Cumulative Cancer Risk from Air Pollution in Houston: Disparities in Risk Burden and Social Disadvantage." *Environmental Science & Technology* 42(12):4312-22.

Lockeman, Kelly S. and Lynn E. Pelco. 2013. "The Relationship between Service-Learning and Degree Completion." *Michigan Journal of Community Service Learning* 20(1):18-30.

Lue, Evan, John P. Wilson, and Andrew Curtis. 2014. "Conducting Disaster Damage Assessments with Spatial Video, Experts, and Citizens." *Applied Geography* 52:46-54.

McCall, Michael K. 2003. "Seeking Good Governance in Participatory-GIS: A Review of Processes and Governance Dimensions in Applying GIS to Participatory Spatial Planning." *Habitat International* 27(4): 549-73.

Méheux, Kirstie, Dale Dominey-Howes, and Kate Lloyd. 2010. "Operational Challenges to Community Participation in Post-Disaster Damage Assessments: Observations from Fiji." *Disasters* 34(4):1102-22.

Miller, Richard L., Robert F. Rycek, and Krista Fritson. 2011. "The Effects of High Impact Learning Experiences on Student Engagement." *Procedia Social and Behavioral Sciences* 15: 53-9.

Morin, Shauna M., Audrey J. Jaeger, and Kerry Ann O'Meara. 2016. "The State of Community Engagement in Graduate Education: Reflecting on 10 Years of Progress." *Journal of Higher Education Outreach and Engagement* 20(1):15-56.

Muñoz, Leslie A., Francisco Olivera, Matthew Giglio, and Philip Berke. 2018. "The Impact of Urbanization on the Streamflows and the 100-year Floodplain Extent of the Sims Bayou in Houston, Texas." *International Journal of River Basin Management* 16(1):61-9.

National Academy of Sciences. 2004. *Facilitating Interdisciplinary Research*. Washington DC: The National Academies Press.

Newman, Galen, Jun-Hyun Kim, Philip Berke, Jeremy Merrell, Yangdi Wang, and Qiushuo Li. 2016. "From Idle Grounds to Ecological Infrastructures—The Resilient Design of Manchester Neighborhood in Houston." *Landscape Architecture Frontiers* 4(5):68-83.

Newman, Galen, Allson Smith, and Samuel D. Brody. 2017. "Repurposing Vacant Land through Landscape Connectivity." *Landscape Journal* 36(1): 37-57.

Reising, Deanna L., Patricia N. Allen, and Susan G. Hall. 2006. "Student and Community Outcomes in Service-Learning: Part 1— Students Perceptions." *Journal of Nursing Education* 45(12):512-15.

Rittel, Horst W.J. and Melvin M. Webber. 1973. "Dilemmas in a General Theory of Planning." *Policy Sciences 4*: 155-69.

Ross, J. Ashleigh and Randy Stoecker. 2016. "The Emotional Context of Higher Education Community Engagement." *Journal of Community Engagement and Scholarship* 9(2):7-18.

Rowe, Debra and L. Johnston. 2012. "Learning Outcomes: An international Comparison of Countries and Declarations." Pp. 45-60 in *Higher Education for Sustainability: Cases, Challenges, and Opportunities from Across the Curriculum,* edited by Lucas F. Johnston. New York, NY: Taylor and Francis Group.

Sansom, Garett, Philip Berke, Thomas McDonald, Eva Shipp, and Jennifer Horney. 2016. "Confirming the Environmental Concerns of Community Members Utilizing Participatory-Based Research in the Houston Neighborhood of Manchester." *International Journal of Environmental Research and Public Health* 13(9):839-51

Silka, Linda, Robert Glover, Karen Hutchins, Laura Lindenfeld, Amy Blackstone, Catherine Elliott, Melissa Ladenheim, Claire Sullivan. 2013. "Moving Beyond the Single Discipline: Building a Scholarship of Engagement that Permeates Higher Education." *Tamara Journal for Critical Organization Inquiry* 11(4):41-52.

Stoecker, Randy. 2016. *Liberating Service Learning and the Rest of Higher Education Community Engagement*. Philadelphia, PA: Temple University Press.

Stoecker, Randy and Elizabeth A. Tryon. ed. 2009. *Unheard Voices: Community Organizations and Service Learning*. Philadelphia, PA: Temple University Press.

Stoecker, Randy, M. Beckman, and B. Min. 2010 "Evaluating the Community Impact of Higher Education Community Engagement." Pp. 177-198 in *Handbook of Engaged Scholarship: The Contemporary Landscape. Volume Two: Community-Campus Partnerships,* edited by H.E. Fitzgerald, C. Burack and S. Seifer. East Lansing, MI: Michigan State University Press.

Texas Organizing Project: Texas Low Income Housing Information Service. 2016. *Sunnyside Neighborhood Plan*. A Preliminary Draft by Houston's Sunnyside Neighborhood, Houston, TX. Retrieved March 12, 2019 (https://txlihis.files.wordpress.com/2016/08/sunnyside-neighborhood-plan.pdf).

United States Environmental Protection Agency (EPA). 2015. *Envirofacts.* Retrieved February 1, 2015 (https://www3.epa.gov/enviro/).

Van Zandt, Shannon, Walter Gillis Peacock, Dustin W. Henry, Himanshu Grover, Wesley E. Highfield, and Samuel D. Brody. 2012. "Mapping Social Vulnerability to Enhance Housing And Neighborhood Resilience." *Housing Policy Debate* 22(1):29-55.

Ward, Kelly and Lisa Wolf-Wendel. 2000. "Community-Centered Service Learning: Moving from Doing For to Doing With." *American Behavioral Scientist* 43(5):767-80.

Ware, John E. Jr., Mark Kosinski, and Susan D. Keller. 1996. "A 12-item short-form health survey. Construction of scales and preliminary tests of reliability and validity." *Medical Care* 34:220-33.

Yancey, Antronette K., Alexander N. Ortega, and Shiriki K. Kumanyika. 2006. "Effective Recruitment and Retention of Minority Research Participants." *Annual Review of Public Health* 27(1):1-28.

Yang, Bo, Shujuan Li, and Chris Binder. 2016. "A Research Frontier in Landscape Architecture: Landscape Performance and Assessment of Social Benefits." *Landscape Research* 41(3): 314-29.