INTERNATIONAL DESIGN CONFERENCE – DESIGN 2022
https://doi.org/10.1017/pds.2022.240

Project-Based Learning in Disaster Response: Designing Solutions with Sociotechnical Complexity

V. Rao [1,✉], R. Dzombak [2], D. Dogruer [1] and A. Agogino [1]

[1] University of California, Berkeley, United States of America,
[2] Carnegie Mellon University, United States of America
✉ vivek.rao@berkeley.edu

Abstract

Design education increasingly blends technology learning with sociotechnical challenges, but little is understood about how students simultaneously engage with both of these elements. In this preliminary study, we describe the results of two offerings of a design course focusing on disaster response at a major public research institution. We present a preliminary analysis of 52 students' course reflections suggesting that sociotechnical challenges uniquely contextualize technology during project-based learning, presenting promising opportunities for future design education and research study.

Keywords: design education, socio-technical systems, blended learning in design, humanitarian assistance and disaster response, project-based learning

1. Introduction

Innovation is widely accepted to be a global priority, with design playing a key role in its realization (National Academy of Engineering, 2004). Design pedagogy is considered critical training, as ‘‘graduates of today are increasingly expected to work in dynamic and fluid ways, able to approach any wicked problem creatively’’ (Dixon and Murphy, 2016). Design offers powerful strategies for unlocking creativity and creating solutions for real-world, complex sociotechnical problems (Buchanan, 1992).

Key to student innovation outcomes is the ability to think creatively and address complex problems (Cropley, 2015; Zhou, 2012). While many aspects of the university seek to support such outcomes, courses are central (Bradforth et al., 2015); courses dedicated to design and innovation typically involve project-based learning (Dym et al., 2005). Beyond specific course content and methods, a critical component to developing innovation capacity in students, studied as open-mindedness and teamwork, is believed to be reflection and personal development (Hirsch and McKenna, 2008).

A critical question is what kinds of projects offer both promise and meaningful context for project-based learning outcomes while simultaneously engaging students. Previous research has illustrated that while project-based learning outcomes in design education can be achievable by a range of project types (Lande and Leifer, 2009), students, especially student groups historically under-represented in Science, Technology, Engineering and Mathematics (STEM) education, are drawn to projects or service-based projects exploring humanitarian and social challenges (Duffy et al., 2011, 2011; Oehlberg et al., 2010).

In this paper, we detail how we developed a design course focused on disaster response, recovery and resilience, an urgent and growing sociotechnical challenge facing communities worldwide (Coronese et al., 2019). We present details of the course and examine how three core elements of the class, also the class's key learning objectives, related to student experience: sociotechnical fluency, technology toolkits, and reflection on individual and team goals. We conducted a thematic analysis on end-of-course reflection papers from 52 students to assess these elements, and describe how they manifested in student experience. We close by highlighting opportunities for the educators to enhance pedagogy for complex problem solving in their own domain areas, and to further generalize the findings we developed here.

2. Background & Related Work

2.1. Disaster Response, Recovery & Resilience

Between 1995 and 2015, more than 6000 weather-related disasters were recorded worldwide, causing 606,000 fatalities and leaving 4.1 billion individuals in need of medical care, shelter, or financial assistance (UNISDR, 2015). In the United States, disaster management has become a national security issue, as the country experiences the largest recorded number of natural disasters globally (UNISDR, 2015). Disaster management is widely acknowledged to be a highly complex problem: it crosses jurisdictional boundaries, demands knowledge aggregation across geographies, and is often exacerbated by institutional, environmental, and social conditions (Güiza et al., 2016; O'sullivan et al., 2013). This characteristic makes effective interventions highly challenging. Encouraging signs of innovation exist, with technology highlighted as a key element in disaster management (Aitsi-Selmi et al., 2016).

Effective technology is only one aspect of relevantly addressing disaster management, however. Given the complexity of disaster management, effective solutions require a nuanced understanding of the crucial needs in disaster management, and effective training of innovators to transform technology into relevant products, services, and systems. However, efforts to train and educate students and practitioners appear to have focused on preparedness (Shiwaku and Fernandez, 2011). Cultivating design and innovation mindsets in the disaster response field could deliver more effective outcomes.

Accounting for the unique challenges of stakeholders, contexts, and interconnectedness makes disaster response and management, as Comfort describes it, “a complex, adaptive system” (Comfort et al., 2010) which warrants examination through frameworks such as actor network theory (Thapa et al., 2017). Few reported innovations explicitly include stakeholders and other participants in their efforts. Kristensen used a participatory design approach to develop new ways of coordinating emergency personnel, interviewing practitioners and sociologists who had studied disaster response extensively (Kristensen et al., 2006). Particularly relevant to this discussion, Moshin proposed an aerial drone-enabled system to help first responders make decisions and collect information, co-designing it with frequent input from emergency responders (Mohsin et al., 2016). This type of human-centered design approach (see below) has been noted for helping teams adapt to complex conditions and create relevant solutions (Boy, 2012).

While this previous work highlights the potential for innovation in disaster response, and underlines the impact of a human-centered approach, these insights have not been incorporated into disaster-related education. Our contribution is to bridge the community of design, innovation practice, and education with the unique challenges of disaster response, to propose a new approach to innovation in the field.

2.2. Innovation as Learning Model

In 2007, Beckman and Barry proposed a framework for the innovation process that situates innovation as a learning process (Beckman and Barry, 2007), building on earlier work in experiential learning theory (Kolb, 2014, 2007) and on approaches to design (Owen, 1993). The framework (Figure 1) is built upon the dimensions that guide learning. In learning, as individuals or as teams, we toggle between taking in information from the concrete world (concrete experience) and making sense of information in our heads (doing abstract conceptualization). We further toggle between doing analysis work, or asking why and doing synthesis, which involves asking how or engaging in active experimentation (Kolb, 2007). Beckman and Barry proposed that this experiential learning framework can be used to guide and define the innovation process (Beckman and Barry, 2007). The four quadrants formed by this learning framework highlight the four activities in the innovation process: (1) Observing and Noticing, (2) Framing and Reframing, (3) Imagining and Designing, and (4) Experimenting to Learn.

In ***Observe and Notice,*** at the intersection of concrete experience and analysis, students take in information about the world around them to learn about people embedded in the problem or system of interest. Often described as the empathy quadrant, core tools for Observe and Notice include ethnographic interviews, qualitative data collection, participant observation, and informant diaries. In ***Frame and Reframe***, at the intersection of analysis and the abstract mode of learning, framing and reframing occurs when innovators look for patterns in the data collected from the Observe and Notice phase. Frame and reframe asks the individual or team to step back and consider ‘What is the problem to be solved?’ ultimately developing a new frame for the problem based on data collected in Observe and Notice. In ***Imagine and Design***, at the intersection of abstract thinking and synthesis, teams generate solutions to a given problem. Here, innovation entails diverging to generate a set of potential solutions, followed by converging to select from given options. Diverging means imagining a wide range of alternative futures in response to the problem frame developed earlier from Frame and Reframe. In ***Make and Experiment***, at the intersection of concrete experience and synthesis, teams experiment rapidly and use prototypes to test assumptions. This stage also critically involves soliciting feedback about potential solutions from real users or customers, users and other stakeholders.

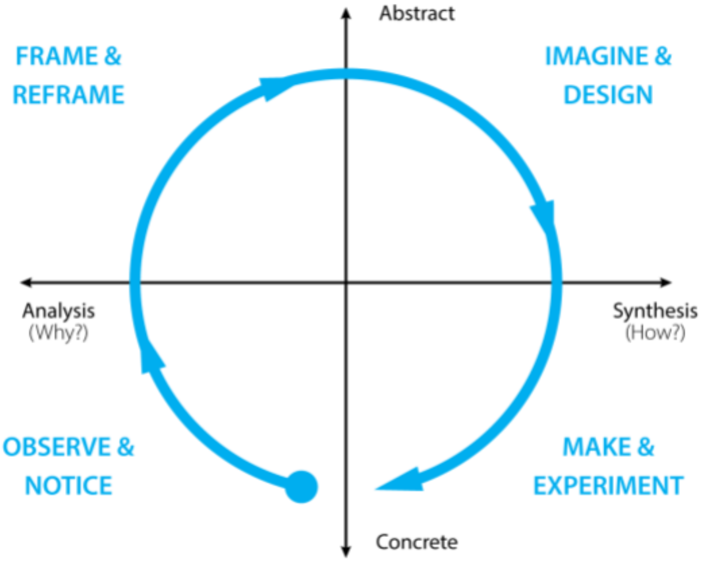

Figure 1. Innovation as a Learning Process Framework (Beckman and Barry, 2007)

Each phase of the innovation process requires a different set of mindsets, skillsets, and toolsets. Innovation education has the task of exposing students to each phase of the process and giving an opportunity to develop the mindsets, skillsets, and toolsets that are involved. Even when students have different levels of comfort with each phase, the important factor is helping them to recognize what phase of the innovation process they are in and why, in order to know where they might go next. While technologies might be highly adept at developing advanced prototypes, they also must be able to connect with potential users and articulate the problem to be solved if they are to become an effective innovator.

2.3. Project-based Service Learning in Design Education

Presenting engineering as a field that can serve a broader societal impact, in contrast to the technology-centric, has been established a key method to improve retention in engineering (Sochacka et al., 2014). Among approaches to bring engineers a focus on societal impact, Project-based Service Learning (PBSL), “... where students work on projects that benefit a real community or client while also providing a rich learning experience” (Bielefeldt et al., 2010) has shown encouraging outcomes.

In their review of PBSL experiences, Bielfeldt at al. found that PBSL improved retention in engineering students and voluntary participation in PBSL opportunities of women engineering students was higher compared to their representation in engineering overall. In a survey asking students to compare their service learning experiences with their traditional coursework-based learning, on average students reported 45% of their technical skill learning and 62% of their professional skill learning was acquired through their service learning opportunities. Furthermore, women engineering students reported service learning opportunities as the source of the technical and professional skills significantly higher than male students (Carberry et al., 2013). However, project-based learning (PBL), a generalized form of PBSL, is not without its challenges. Most notably, PBL is hindered by high time investment on students' and faculty's parts in project management and *knowledge application* rather than *knowledge acquisition* (Noordin et al., 2011). PBSL presents specific challenges, too: recent work has suggested that the management of partnerships with service organizations can be difficult to sustain and scale to larger classes, that it is unclear how PBSL generally delivers value to partner organization, and that often service-learning courses prioritize student learning over community impact (Brubaker et al., 2022; Choudhary and Jesiek, 2016; Thompson and Jesiek, 2017). Strategies to address these challenges include Pucha et al. scale-up of sociotechnical PBSL across a major university (Pucha et al., 2018) through the use of case studies.

3. Methods

3.1. Course Framework & Activities

Beckman and Barry's innovation as a learning process built on experiential learning theory and approaches to design inspired the innovation model for the course (Beckman and Barry, 2007; Owen, 1993). In our course, we augmented this learning model with curricular elements to establish three intended learning outcomes, that students will be able to:

(1) **assess and use** technical tools for prototyping, and **analyze** prototypes' effectiveness through tests;
(2) **give and receive** feedback to teams and themselves, and **structure** personal and shared goals;
(3) **develop** impactful and data-driven solutions to a complex sociotechnical challenge, and **account for** the unique constraints and context of disaster response, what we term *sociotechnical fluency*.

The course consisted of a structured process following the learning model and invoking a variety of design methodologies, including systems maps, ethnographic research methods, concept generation, and rapid prototyping. Throughout the semester, labs focusing on technology toolkits, which focused on relevant tools ranging from augmented reality prototyping with ARKit and ARCore to data science tools using Tableau, were delivered in the context of a class assignment.

3.2. Project-Based Learning: Design Project Topics

The overall project prompt for the class was to address a challenge in disaster response as a team using a structured design innovation approach. In 2020, prior to the launch of the course, the instructors convened framing sessions to solicit problem prompts from a collection of five diverse disaster response experts representing academia, industry and government. From these sessions, 13 problem prompts emerged; students voted on project topics resulting in six project teams: (1) Evacuation Enforcement and Optimization; (2) Sustainable Rebuilding; (3) Disinformation in Disasters; (4) Drone Imagery Prediction & Surveying; (5) Cash Disbursements; (6) Scanning for Survivors after Airframe Disasters.

In 2021, the course built on a university partnership to direct project-based learning experiences toward challenges related to United States National Security. The initiative has been described in detail in other venues (National Security Innovation Network: Hacking for Defense (H4D), 2019). Projects were scoped in partnership with a US Federal Government entity with a remit related to disaster response and recovery, and student teams were connected directly with their project sponsor and entity. Challenges included (1) Synchronizing Real-time Data en route to Disaster Response; (2) Preparing and Protecting Aircraft in Advance of Disaster Events; (3) Resilient and Robust Navigation During Disaster Response; (4) Digital Transformation for Disaster Response Teams; (5) Data

Acquisition for Search and Rescue Operations; (6) Awareness and Accounting of Personnel Post-Disaster.

3.3. Data Collection

Data collection was carried out under a protocol approved by the host university's institutional review board. At the end of the semester, students were required to complete a written course reflection assignment addressing five questions: (1) What did you learn most about yourself during the course?; (2) What did you learn most about or from others?; (3) How did the course shift your perspectives?; (4) What did the course help you learn about your life objectives?; (5) What do you think you could use from the class going forward? Prompts were designed explicitly not to inquire about technology or socio-technical fluency, as we sought to understand student experiences in their own words and as it related to their short- and long-term interests.

Three of the researchers participated in course learning activities as instructors. However, data collection and analysis was performed 18 months after the conclusion of the 2020 course, and 6 months after the conclusion of the 2021 course, so as not to influence student evaluations in each course and to minimize bias among researchers in analyzing course data. Across both courses, a total of 52 reflections were collected and reviewed by one member of the research team, who was a member of the instructional staff, and thematically analyzed for evidence of the key themes of technology and socio-technical fluency. Key quotes selected for and discussed in this manuscript represent themes with two or more supporting quotes identified, with one exception with a single quote (Quote 7, see Section 5.3).

4. Results

4.1. Course Enrollment Data & Outputs

Course enrollment information is summarized in Table I. In terms of majors, across both years the class was offered, Mechanical Engineering students represented 46% of enrollment; Development Practice students represented 17% of enrollment; Architecture and Planning students represented 12% of enrollment; Cognitive Science represented 8% of enrollment; other Engineering fields (not Mechanical) represented 6% of enrollment; Information Science represented 6% of enrollment; Business and Economics represented 6% of enrollment; and Public Health represented 2% of enrollment. Students with more than one declared concentration are counted twice in the above proportions, resulting in a total greater than 100%. The course ran for 16 weeks total.

Table 1. Final enrollments by class standing.

Topic	Category	2020 Total	2021 Total	% (both years, rounded)
Class Standing	Graduate	16	24	77
	Undergraduate	7	5	23

4.2. Design Process & Project Outcomes

Over the course of the semester, students completed a series of assignments aligning with the class curriculum. As described in Section 3.2, core to the class was a focus on learning from stakeholders and end-users. In 2020, students engaged with more than 60 stakeholders for in-depth insights on their problem space, including conversations with the former director of the National Transportation Safety Board; first responders at the local, state, and federal levels; and city managers and emergency preparedness coordinators. In 2021, aided by project sponsors, students interacted with more than 130 stakeholders, ranging from search and rescue first responders to senior leaders responsible for operations, administration, facilities, and other key facets of disaster response.

Synthesizing this information, teams proposed first a range of rough design artifacts, including sketches and diagrams, and then rough prototypes. These were used as the basis for further stakeholder research, findings from which ultimately helped each team narrow to a single conceptual solution supported by an illustrative prototype. In 2020, prototypes ranged from a decision-making framework for city emergency managers to a system for coordinating private operators' drones to observe wildfire events; in 2021, project results ranged from a data fusion system to combine disparate datasets at the onset of a disaster to an augmented reality heads-up display to help first responders navigate during fire events (Figure 2).

Figure 2. Representative early-stage prototypes developed in class, of a helmet-integrated AR system for first responders (top) and an app and data infrastructure service to direct evacuation planning (bottom).

5. Discussion

5.1. Course Enrollment

The course attracted a diversity of students, including a variety of majors. As an elective, the course was chosen freely by students. The course demographics align with other courses that position technology as one component of societal problem solving, rather than the sole focus (Dzombak et al., 2016), supporting previous findings about the role of social impact projects in drawing diverse audiences to STEM education (see Section 2.3).

5.2. The Ability to Contextualize the Role of Technology

In Disaster Response scenarios, technology can be an enabler, a constraint, or a complexifier - but is almost always a factor (Aitsi-Selmi et al., 2016). Helping students of both STEM and non-STEM backgrounds develop the creative confidence to engage with a diverse portfolio of technologies as problem-solving assets was essential to the vision of the course model. We sought to contextualize what is traditionally disciplinarily siloed technical knowledge and tools in a problem space and framework that, by necessity, deeply engages with human needs and complex systems. Through student reflection papers, we believe this approach has particular resonance and impact with multidisciplinary students working in the disaster response space. However, there remains much work to do. As one student wrote,

> *"... I always have a tough time learning a new technology or skill if it's something I'm unfamiliar with. I find the material very intimidating (e.g. data visualization), so that's why I found the strategy of proposing a goal or prototyping beforehand to be super helpful."* **(Quote 1)**

This particular student responded to the importance of contextualizing the use of technology in a clear hypothesis that the designer seeks to address. Grounding technology in an application, or a purpose, helped focus the student's acclimation to technical tools, and their confidence in leveraging those tools. This sentiment was nuanced by another student's commentary:

> *"I learned a lot about iterations and FIGMA which I had never heard of or used before. I thought it was nice to work with more engineers who were okay presenting a concept prototype instead of a fully fleshed out working prototype. I was worried about the technical skills needed to be successful in this course, but it was nice to learn about different solutions that did not fully rely on technology and more thought about creative solutions to the same problems."* **(Quote 2)**

Here, the student conveys some initial hesitation about the technical skills that would be required for this course and expresses the value of developing low-fidelity prototypes during the innovation process. The reconsideration of what constitutes a prototype is also exemplified in the following:

> *"The range of prototypes I imagine possible in design classes has undoubtedly been expanded due to [the course] ... Additionally, the few labs reintroduced me to tools I have used before but gave me the confidence to consider using them beyond the lab. For my last round of data analyses for research, Tableau helped create visualizations that I wanted firsthand before creating custom visualizations in R or Python."* **(Quote 3)**

This student shares the knowledge developed while completing the course lab assignments were useful beyond the course. The ability to transfer knowledge from one context to another is often used as a metric to evaluate learning outcomes and educational success (Bransford and Schwartz, 1999).

5.3. Socio-technical Fluency

We additionally had the goal of students developing what we termed sociotechnical fluency: feeling as comfortable engaging with technology as they do working with social systems that contextualize technology in disaster scenarios, and that are mandatory for its success. The challenge for students was to simultaneously embrace complexity, identify opportunities to drive change, and understand how to design a technical solution that addressed stakeholder needs:

> *"... [a] working prototype is awesome, but just that by itself isn't enough – you need so many people in so many different focuses to make a project succeed ... I enjoyed puzzling out where the different pieces of the project came together to get the information needed to support designs."* **(Quote 4)**

This student emphasizes, unprompted, the importance of context in delivering not just a working prototype, but a successful project in the context of disaster response. The distinction between the two, and their mutual interplay is critical for design success. Another student expanded on this sentiment:

> *"This course was an eye opening experience for my perspective on how difficult it can be to generate innovation in a large organization... This shifted my perspective on what a solution actually is. I had not considered or worked on the adoption and integration of my solution into the world simply because I always believed the right*

> *solution just slides into place. This was a unique experience to see how 'good engineering' does not always make 'good solutions.'"* **(Quote 5)**

The distinction between "good engineering" and "good solutions" made by this student illustrates the need to evaluate any potential solution within the social system it will be implemented in. Adoption and integration, and their importance in innovation, are described by the following student:

> *"The course shifted my perspective on the way technology and disaster response interact... The goal of using technology to save lives comes from a place of genuine hope, but the regulatory, technological, and political hurdles that emerge when trying to implement technology make it extremely difficult to implement."* **(Quote 6)**

This student articulates the importance of understanding and navigating the complexities of the social system they are developing a solution for. They further express the importance of critically evaluating potential solutions for unintended negative implications, even for solutions being developed with altruistic motives, such as saving lives.

Several students surfaced arguments similar to contemporary critiques of human-centered design and design innovation methods, such as that while HCD seeks to invite new voices to the design process, it often simultaneously exclude voices ("On Design Thinking," 2019). One student wrote:

> *"I would have loved to hear from people willing to share their stories about their experiences with disasters, or sociologists investigating the ways in which our social structures affect disaster response. There are people outside the tech world doing the work as we speak ... those are the people worth working with first."* **(Quote 7)**

This comment extends dialogue about *contextualizing technology* to *balancing technologists' perspectives* with the experiences of individuals whose experiences and expertise are grounded in the lived experience and social structures surrounding disaster response.

5.4. Implications for Design Education & Design Research

These findings highlight several opportunities for the design education and research communities. In terms of design education, we see three implications. First, to address the salient connection between solutions and stakeholder contexts, we invite the design education community and problem domain-specific communities - e.g., the disaster response community for our course - to contextualize resources, information, and project outputs with the stakeholders, problems, and systems constituent information relates to. Successfully bridging this gap would set a foundation for addressing the opportunities identified by Thompson and Jesiek and Choudhari and Jesiek to improve partnership outcomes in PBSL (Choudhary and Jesiek, 2016; Thompson and Jesiek, 2017).

Second, to address holistic exploration and sociotechnical fluency, we invite the design education community to consider how to elevate voices that are often left out of the dialogue around innovation in disaster response: beyond first responders and technologists, are there ways to incorporate disaster victims, social entrepreneurs, and community organizers into this dialogue? Human-centered design and innovation is only as effective as the individuals considered and listened to in the design process.

Third, we believe the power of sociotechnical challenges to contextualize and motivate technical learning is an emerging opportunity for the broader design education community. This is especially true as designers are increasingly asked to develop product-service systems and sociotechnical systems (Ceschin and Gaziulusoy, 2016). There is a rich opportunity for the design education community to take leadership of how technology education can be even more impactful and drive more meaningful student outcomes by engaging with sociotechnical challenges.

In terms of design research, two central questions arise from this work. First, we observe from this that the emphasis on context and sociotechnical systems influences designers' behaviors and reflections. This invites the question, how do traditional models of design cognition - such as the Function, Behavior, and Structure model (Gero and Kannengiesser, 2004) - account for emergent behaviors in complex sociotechnical design challenges? Second, how generalizable are design approaches and methodologies across sociotechnical design challenges? In our course, we focused on a highly specific problem space, disaster response. Replicating our findings across other sociotechnical challenges such as cybersecurity or sustainability (Oehlberg et al., 2010; Rao et al., 2020) would add rich insight to the ongoing research conversation on this theme. Here, Pucha et. al's scale-up of freshman-year socio-technical PBSL experiences (Pucha et al., 2018) presents a model for further investigation.

6. Conclusions

In this work, we describe an interdisciplinary, project-based design design course developed and delivered at a major research university that explored challenges in disaster response. By examining 52 student end-of-course analysis over two separate offerings of the course, we identified three salient themes that emerged about key takeaways students derived from the class to address sociotechnical challenges: technical toolkits, sociotechnical fluency, and individual and team reflection. These findings suggest rich opportunities for PBSL to enhance design and learning outcomes, and a corresponding design research agenda to support it.

Acknowledgements

The authors are grateful for the support of [redacted for blind submission] at [redacted for blind submission]. The authors also gratefully acknowledge support from [redacted for blind submission], [redacted for blind submission], and [redacted for blind submission], for their support in helping identify, scope, and establish projects for the course in the years studied in this paper.

References

Aitsi-Selmi, A., Murray, V., Wannous, C., Dickinson, C., Johnston, D., Kawasaki, A., Stevance, A.-S., Yeung, T., 2016. Reflections on a science and technology agenda for 21st century disaster risk reduction. International Journal of Disaster Risk Science 7, 1–29.

Beckman, S.L., Barry, M., 2007. Innovation as a Learning Process: Embedding Design Thinking. California Management Review 50, 25–56. https://doi.org/10.2307/41166415

Bielefeldt, A., Paterson, K., Swan, C., 2010. Measuring the Value Added from Service Learning in Project-Based Engineering Education. International Journal of Engineering Education 26, 535–546.

Boy, G., 2012. Orchestrating human-centered design. Springer Science & Business Media.

Bradforth, S.E., Miller, E.R., Dichtel, W.R., Leibovich, A.K., Feig, A.L., Martin, J.D., Bjorkman, K.S., Schultz, Z.D., Smith, T.L., 2015. University learning: Improve undergraduate science education. Nature News 523, 282.

Bransford, J.D., Schwartz, D.L., 1999. Chapter 3: Rethinking transfer: A simple proposal with multiple implications. Review of research in education 24, 61–100.

Brubaker, E., Trego, M., Cohen, S., Taha, K., 2022. Partnerships Compass: Guiding Questions for Equitable and Impactful Engineering Community-Engaged Learning. Advances in Engineering Education In Press.

Buchanan, R., 1992. Wicked problems in design thinking. Design issues 8, 5–21.

Carberry, A.R., Lee, H.-S., Swan, C.W., 2013. Student Perceptions of Engineering Service Experiences as a Source of Learning Technical and Professional Skills. International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship 8, 1–17. https://doi.org/10.24908/ijsle.v8i1.4545

Ceschin, F., Gaziulusoy, I., 2016. Evolution of design for sustainability: From product design to design for system innovations and transitions. Design Studies 47, 118–163. https://doi.org/10.1016/j.destud.2016.09.002

Choudhary, N., Jesiek, B.K., 2016. Community partners' perspectives on the outcomes from international Service-learning programs: Project scope and method, in: 2016 IEEE Frontiers in Education Conference (FIE). Presented at the 2016 IEEE Frontiers in Education Conference (FIE), pp. 1–4. https://doi.org/10.1109/FIE.2016.7757499

Comfort, L.K., Boin, A., Demchak, C.C., 2010. Designing Resilience: Preparing for Extreme Events. University of Pittsburgh Pre.

Coronese, M., Lamperti, F., Keller, K., Chiaromonte, F., Roventini, A., 2019. Evidence for sharp increase in the economic damages of extreme natural disasters. Proceedings of the National Academy of Sciences 116, 21450–21455.

Cropley, D.H., 2015. Promoting creativity and innovation in engineering education. Psychology of Aesthetics, Creativity, and the Arts 9, 161.

Dixon, B., Murphy, E., 2016. Educating for appropriate design practice: Insights from design innovation. Design Management Journal 11, 58–66.

Duffy, J.J., Barrington, L., Heredia, M.A., 2011. Attitudes of engineering students from underrepresented groups toward service-learning, in: 2011 ASEE Annual Conference & Exposition. p. 22.263. 1-22.263. 29.

Dym, C.L., Agogino, A.M., Eris, O., Frey, D.D., Leifer, L.J., 2005. Engineering design thinking, teaching, and learning. Journal of engineering education 94, 103–120.

Dzombak, R., Mouakkad, S., Mehta, K., 2016. Motivations of Women Participating in a Technology-Based Social Entrepreneurship Program. Advances in Engineering Education 5.

Gero, J.S., Kannengiesser, U., 2004. The situated function–behaviour–structure framework. Design Studies 25, 373–391. https://doi.org/10.1016/j.destud.2003.10.010

Güiza, F., Simmons, P., Burgess, J., McCall, M.K., 2016. Chronic institutional failure and enhanced vulnerability to flash-floods in the Cuenca Altadel Río Lerma, Mexico. Disasters 40, 112–133.

Hirsch, P.L., McKenna, A.F., 2008. Using reflection to promote teamwork understanding in engineering design education. International Journal of Engineering Education 24, 377.

Kolb, D.A., 2014. Experiential learning: Experience as the source of learning and development. FT press.

Kolb, D.A., 2007. The Kolb learning style inventory. Hay Resources Direct Boston, MA.

Kristensen, M., Kyng, M., Palen, L., 2006. Participatory design in emergency medical service: designing for future practice, in: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI '06. Association for Computing Machinery, New York, NY, USA, pp. 161–170. https://doi.org/10.1145/1124772.1124798

Lande, M., Leifer, L., 2009. Classifying student engineering design project types, in: Proceedings, American Society for Engineering Education Pacific Southwest Regional Conference, San Diego, California. pp. 13–19.

Mohsin, B., Steinhäusler, F., Madl, P., Kiefel, M., 2016. An Innovative System to Enhance Situational Awareness in Disaster Response. Journal of Homeland Security and Emergency Management 13, 301–327. https://doi.org/10.1515/jhsem-2015-0079

National Academy of Engineering, U.S., 2004. The engineer of 2020: Visions of engineering in the new century. National Academies Press Washington, DC.

Noordin, M.K., Skudai, M., Malaysia, J., Nabil, A., Md Nasir, A.N., Farzeeha, D., Teknologi, A., Nordin, M., 2011. Problem-Based Learning (PBL) and Project-Based Learning (PjBL) in engineering education: a comparison.

Oehlberg, L., Shelby, R., Agogino, A., 2010. Sustainable product design: Designing for diversity in engineering education. International Journal of Engineering Education 26, 489.

On Design Thinking, 2019. . n+1. URL https://www.nplusonemag.com/issue-35/reviews/on-design-thinking/ (accessed 11.14.21).

O'sullivan, T.L., Kuziemsky, C.E., Toal-Sullivan, D., Corneil, W., 2013. Unraveling the complexities of disaster management: A framework for critical social infrastructure to promote population health and resilience. Social Science & Medicine 93, 238–246.

Owen, C., 1993. Considering design fundamentally. Design Processes Newsletter 5, 2.

Pucha, R., Thurman, C.J., Yow, R., Meeds, C.R., Hirsch, J., 2018. Engagement in Practice: Socio-technical Project-based Learning Model in a Freshman Engineering Design Course. Presented at the 2018 ASEE Annual Conference & Exposition.

Rao, V., Kim, E., Jung, H.J., Goucher-Lambert, K., Agogino, A., 2020. Design for Cybersecurity (DfC) Cards: A Creativity-Based Approach to Support Designers' Consideration of Cybersecurity, in: Proceedings of the 9th International Conference on Design, Computing, and Cognition DCC'20. Presented at the Design, Computing, and Cognition 2020, Atlanta, GA.

Shiwaku, K., Fernandez, G., 2011. Innovative approaches in disaster education, in: Disaster Education. Emerald Group Publishing Limited.

Sochacka, N., Walther, J., Wilson, J., Brewer, M., 2014. Stories 'Told' about engineering in the Media: Implications for attracting diverse groups to the profession, in: 2014 IEEE Frontiers in Education Conference (FIE) Proceedings. Presented at the 2014 IEEE Frontiers in Education Conference (FIE) Proceedings, pp. 1–9. https://doi.org/10.1109/FIE.2014.7044009

Thapa, D., Budhathoki, N., Munkvold, B., 2017. Analyzing Crisis Response through Actor-network Theory: The Case of Kathmandu Living Labs. Communications of the Association for Information Systems 41. https://doi.org/10.17705/1CAIS.04119

Thompson, J.D., Jesiek, B.K., 2017. Transactional, Cooperative, and Communal: Relating the Structure of Engineering Engagement Programs with the Nature of Partnerships. Michigan Journal of Community Service Learning 23, 83–99.

UNISDR, C., 2015. The human cost of natural disasters: A global perspective.

Zhou, C., 2012. Fostering creative engineers: a key to face the complexity of engineering practice. European Journal of Engineering Education 37, 343–353.