Laying the Foundations of a Learning Platform for Humanitarian Engineering: Methodological Approach and Results

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Introduction

Humanitarian engineering (HE), global and local service learning, and similar courses and programs have increasingly appeared in U.S. engineering schools[1], in part because they allow institutions to meet accreditation requirements. At the same time, such experiences can provide students with opportunities to develop a wider variety of desirable competencies[2,3,4], while opening up pathways for engineering programs to positively impact communities in need. Yet while there is broad consensus on the benefits of local community engagement programs in engineering schools, scholars express contrasting views regarding activities and placements of students in communities abroad[5,6,7]. Additionally, many humanitarian projects have failed over the years because they do not properly involve community members and do not take into account the cultural, social, historical, and political realities where projects are undertaken.[8] This can create tensions between the needs of university programs and their partner communities, which often is resolved in favor of students' learning, increasing the likelihood that partner communities are left with inappropriate and unusable solutions.[6]

To address these tensions and make sure that communities also benefit from these programs, many scholars have proposed elaborate frameworks and philosophical commitments to inform the practice of humanitarian engineering projects. For instance, Amadei and colleagues published a model comprising 10 guiding principles for Sustainable Humanitarian Engineering projects. [9] The principles stress the importance of following ethical and professional codes and collaborating with a wide range of internal and external stakeholders. Another model for HE is Engineering for Social Justice (E4SJ)[10] which provides six SJ criteria to guide HE and similar engineering practices. These frameworks are very useful guides that can bolster the chances of success of HE and similar projects.

While the humanitarian engineering and similar literature is abundant with theoretical models and frameworks, there are only a few field guides that can help translate the principles into practice. For instance, Baillie and colleagues provide a processes to assess needs and feasibility of transferring technology into a disadvantaged community. [11] Additionally, Mihelcic and colleagues developed a field guide for environmental engineers working in developing countries, which provides a set of methods for interacting with communities and instructions related to specific technologies.[12] IDEO's human-centered design toolkit is also often cited as a practical guide for humanitarian engineering and similar projects. Casting a wider net, useful resources can be found in the international development literature. Yet, the extant literature is still missing a comprehensive repertoire of field-tested methods, including how such methods might be compared, contrasted, and integrated, making them available and useful to both novices and experts engaged in humanitarian engineering projects.

To fill this gap and address shortcomings of current HE projects, we undertook a research project that lays the foundations for a learning platform or a toolkit which students, faculty, and professionals involved with HE projects can consult to learn about methods that may facilitate community participation while at the same time achieving many of the tasks required during an HE design project. The research questions that guided this study were:

1. What are the key characteristics of specific design methods that have been used/proposed in the HE and related literature?
2. What are other conditions (e.g., philosophical commitments, culture of the community, engineers' skills and mindsets, and others), not specific to any design stage, may facilitate meaningful community participation?

In this paper we present the methodological approach used to answer the research questions and share representative results of each research phase. More specifically, we start by discussing Boyer's notion of the "scholarship of Integration" (SoI) which served as the methodological framework for this study.[13] Second, we discuss the methods used in the two major phases of the research project and present select results. Finally, we present the results of integrating the findings from the two phases, namely in the form of information sheets for two design methods. In sum, the main contributions of this paper are: 1) the discussion of the methodological approach of our study that could be transferred to other contexts, and 2) the example information sheets that resulted from the integration of the multiple findings of the two main phases of our research project. And while this study is specifically focused on humanitarian engineering, this paper may be of interest to any scholar wanting to learn more about SoI and strategies for translating research into practice.

Methodological Framework: Scholarship of Integration

This research study was grounded in the scholarship of integration (SoI). Boyer defines SoI as "serious, disciplined work that seeks to interpret, draw together and bring new insight to bear on original research" (p. 19)[13], and adds that it is "interdisciplinary, interpretive, integrative" (p. 21).[13] Additionally, SoI is use-inspired, that is, it pursues the "double quest for fundamental understanding […] and practical considerations" (p. 11)[14], thus going beyond being just a synthesis of interdisciplinary knowledge and practices.

Although Boyer proposed SoI as one of four types of scholarship (alongside application, teaching and learning, and discovery), SoI has received less attention and is still outside the mainstream of educational scholarship.[14] Yet, a few notable examples are worth citing, especially in the engineering design education area. Crismond and Adams, for instance, used SoI to synthesize literature on design teaching and learning and develop the well-known Informed Design Teaching and Learning Matrix.[15] Additionally, Fleming and Prichett[16] and Coso[17] created frameworks to understand design processes related to aerospace engineering by integrating interdisciplinary knowledge and practices. While SoI efforts have traditionally consisted of systematic literature reviews and meta-syntheses, other SoI work has also leveraged interviews and surveys.[17,18] The common denominator for all of the SoI we are aware of is that they are: 1) interdisciplinary, 2) iterative, 3) integrative, and 4) use-inspired.[14]

In this specific study, SoI was a particularly appropriate theoretical framework because we knew that many methods had been published in peer-reviewed journals, books, field guides, and other sources, but we realized the lack of a framework to integrate these methods and no prior efforts to collect the experiences of practitioners who use such methods. Thus, the SoI approach enabled us to integrate information from multiple sources (i.e., literature and practitioners) in one cohesive product: the information sheets presented at the end of this paper. To achieve this goal, we devised a study that was aligned with the philosophical commitments of SoI by drawing from interdisciplinary knowledge, utilizing highly iterative and integrative methods, and maintaining a use-inspired goal of developing a learning platform or toolkit that students, educators, and professional engineers can access to learn about strategies and methods that can enhance their partnerships with communities.

Specifically, we organized the study in three phases as illustrated in Figure 1. The first phase focused on integrating methods from the existing literature. Consequently, we undertook a systematized literature review to identify 64 methods that have been used, or proposed to be used, in humanitarian engineering or similar types of projects. We then developed a two-dimensional framework to classify the methods. In the second phase, we interviewed 14 practitioners to learn about the nuts-and-bolts of using these methods in the field. Methods and results of these two phases are briefly discussed in the next sections of this paper, while the details of the methods and the full results can be found in other publications.[19].

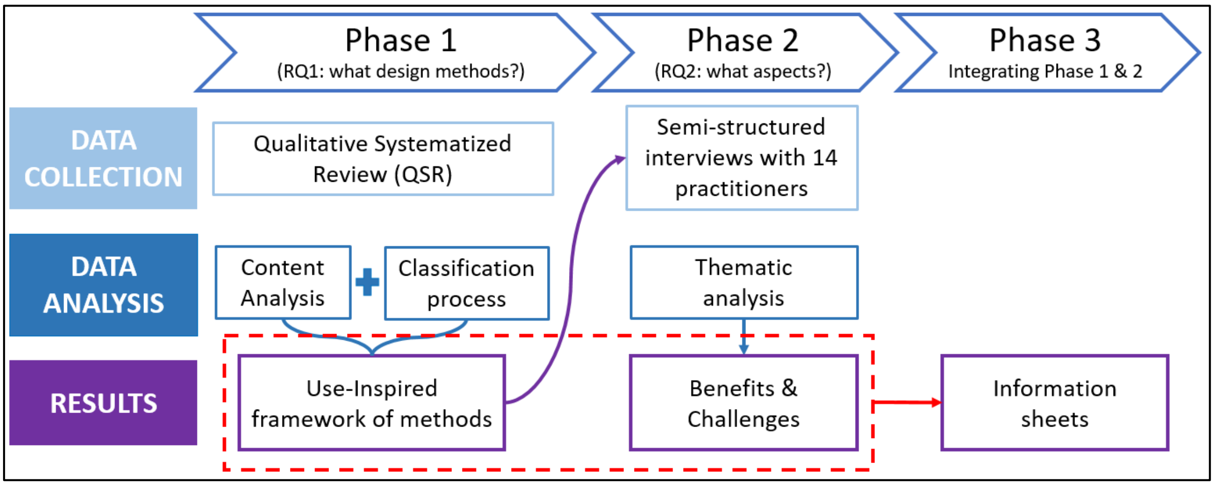


Figure 1. Study design

Phase 1: Developing the Classification System

The goal of the first phase of the research project was to identify design methods that have been used or proposed to be used in HE and similar projects. While detailed descriptions of methods and full results are reported elsewhere[19], below we provide a brief overview of our data collection and analysis processes for this phase and the final framework, which was then integrated in the information sheets presented at the end of the paper.

Data collection. To ensure that a large enough sample of methods was gathered, we used a systematized literature review process. As suggested by Borrego and colleagues[20], we followed the PRISMA selection process to search for and select potentially relevant papers. First, we defined three inclusion criteria:

1. The papers needed to focus on the social or procedural aspects of small scale HE projects, such as:
    a. Frameworks, methodologies, processes, approaches, principles, or collections thereof,
    b. Methods, tools, techniques, dimensions, mindsets,
    c. Lessons learned, and/or
    d. Case studies focused on small-scale or community-based projects.
2. The papers were peer-reviewed journal papers.
3. The papers were published between 1992, or when the first EWB chapter was established[21] and August 2015 (when this literature search was conducted).

We next initiated our literature search, which included three phases: 1) database search, 2) title and abstract screening, and 3) full text appraisal. More details are provided in a previous works.[19] At end of each phase, we asked several other researchers to apply our strategies for inclusions to a subset of papers. Inter-rater reliability provided satisfactory results (Cohen kappa above 0.7 in all cases, which is considered “substantial” agreement[22]) and allowed us to better refine our search and strengthen our procedures. Following this process, we obtained a final set of 48 papers. Some of these papers discussed one or more design methods. For instance, Leydens and Lucena included discussion of methods such as “Privilege by Numbers” and the “Design Evaluation Matrix on Human Capabilities.”[10] Other papers instead cited manuals that contained several methods useful for designing in the context of HE projects. For instance, Amadei and colleauges[9] suggested that humanitarian engineers could use Beebe’s guide on rapid rural assessment[23] to support their field trips. After extracting methods from the retrieved journal articles and cited manuals, we obtained a final set of 64 methods that we analyzed to produce the classification system of methods.

Data analysis. The process for developing the final classification system of methods was grounded in Nickerson and colleagues’ process for developing taxonomies.[24] This process is very iterative, requiring both deductive and inductive analysis of the objects that are being classified. The analysis of the objects in turn leads to the development of dimensions along which the objects are classified. In the case of this study, the objects being classified were the 64 methods, and we used a qualitative content analysis approach to extract the classification dimensions from the methods. Once we developed a solid draft of the classification system, we asked research colleagues to classify a set of randomly selected methods. The inter-rater reliability scores (Cohen’s kappa greater than 0.7) and the consequent discussion led us to develop the final version of the classification system, briefly presented in the section below.

Results. The results of the classification and analysis process led to a framework represented by a 3x3 matrix that organizes methods based on 1) level of community participation, and 2) design phases (fully discussed in another publication). The analysis of the methods showed that the methods could be organized in three hierarchical levels of community participation:

1. *Passive:* Community participation is not required. These methods typically prepare engineers to conduct fieldwork. For instance, one of such methods is secondary research (Beebe, 2001) in which information is retrieved from secondary sources.
2. *Consultative:* Engineers elicit relevant information from community members. A typical example of a consultative method is semi-structured interviews.[23,25-27]
3. *Co-constructive:* Engineers act as facilitators, working with community members to co-produce an artefact. A typical example of a co-constructive method is participatory mapping, in which community members draw a map of their community with facilitation provided by engineers (or other professionals).[25,26]

The second dimension is organized around three broad design phases: 1) problem framing and planning, 2) information gathering, and 3) problem solving. Within each phase, the methods are organized in groups based on their specific function:

1. *Problem Framing and Planning:* Methods in this category allow engineers to: 1) understand a problem, 2) formulate objectives, 3) rank problems and objectives, and 4) create project plans. An example of a method in this category is “Gaps and Conflicts” by Chevalier and Buckles.[28] With this technique, engineers can understand if the problem at

hand is "mostly about gaps or conflicts in power, interests (gains and losses), moral values, or information and communication" (p. 133).
2. *Information Gathering:* Methods in this category allow engineers to: 1) learn about socio-cultural and political aspects of the community, 2) identify and characterize stakeholders, and 3) map the community. An example of this category is "Wealth Ranking"[26], which can help an engineer understand the distribution of wealth and resources in a community.
3. *Problem solving:* Methods in this category allow engineers to: 1) ideate and prototype a solution, and 2) evaluate and select solutions. An example in this category is Leydens and Lucena's "Design Evaluation Matrix on Human Capabilities,"[10] in which engineers select a solution based on its potential to enhance human capabilities of a community.

Table 1 reports the total number of methods identified as belonging to each level of community participation and each design phase.

Table 1. Number of methods in each dimension[19]

	Levels of community participation			
Project phases	Passive	Consultative	Co-constructive	Total
Problem Framing & Planning	6	1	10	17
Information Gathering	9	13	10	32
Problem Solving	10	3	2	15
Total	25	17	22	64

Phase 2 – Insights from practitioners

While the first phase focused on the methods and their characteristics, the complimentary second phase of the study investigates the nuts-and-bolts of using these methods in the field. Here we summarize our data collection and analysis strategy and give sample findings.

Data collection. To learn about how the collected methods have been used in the field, we interviewed 14 practitioners who were selected based on three criteria: 1) had experience with at least one HE or similar project from start to finish, 2) had worked on an HE project in the last 5 years, and 3) had an engineering background or have worked closely with engineers. Through a purposive and snowballing selection process, we recruited 14 practitioners. Four were professional engineers who volunteer their time for an international HE non-governmental organization (NGO), one worked full time for an international HE NGO, and the other nine are faculty members who work as adviser in international service-learning programs. The full list of participants is available in another publication[19].

The participants were additionally offered the option to maintain the copyright on their transcripts, and thus to have their identity unconcealed. The process of transferring the copyright of interview transcripts to the original interviewee is known as "Radically Transparent Research" (RTR) and was developed by Mel Chua.[29] RTR is an "emergent qualitative research methodology inspired by the radical real-time transparency practices of open communities such as Free and Open Source software, hardware, and content projects" (par 1).[30] The process is very similar to traditional interview research, but additionally involves the possibility of publishing interview transcripts under a Creative Common license in the interviewee's name. The procedure is as follows:

1. Interviewer explains the process and offers interviewee option to: A) maintain copyright or B) remain anonymous.

2. Interview proceeds as usual.
3. Interviewer transcribes interview and sends transcript to interviewee.
4. Interviewee reads transcript and modifies as he/she sees fit. Interviewee is free to delete sections that they do not want to be made public, and rephrases any part of the transcript to more appropriately or accurately represent his/her own ideas.
5. Interviewee releases transcript under Creative Common license to interviewers.

The interviewer then analyzes the data and when publishing the results cites quotes from the transcripts using proper citation style as he/she would if citing any other type of publication.

In this study, the RTR procedure was chosen because we recognized that the knowledge shared by the practitioners belonged to them and we needed a proper way to attribute that knowledge. Of the 14 practitioners we interviewed, 10 elected to release their transcript under a Creative Common license. Three of them accepted at the beginning, but then did not have time to review transcripts so asked to remain anonymous. The other practitioner decided not to publish his transcript under Creative Common license and requested to retain anonymity when the interview began.

Data analysis. The transcripts were analyzed using an iterative, inductive Thematic Analysis (TA) approach.[31] First, we read through all of the transcripts and annotated possible codes along the way. Second, we created an initial codebook based on the memos and re-analyzed the transcript using the new codebook. Third, we further refined the codes and created the final themes that emerged from the analysis.

Findings. The thematic analysis of the transcript allowed us to identify two main themes, namely benefits and challenges associated with using the methods collected during phase 1. In terms of benefits, all of the participants reported that co-constructive methods were especially useful to more effectively engage community members. Most importantly, co-constructive methods were described as good icebreakers with the potential to help build trusted relationships with partner communities. For instance, professor Mark Henderson (one of the practitioners we interviewed) reported that using “Participatory Mapping” has often helped him create a comfortable environment in which community members felt free to share what they had in their minds:

> Some great experiences we've had is that when we're doing the [participatory] maps and things like that, some of the community members will actually get in arguments themselves about where to put things on the map. That means that they're relaxing around us; that means that they're comfortable disagreeing with each other (p. 7).[32]

Other practitioners shared similar experiences when using co-constructive methods similar to participatory mapping.

As a second major theme, practitioners reported four specific types of challenges that humanitarian engineers may encounter trying to use these methods, namely: 1) practical, 2) communication, 3) cultural, 4) and ethical. Although co-constructive methods tend to offer the greatest benefits, they also involve practical challenges because they require a larger amount of resources, including materials, facilities, favorable climate, cost, and most importantly community members’ time. Communication and cultural challenges are closely related and apply to both consultative and co-constructive methods. Among the 64 methods, "Wealth Ranking" was one that many recognized as culturally challenging. For instance, professor David Frossard (another of our practitioners) reports that "Wealth Ranking" can create an atmosphere that is not favorable to create harmonious collaborations:

> Wealth ranking, I've only done that as a social scientist and it's really touchy, in a lot of places. Because when you make the wealth differences apparent, it sort of implies that things are a bit unfair. And the people on the top get uncomfortable, the people at the bottom sort of like it, but it doesn't really build camaraderie (p. 17).[33]

Finally, practitioners recognized that some of these 64 methods, especially those involving photography, may present ethical problems related to collecting and handling data associated with a community. In sum, this second phase of the study allowed us to identify aspects of using the methods that may help engineers more effectively identify and use the methods. The last step of this study was to integrate the findings of the two phases.

Phase 3 - Integrating phase 1 and phase 2

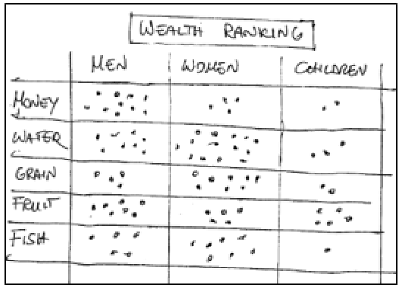
The first phase of this project allowed us to collect 64 methods and create a classification system characterizing the methods based on level of community participation and when it is most appropriate to use them in the design process. While this process was very useful to get a theoretical understanding of the mechanics of each method collected, it did not provide us with much information regarding the actual use of the methods, including possible benefits and limitations. To address this gap in our evidence, we interviewed 14 practitioners during the second phase of the research project. The critical incidents and insights shared by the practitioners revealed benefits and challenges of many of the methods collected.

The last phase of this project was the one with the strongest use-inspired component as we needed to find a way to translate the information collected into artifacts that could be usable by students, educators, and professionals. To achieve this goal, we looked at previous attempts to create use-inspired artifacts to support engineers in designing solutions. We ultimately took an approach similar to IDEO's toolkit[27] and the Design Heuristics Cards[34] (DHC). Both of these resources present methods using a common template, i.e., a name or title, a picture to provide a visualization of the method, and a description of the method. We used a similar use-inspired concept to develop information sheets that integrated the findings from the two preceding phases. Each information sheet includes seven pieces of information: 1) name of the method, 2) the purpose of the method, 3) a visualization of the method, e.g., a representation of the final outcome or a representation of the process, 4) which project stage and participation level the method belongs to, 5) a brief description of the process (i.e., steps), 6) insights (positive or negative) from practitioners, and 7) links to original sources. Items 1-5 and 7 were gathered during phase 1, while item 6 was gathered during phase 2.

In Figures 2 and 3 we provide information sheets for two methods: Wealth Ranking and Participatory Mapping. We decided to show the information sheets for these methods because many of the practitioners agreed that the former was usually culturally insensitive (although one of the practitioner acknowledged that there might be times when it could be appropriately used), while the latter was praised by many practitioners as a very effective icebreaker, a good tool to start building a relationship with a community, and a way to get more precise information regarding the way the community members see their own community.

Wealth Ranking

Purpose: to understand the wealth and the distribution of resources within communities.



Project stage:
Problem framing and planning
Information gathering
Problem solving

Community participation:
Passive
Consultative
Co-constructive

Steps:
1. Discuss concept of wealth with community members
2. Discuss appropriate unit to rank (individuals, households…)
3. Participant pile stones or beans proportionally to the wealth of each unit to rank
4. The outcome is a sort of matrix like the one in the picture above.

Insight from a practitioner: often culturally inappropriate!

"**it's really touchy**, in a lot of places. Because when you make the wealth differences apparent, it sort of implies that things are a bit unfair. And the people on the top get uncomfortable, the people at the bottom sort of like it, but **it doesn't really build camaraderie**, let's say." (David Frossard, 2015)

Links to original sources:
Description: http://www.crs.org/sites/default/files/tools-research/rapid-rural-appraisal-and-participatory-rural-appraisal.pdf

Figure 2. Information Sheet for Wealth Ranking

Participatory mapping

Purpose: to map the territory of the community

Project stage:
Problem framing and planning
Information gathering
Problem solving

Community participation:
Passive
Consultative
Co-constructive

Steps:
1. Clear a large open area on the ground
2. Facilitator draws one or two landmarks (roads, major buildings…)
3. Community members continue completing the map as a group.
4. Facilitators step back and do not intervene until map is completed

Insights from practitioners: great icebreaker!

Some great experiences we've had is that when we're doing the maps and things like that, some of the community members will actually get in arguments themselves about where to put things on the map. **That means that they're relaxing around us; that means that they're comfortable disagreeing with each other.** (Mark Henderson, 2015)

Links to original sources:
Description: http://www.crs.org/sites/default/files/tools-research/rapid-rural-appraisal-and-participatory-rural-appraisal.pdf

Figure 3. Information Sheet for Participatory Mapping

Discussion and Conclusion

In this paper we presented the methodological approach and the final outcome from a Scholarship of Integration (SoI) approach to build the foundation for a learning platform or a toolkit of methods for humanitarian engineering students, scholars, and professionals. The SoI provided the ideal methodological framework for our study as it aligned well with our goal of integrating existing knowledge across disciplines and sources with a use-inspired purpose. Yet while Boyer proposed four types of scholarship, including SoI, he did not provide a standardized approach to conduct SoI and the literature still lacks such a framework (assuming one is needed). Therefore, in this study, we had to select procedures and methods that aligned with both our project goals and the philosophical commitments of SoI.

In this study, we more specifically carried out two data collection and analysis phases. The first phase involved collecting and analyzing existing methods. This approach is quite similar to other SoI studies[35]. For instance, many engineering education scholars synthesized existing literature in order to create their use-inspired, interdisciplinary frameworks[15,16, 36]. However, SoI can also use other methods, including interviews.[17,18] Similar to other SoI efforts[17,18], we recognized the need to bring in perspectives of practitioners to integrate real life accounts of using the methods we collected. Additionally, we leveraged Radically Transparent Research (RTR) to properly attribute and share the accounts of the interviewed practitioners. The combination of literature synthesis and interviews allowed us to strengthen our study.

A major challenge that we encountered during the study was related to ensuring proper levels of quality for the study. The challenge arises from the fact that Boyer did not provide any specific guidelines or procedures for conducting SoI projects to ensure rigor, and guidelines from other scholars remain limited.[14] In our case, we used two main strategies to promote quality. First, we designed the study to be well-aligned with the four principles of SoI (interdisciplinary, integrative, iterative, use-inspired). To ensure interdisciplinarity, we collected methods from multiple disciplines and interviewed engineers and non-engineers. The integrative principle was achieved through the use of integrative methods (e.g., developing taxonomies[24]) to analyze and synthesize data. Each project phase required multiple iteration to produce the presented results and the future work will require us to conduct additional iterations to further develop the framework and toolkit. Finally, we maintained a use-inspired approach by seeking fundamental understanding (evidenced by the development of the methods classification system during phase 1, typology of benefits and challenges during phase 2, and usability of results through creation of information sheets).

The second strategy was to abide to quality standards and guidelines related to all the specific research methods we used. In the first phase, we follow as closely as possible all the guidelines suggested for both the systematized literature review and the iterative process of developing classification systems. For instance, in both cases we used an inter-rater evaluation process to increase the reliability of the final results. The second phase was more qualitative, so we followed the eight “Big-Tent” criteria for excellent qualitative research[37]. For instance, to meet the “credibility” criteria, we extensively used the “member reflections” approach by sharing the interview transcripts and our results with the participants of our study. The use of RTR, especially, allowed us to enhance the opportunities and the quality of the “member reflections” as our participants were highly engaged in reviewing and revising the transcripts and providing feedback on the analysis. The combination of these two strategies allowed us to maintain high levels of research quality despite a lack of established procedures and standards for conducting SoIs.

In conclusion, in this paper we presented the methodological framework and process to develop the foundation for a learning platform or toolkit. Specifically, we reviewed and discussed the Scholarship of Integration (SoI) as a viable methodological framework and through our study demonstrated a specific process to conduct an SoI. We also shared the final outcome of our SoI study, namely information sheets for two humanitarian engineering methods. We hope that this study can serve as inspiration and support for others scholars who are interested in conducting an SoI project, but are having hard time (as we did) to find proper resources to guide their studies.

While this study has provided many insights into the practice of HE and into possible methods to study HE practices, the limitations of our study also point to many areas of future work. First, although we were able to collect many methods for community participation, there are still aspects that need further investigation. Due to limitations related to how the methods were described in their original sources, for instance, we were not able to categorize methods based on required materials, difficulty, and time. Future research may focus on expanding our understanding of other key characteristics of participatory methods, including more detailed information regarding preferred conditions for their use. Second, interviewing a larger pool of HE practitioners and professionals in other fields may reveal other important aspects of using the methods and engaging with community members. Third, this study suggests the need to further investigate what competencies are needed to be effective in engineering for development or humanitarian engineering projects. This line of research could also be integrated with the development of assessment instruments and training interventions specifically conceived to develop those needed competencies. Fourth, due to limitations in time and available resources, we were not able to include the most important stakeholders of HE projects: the community members and project partners themselves. Future research should focus on the perspective of community members and project partners who have been involved in HE and similar projects, as it has been already done for domestic service-learning partnerships.[38] Finally, while the current project was use-inspired, the next research steps should take a user-centered approach, which would allow creation of a learning platform which we envision will include information sheets for the all 64 methods, but will be interactive so that users can comment on the methods, add their own approaches, and share their perspective from the field.

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