The Role of Human-Centered Design in Humanitarian Engineering

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An introduction to HCD in humanitarian work

"You don't give people dignity. You affirm it." These profound words by John Perkins, the founder of The John and Vera Mae Perkins Foundation, reveal his foundational mindset of treating individuals with dignity that shapes decades of humanitarian work (Meidl & Dowell, 2018). Meanwhile, the National Society of Professional Engineers (NSPE) outlines the first fundamental canon of its Code of Ethics as engineers holding "paramount the safety, health, and welfare of the public" (NSPE, 2019). If engineers strive to serve their local and global communities through their profession, then it follows that humanitarian work strikes at the heart of engineering. In fact, in its discussion of how engineers are obligated to "strive to serve the public interest," NSPE states that they are "encouraged to participate in civic affairs; career guidance for youths; and work for the advancement of the safety, health, and well-being of their community" (NSPE, 2019). Is there any doubt that engineers ought to invest time and effort in the positive development of social systems, which is often realized through humanitarian projects?

In light of professional responsibility, one particularly grievous hardship to address is poverty. According to the World Bank Group, 736 million people around the world live in extreme poverty (The World Bank Group, 2019). Engineers have the opportunity to put their skills to use for the benefit of those who struggle with the effects of poverty, which substantially involves humanitarian projects. In considering how engineers can help impoverished communities, one must inquire of the metrics for measuring the success of a humanitarian project that strives to combat poverty, or at least mitigate the effects thereof. This paper critically examines the role of engineers in these humanitarian projects as well as the impact of

engineering design thinking on solutions. More specifically, this paper focuses on assessing one particular method of design thinking, commonly known as human-centered design (HCD), on humanitarian engineering efforts around the world.

By using empirical evidence to investigate the use of HCD in humanitarian work, this research characterizes successful humanitarian engineering projects. Furthermore, this paper situates HCD in humanitarian engineering within the context of the science, technology, and society (STS) framework of technological momentum, analyzing how the interaction between communities and humanitarian technology evolves over time to evaluate project success. For the purposes of this paper, a successful project is defined as one that increases the effectiveness and impact of its technological system on its beneficiaries. As such, the investigation addresses the following question: To what extent does HCD increase the effectiveness and impact of humanitarian engineering?

Methods of research

In accordance with the topic at hand, analysis includes documentary research, case studies, and interviews in order to investigate the question on the philosophical, historical, and narrative levels, respectively. The documentary research draws heavily from the work of Paulo Freire and similar scholarly publications that explore HCD and humanitarian engineering. Additionally, the cited case studies, such as those released by IDEO.org, record details of humanitarian projects approached through the HCD framework. Along with the interviews, the case studies complement the documentary research by providing empirical evidence of how HCD and humanitarian engineering interact.

Finally, two interviews provide unique perspectives on the relevance of this topic to the field of engineering. One interviewee is David Chen, the director of the Biomedical Engineering

(BME) Design Lab at the University of Virginia (UVA). Another interviewee is Jaykumar Vaidya, who grew up in extreme poverty in India and now pursues his PhD in electrical engineering at UVA. Chen offers an assenting voice to the value of incorporating HCD into the engineering design cycle, drawing on the projects that he has overseen as director of the BME Design Lab. He is passionate about educating his students in HCD and believes strongly in the necessity of empathetic design thinking in shaping successful technical products. Vaidya discusses his childhood, which he spent in a Kurla slum, and shares how he believes engineers can best help those struggling for upward mobility against the bleak realities of poverty. For a complete list of the interview questions, see Appendix I.

The status quo of HCD and technological momentum

In this paper, the definition of HCD is a "systematic approach to problem solving that is human-centered, that is, the problem and its solution is defined with the user in mind" (Naval Postgraduate School 2017). As engineering students typically learn in their first-year courses, there are stages in design that are roughly defined as first defining a problem, then brainstorming ideas, then creating and refining prototypes, and then finally evaluating the subsequent system. The essence of HCD is that each design stage must prioritize the needs and desires of the end users of the engineered system. From the problem definition to the product evaluation, the driving question is whether or not the system's features truly meet the clients' needs; as such, the designers engage the clients in each design stage to help ensure that the resulting system will meet their needs to the fullest extent possible. In other words, there is no room for engineers to incorporate their own ideas without first consulting the end users about what they need.

Given the context of technological momentum as the principle STS theory for this exploration, it is important to consider how the user shapes the HCD process, and vice versa.

Tim Brown, chair of IDEO.org and a well-known figure in the field of design thinking, asserts that architects are "not merely the designers of buildings, but designers of systems" (Brown 2015). Engineers planning and implementing solutions as a part of humanitarian projects are indeed architects, and the solutions that they build must be compatible with the systems already at work in their end users' societies. Consequently, as far as social compatibility is concerned, the process of design must "focus more on the meaning and less on the mechanisms" (Brown 2015). After all, engineers who successfully create a technically proficient, or even advanced, system for a society that does not or cannot use it should evaluate the overall system as unsuccessful in meeting the needs of its end users.

Weighing the trade-offs of using technological momentum as the key STS framework

Answering the research question requires the study of progress over time. Some STS scholars and historians may argue that different STS frameworks are more appropriate than technological momentum, such as the social construction of technology (SCOT) and technological determinism. One such criticism is that Thomas Hughes, who proposed the theory of technological momentum, fails to provide "an alternative to the models of social construction and technological determinism," thus rendering the novel concept of technological momentum superfluous at best in light of previously established frameworks (Colarossi, n.d.). However, technological momentum by its very definition accounts for "how fast the technology is progressing," such that it must encompass the perspectives of both SCOT and technological determinism (FreedomLab, 2018). In this context, technological momentum is appropriate because it allows for a comprehensive analysis from at least two different perspectives: that of the engineers as their project is initially developing in its SCOT stage, and that of the long-term influences of the project in its technological determinism stage. Should this paper employ either

alternative individually, it cannot adequately address the research question's focus on both HCD and its effectiveness. The conclusion thus lies in the intersection between the initial and maturing developments of humanitarian technology.

Moreover, Hughes weaves his definition of a technological system into the concept of technological momentum, which includes "both physical hardware and software — the technical components — and the associated social components" (Lo & Chen, 2011). Opponents to technological momentum such as Colarossi claim that there is not a significant difference between determinism and momentum (Colarossi, n.d.); however, Hughes only regards technological momentum as the final phase in the deployment of a technological system. In this phase, the system has markedly matured and gained momentum in shaping its host communities, for better or for worse. Reaching the era of technological determinism in the timeline of a technological system means that "change of direction is unlikely without a significant historical event" (Lo & Chen, 2011). Even if Hughes concedes that determinism and momentum are quite similar to each other as STS frameworks, engineers still do themselves a great disservice when they neglect the socio-political, SCOT-driven aspects of their projects. After all, if technological determinism is the end result of the process of technological development, would it not be a major concern to engineers and their communities if they fail to take seriously the potential ramifications of their projects, especially since change of direction eventually becomes unlikely and difficult? Technological momentum, as utilized in this investigation, is the art of informing the direction of technological systems such that they can continue growing in an advantageous direction, nurtured by the communities that take proud ownership of them, long after their engineers have laid their foundations.

Results and discussion: The three E's of an effective and impactful humanitarian project

To answer the research question, this paper will first briefly analyze the effectiveness and impact of current humanitarian engineering efforts, which includes exploring the dehumanizing nature of poverty and how projects tend to address it. Then, this paper uses technological momentum to discuss how to best execute humanitarian engineering projects, which is realized through the following stages: first empathy, then education, and finally empowerment. As Thomas Hughes asserts, social constructivism, or SCOT, defines the beginning stages of a technology, technological determinism informs the last stage of the project, and time is the unifying factor between the two. When incorporating design thinking into humanitarian engineering projects, HCD inevitably weaves empathy into the SCOT stage, setting the stage for educating the community on how to take ownership of the project up until the technology is deterministic and empowers its beneficiaries. Coupled with evidence from scholars that analyze the effectiveness of humanitarian projects, the paper paints a picture of effective humanitarian projects with respect to alleviating the harms of poverty that uses HCD as the ink and technological momentum as the outline. Ultimately, HCD is a tried-and-true approach for increasing the impact of humanitarian engineering projects, and it has even greater potential to affect impoverished communities if engineers afford it that opportunity. When critically examined through the lens of technological momentum, it becomes all the clearer how the values and process of HCD make a difference through empathy, education, and empowerment, which this paper calls the three E's of an effective and impactful humanitarian engineering project. The story of this solution starts with the story of Vaidya, a living testament to the detrimental effects of poverty who gives voice to how to overcome it.

Vaidya was born and raised in a slum in Mumbai, India. “My childhood was not a childhood. At that time, I was already working,” he recalled as he described his upbringing during a personal interview. Vaidya and his single mother received support from "a local temple trust, who helped them with rations and second-hand clothes, which the family wears till this day" (Wangchuk, 2019). "There was never any money. I never went to school picnics, to eat outside with friends, to hang out or for movies," Vaidya told the Mumbai Mirror (Gaikwad, 2019). Now, Vaidya is pursuing his PhD at the University of Virginia (UVA) as a graduate research assistant in the Department of Electrical and Computer Engineering (ECE), and financially supports himself and his mother. When asked about his goals for his life while in poverty, Vaidya's response was immediate: "To prove to the world that I exist" (Vaidya, 2020). As someone who lived on the margins of society and could not afford the same privileges as his friends, memories of ostracism have taught him that “time is something [one] can never get back” (Vaidya, 2020).

Since this exploration revolves around HCD, it is only appropriate that its discussion begin with the very initial stage that it advocates for: empathy for people like Vaidya, which comes by listening to their stories. In the book *Poverty, Agency and Human Rights,* Ann E. Cudd states that poverty generally deprives people of “choices among ways of life and living, it deprives them of many aspects of material and emotional well-being, and it deprives them of the capabilities to function in ways that are meaningful to human beings” (Cudd, 2014). With dehumanization established as a significant characteristic of poverty, it is important to seek solutions that affirm humanity and bring forth value rather than reduce the impoverished to mere recipients in a transaction.

Unfortunately, many historians and experts agree that current humanitarian projects tend to represent the latter category. Hubbard and Duggan assert in their book *The Aid Trap: Hard Truths About Ending Poverty* that non-governmental organization (NGO) projects are "fine for charity, like refugee relief" in that they "kept aid alive but failed to bring prosperity" (Hubbard & Duggan, 2009). Along those lines, Dr. Paul Godfrey, professor of business strategy, maintains that all the billions of dollars "thrown" at projects to mitigate the effects of poverty end up "alleviating the symptoms of poverty" while doing "little to develop or encourage self-reliance" (Godfrey, 2013). As such, humanitarian aid does not necessarily lead to upward mobility among the impoverished, nor does it guarantee self-reliance and personal agency to empower its beneficiaries with practical skills. A succinct summary of an effective and meaningful humanitarian project is found in an old adage: Give a man a fish and you feed him for a day, but teach a man to fish and you feed him for a lifetime. How can engineers incorporate the principles of the proverb into their humanitarian projects? The investigation explores this problem next through the eyes of HCD.

Empathy functions as the starting point for HCD projects. Brown defines empathy as "the effort to see the world through the eyes of others, understand the world through their experiences, and feel the world through their emotions," which allows us to move "beyond thinking of people as laboratory rats or standard deviations" (Brown, 2009). Though some may argue that the mindset of empathy is not germane to a successful humanitarian engineering project, one certainly cannot deny that it forges deeper connections with its beneficiary communities than if engineers did not take their personal experiences into account. In this manner, not only does empathy actively shape products and systems that cater to the needs of the end users, it also makes the design process meaningful. During a personal interview, Chen

confirms that HCD "puts the user at all points of the design process" (Chen, 2020). While recognizing that a lot of engineers enjoy the thrill of building innovative new technology, Chen emphasizes that HCD forces engineers to consider users' needs above that, which he claims is necessary to evaluate societal impact. Student researchers in his BME Design Lab frequently engage in empathy exercises to help them better understand who they are designing for, then refining their design plans accordingly.

Within the framework of technological momentum, empathy informs the initial stages of social constructivism, or SCOT, in the lifetime of a technology. According to *The Field Guide to Human-Centered Design* by IDEO.org, HCD "is premised on empathy, on the idea that the people you're designing for are your roadmap to innovative solutions" (IDEO.org, 2015). Again, the book iterates that empathy is "the best route to truly grasping the context and complexities of their lives" (IDEO.org, 2015). The terms premise, roadmap, and route indicate that the engineering process for an HCD project ought to start with empathy and let it shape its ensuing design decisions. As such, empathy forms the basis of the SCOT stage of an HCD project in the timeline of technological momentum. Harold Kerbo agrees with this idea in his book *World Poverty: Global Inequality and the Modern World System*, where he discusses that most "attempts to reduce world poverty are only quick fix schemes that do not adequately consider the underlying social conditions or political economy of poor nations before applying only technical solutions that otherwise appear logical and promising" (Kerbo, 2006). In this manner, SCOT is inherently woven into the HCD framework in a way that technological determinism in and of itself cannot address.

HCD emphasizes incorporating empathy from the start, and IDEO.org case studies testify to its effectiveness. One such case study is of the Clean Team, which aimed to build a sanitation

system that “delivers and maintains toilets in the homes of subscribers” (IDEO.org, n.d.). During the initial stages of planning the project, the team records that they conducted the “scores of interviews needed to understand all facets of the design challenge” (IDEO.org). The Field Guide to HCD confirms that this behavior is empathy-driven: “to build deep empathy with the people we’re trying to serve, we always conduct interviews with them” (IDEO.org, 2015). Even after interviews, the team valued “brainstorming with its partners and everyday Ghanaians” to gather as many details as possible about how to implement the sanitation system, ranging from aesthetics to practicalities. Through the view of technological momentum, HCD integrates empathy into the SCOT stage in order to better inform the direction of the rest of the project, which the engineers and designers of the Clean Team certainly demonstrate. In their paper on humanitarian engineering, students and faculty of the Department of Biological & Agricultural Engineering at Louisiana State University agree that "the engineering profession tends to focus on the technological aspects of problem-solving and lends less credence to human dimensions and capacities," which leads to "improperly “solved” problems, unanticipated impacts, and alienation of the community" (Bergeron et al., 2019). By shifting the focus towards the needs of the end users, empathy in the SCOT stage of a design cycle is critically important to the success of a humanitarian engineering project.

With the SCOT stage set in place, the paper now explores the time between SCOT and technological determinism, which Hughes posits as the unifying factor between the two. Hughes further elaborates that “the interaction of technological systems and society is not symmetrical over time. Evolving technological systems are time dependent,” then explaining that the time between social constructivism and technological determinism is when technology gains momentum (Hughes, 1994). How does HCD account for this increase in momentum during the

engineering design process? The answer lies in its strong emphasis on education. Brown addresses this matter directly when he asserts that a project's "effective storytelling, as a part of a larger campaign of using the element of time to advance an integrated program of design thinking, relies on two critical moments: the beginning and the end" (Brown, 2009). He characterizes this element of time with increasing "traction when it is picked up by its intended audience, who feel motivated to carry it forward long after the design team has disbanded and moved on to other projects" (Brown, 2009). Perhaps unknowingly, Brown perfectly uses technological momentum to describe the advantages of HCD, with the beginning representing the SCOT phase and the end representing technological determinism. He recognizes that the traction, or momentum, that moves the project forward is shaped by sufficient motivation and knowledge about the project to continue it.

During this time, it is necessary to engage the beneficiary community in the decision-making process, and to enable its members to continue the project, all of which constitute education. Such education prepares them for the technological determinism phase, where they will carry on the projects themselves. "Education is really important. It can fight anything, even poverty," Vaidya replied in response to a question about how he has helped people out of poverty in India (Vaidya, 2020). In reflecting on his own life and the lives of the people he has helped, Vaidya insists that education is a powerful tool that empowers even those in poverty, and paves the way for them to have better quality of life. Critical pedagogy advocate and philosopher Paulo Freire would agree with Vaidya's assessment, asserting that "societies which are… dependent on the metropolitan society cannot develop because they are alienated; their political, economic, and cultural decision-making power is located outside themselves," demonstrating the importance of personal agency that comes through meaningful education (Freire, 1972). In their

book *Breaking the Poverty Cycle: The Human Basis for Sustainable Development*, Susan Pick and Jenna Sirkin eagerly affirm Freire's analysis, sustaining that agency implies "knowledge-based decision making, which allows individuals to foster a greater sense of control over their immediate environment. As choices and actions become more agentic, people develop greater personal responsibility" (Pick & Sirkin, 2010). As such, education heightens the sense of personal agency among those who partake of it.

For humanitarian engineering projects, HCD helps define what education looks like as the engineers of a project allow its end users to work alongside them, helping them realize the system. Kentaro Toyama rightly points out that such a process allows those in poverty to gain employable skills by making "good use of technology" (Toyama, 2015). Cudd adds that joint business ventures are "the best way to fight global poverty because it is the best way to build agency," showing that education in skills that help develop business is valuable (Cudd, 2014). She models such business ventures as a partnership with firms, such as engineering firms, wherein the poor learn through active involvement in the process of developing a business plan (Cudd, 2014).

Hubbard and Duggan elaborate on the business model when they discuss the charity trap: "There is a very human and timeless urge to give poor people whatever they lack. But if the charity system is bigger than the business system, prosperity will never come" (Hubbard & Duggan, 2009). Perhaps Freire would agree with this, given his well-known banking model of education in which students are passive recipients of knowledge. At best, such a model does little to inspire them to achieve more for themselves, and at worst it prevents the students from "being more fully human" (Freire, 1972). It follows that the sort of education endorsed by HCD involves end users as active participants in the design process rather than the passive recipients

of benefits. IDEO.org demonstrates this through its SmartLife project to deliver a hygiene and water business in Nairobi, Kenya. Project documentation records that, “instead of synthesizing its ideas and developing solutions after a trip to the field, the team leaned on its existing knowledge of the problems facing Nairobi’s poor and then dreamed up a handful of entrepreneurial ideas that they could get into the hands of low-income Kenyans to test” (IDEO.org, n.d.). The project managers and engineers essentially planted a business in Nairobi with the active help of its citizens, allowing them to nourish it, continually reaping its benefits for the years to come. In short, establishing businesses is an excellent way to use education in a humanitarian project.

HCD makes extensive use of education, which is part of what makes it effective in humanitarian projects. Brown remarks about design thinking that “perhaps the most important opportunity for long-term impact is through education. Designers have learned some powerful methods for arriving at innovative solutions. How might we use those methods not just to educate the next generation of designers but to think about how education as such might be reinvented to unlock the vast reservoir of human creative potential?” (Brown, 2009). Not only do humanitarian engineering projects have the potential to educate their end users, but they also have great pedagogical value for the engineers themselves. Chen comments that HCD “bridges the gap to the microscale of the user,” such that “the real benefit of design thinking is building the ethical context of the tools that engineers are building” (Chen, 2020). As the NSPE Code of Ethics outlines, engineers ought to invest significant time in the growth and care of their global and local communities. This investment in building the ethical context of technology allows for the growth of both the community and the engineers. Out of this burgeoning education, technological determinism is born.

The fruit of incorporating HCD-fueled education into humanitarian engineering projects is that the technological determinism stage cultivates impact through empowerment. Hughes portrays this concept well in his description of technological momentum, saying that the "social constructivists have a key to understanding the behavior of young systems; technical determinists come into their own with the mature ones" (Hughes, 1994). What does a mature and effective technology look like in the context of humanitarian aid to the poor? Pick and Sirkin offer their perspective on what empowerment looks like: "Individuals who have developed a sense of personal agency are more likely to be active agents, and participatory citizens, take initiative and responsibility, act autonomously, generate their own feedback, and engage in their own lives and those of their families and communities" (Pick & Sirkin, 2010). Vaidya would certainly agree with this, given how he made the most of the few opportunities he had for education when living in a Kurla slum and is now taking initiative and responsibility in helping others out of poverty, as well as advancing his electrical engineering career. Engineers design systems with the anticipation of technological determinism, knowing that velocity will build over time even after they have moved on from their projects, and HCD lists empowerment as a key characteristic of a project's everlasting impact. Chen echoed the same sentiment when answering the question, "Is it important for engineers to study design thinking?" According to him, engineers need to think beyond the scope of the technical problem and consider the broader impact of the resulting project, not just on what the engineers intend for the technology, but also on how the end users may potentially use it well after the design process has concluded (Chen, 2020).

As Lo and Chen note in their case study on technological momentum, once a design reaches the stage of technological determinism, change of direction is unlikely (Lo & Chen, 2011). Since determinism means that "technical forces determine social and cultural changes,"

the initial stages of empathy and education are crucial to ensure that such technical forces are effective and empowering (Hughes, 1994). Humanitarian and social justice organizations seem to have picked up on this motif, since “The World Bank, World Health Organization (WHO) and the United Nations all emphasize empowerment as a means to improve human development, health, and equality” (Pick & Sirkin, 2010). To explain the importance of empowerment, Cudd summarizes its link to education when she says that the "most transformative empowering poverty alleviation strategy is the development of commercial enterprise by the poor themselves, in partnership with profitable local or transnational firms," all the while having the project managers “decide with them how to solve the existing local problems that have posed obstacles in the past” (Cudd, 2014). Indeed, utilizers of HCD aim to empower those that they design for so that the end design is not just a finalized tool but also the affirmation of their humanity, as the Clean Team and SmartLife case studies show.

In short, scholarly discussion on previous humanitarian aid highlights the importance of HCD values and process within a project. Perhaps the most pessimistic of these voices is Thomas Dichter, a cultural anthropologist and lecturer at Harvard University, who goes so far as to recommend that “the best services we development professionals can now render to developing countries is for most of us to fade away quietly and allow the era of externally provided development assistance to come to a close” (Dichter, 2003). What causes Dichter to arrive at the conclusion that no assistance is better than any assistance at all? Throughout his book, he emphasizes the inherent complexity of developmental aid: “Development is not a set of obstinate problems the way cancer is but a historical process that cannot really be engineered or controlled” (Dichter, 2003). Dichter continues to show how industries engineer direct interventions that are similar to how medical professionals attack cancer cells, which is “a gross

mismatch of means and ends" (Dichter, 2003). He recognizes that beneficiary communities are rich tapestries of various political, social, and geographic histories that cannot be handled lightly.

As such, intervention without deep understanding of social problems is meddling that results in short term solutions at best. Toyama observes that "packaged interventions have a kind of curse" because "where people problems exist, even the best technology will flop" if its engineers allow those problems to persist (Toyama, 2015). For instance, Kerbo uses the example of quick fix schemes for debt relief in Latin American and African countries that are "likely to primarily benefit the rich," demonstrating how foreign investors have historically kept a handful of wealthy families rich instead of directly investing in the poor (Kerbo, 2006). Additionally, Hubbard and Duggan shed light on the role of NGOs in sub-Saharan Africa starting in the 1960s. After surveying empirical evidence on village development projects, they claim that such projects "consistently failed as a mechanism of economic development" (Hubbard & Duggan, 2009). Here, they introduce the concept of starting businesses within the impoverished communities as a way to both alleviate poverty and achieve project sustainability, which this paper has explored as an excellent way of empowering communities through humanitarian projects. Their overall assessment is profound: "Almost all that progress came in Asian countries that turned to business, especially China and India. In countries that receive aid instead, especially most of sub-Saharan Africa, the poverty rate remained unchanged over those years" (Hubbard & Duggan, 2009). Ultimately, Toyama's conclusions agree with the principles of technological momentum, stating that "any progress worthy of the name requires progress in human heart, mind, and will" (Toyama, 2015). With HCD, humanitarian projects surely reflect such progress and its potential to impact generations.

The results presented above represent the product of a mere six months of research, with only two of those months dedicated to writing the paper. As such, time is a significant limitation to the scope of the paper. There simply have not been enough hours available to explore more case studies of humanitarian engineering projects, conduct more interviews, and dig deeper into the effectiveness of HCD. During his personal interview, Chen mentions that HCD is difficult to implement when the involved engineering students lack necessary expertise and skills, which the paper has unfortunately not had the chance to explore. Furthermore, for the sake of depth versus breadth in the investigation, the research applies specifically to humanitarian projects that aim to alleviate poverty and its effects. There are myriad other fields within which HCD provides an excellent starting point for how to design better, such as Chen's field in biomedical engineering, but the paper does not explore those possibilities.

It follows that future research would include answering the research question with respect to different areas of humanitarian attention, including social justice issues such as human trafficking and domestic abuse. Statistically, the more projects that have proven effectiveness and impact due to HCD methods, the more validation the research question receives. Furthermore, this paper briefly touched on how including the poor in business ventures demonstrates how to effectively educate them and empower them for the future. There are many case studies that one could examine here, such as the phenomenon of microfinance and many other scenarios that the cited authors discuss. New knowledge that would contribute to the overall topic includes experimentation with the methods proposed in this paper. Proponents of HCD already teach its three stages of design as inspiration, ideation, and implementation. This paper takes that knowledge and builds on it by putting HCD in the context of technological momentum, choosing the three E's of empathy, education, and empowerment to describe why

that particular STS framework explains the effectiveness of HCD. Of course, any future works that contextualize HCD within other STS frameworks are welcome, especially those that highlight flaws in HCD, so that the design thinking method may be improved accordingly.

Conclusion

Overall, the paper overwhelmingly affirms the usefulness of HCD in increasing the effectiveness and impact of humanitarian engineering projects, specifically with a focus on projects that work with the poor. Technological momentum as an STS framework consistently supports this conclusion, and the paper walks through the design process of an HCD-driven project from beginning to end, analyzing its effectiveness in solving the problem at hand and its impact on the overall beneficiary community. The three E's of empathy, education, and empowerment walk through the stages of a typical HCD project within the context of technological momentum, with each stage contributing understanding to how HCD increases its effectiveness and impact. As millions of people around the world continue to struggle with poverty and its dehumanizing effects, engineers who wish to make a difference in this area would do well to embrace a design methodology that caters to those they are designing for. After all, well-designed humanitarian projects lead to more success stories like Vaidya's.

If there is one message for engineers in this paper, it is that technological products consist of much more than the technology itself. The story behind the development process of that technology undoubtedly shapes its community and contributes greatly to the overall outcomes of its utilization. Given the rich tapestry of social factors for any project, engineers who want to make a difference need to approach their designs in a manner that integrates the end systems into the lives of the end users in meaningful ways. This paper proposes that HCD is an excellent starting point to that discussion.

References

Bergeron, C. et al. (2019). Design for the Soul of the Community: Using Community-based Design Principles. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship, 14*(1), 47-59.

Brown, T. (2009). *Change By Design: How Design Thinking Transforms Organizations and Inspires Innovation.* New York: HarperCollins Publishers.

Brown, T. (2015, July 7). Design Is Our Answer: An Interview with Leading Design Thinker Tim Brown. (C. Luebkeman, Interviewer) Retrieved from https://doi.org/10.1002/ad.1922

Chen, D. (2020, January 31). Interview with David Chen. (R. Mitchell, Interviewer)

Colarossi, A. (n.d.). *Summary and critique of Technological Momentum by Thomas P. Hughes.* Toronto: York University. Retrieved from Academia.edu: https://www.academia.edu/1881558/Summary_and_critique_of_Technological_Momentum_by_Thomas_P._Hughes

Cudd, A. E. (2014). Agency and Intervention: How (Not) to Fight Global Poverty. In D. T. Meyers, *Poverty, Agency, and Human Rights* (pp. 197-222). New York: Oxford University Press.

Dichter, T. W. (2003). *Despite Good Intentions: Why Development Assistance to the Third World Has Failed.* Amherst: University of Massachusetts Press.

FreedomLab. (2018, July 13). Technological Momentum. *The Macroscope* (154). Retrieved from http://freedomlab.org/wp-content/uploads/2018/08/Macroscope-NO-154-Technological-Momentum.pdf

Freire, P. (1972). *Pedagogy of the Oppressed.* Middlesex: Penguin Books Ltd.

Gaikwad, Rahi. (2019, August 15). A young scientist's leap from Kurla slum to Virginia. Retrieved from Mumbai Mirror: https://mumbaimirror.indiatimes.com/mumbai/other/a-young-scientists-leap-from-kurla-slum-to-virginia/articleshow/70684461.cms

Godfrey, P. C. (2013). *More Than Money: Five Forms of Capital to Create Wealth and Eliminate Poverty.* Stanford: Stanford University Press.

Hubbard, G., & Duggan, W. (2009). *The Aid Trap: Hard Truths About Ending Poverty.* Chichester: Columbia University Press.

Hughes, T. (1994). Technological Momentum. In M. Smith and L. Marx, Does Technology Drive History? The Dilemma of Technological Determinism (pp. 101-113). Cambridge: MIT Press.

IDEO.org. (2015). *The Field Guide to Human-Centered Design.* San Francisco: IDEO.org.

IDEO.org. (n.d.). *Clean Team: In-Home Toilets for Ghana's Urban Poor.* Retrieved from DesignKit.org: http://www.designkit.org/case-studies/1

IDEO.org. (n.d.). *SmartLife: Designing a Scalable Water and Hygiene Business*. Retrieved from DesignKit.org: http://www.designkit.org/case-studies/4

Kerbo, H. R. (2006). *World Poverty: Global Inequality and the Modern World System.* New York: The McGraw-Hill Companies, Inc.

Lo, K.-M., & Chen, H.-H. (2011, June 1). Technological Momentum and the Hegemony of the Green Revolution: A Case Study of an Organic Rice Cooperative in Taiwan. *East Asian Science, Technology and Society: An International Journal, 5*(2), 135–172. doi:10.1215/18752160-1276808

Meidl, T. D., & Dowell, M.-M. S. (2018). *Handbook of Research on Service-Learning Initiatives in Teacher Education Programs.* Hershey: IGI Global.

National Society of Professional Engineers. (2019, July). *Code of Ethics*. Retrieved from National Society of Professional Engineers: https://www.nspe.org/resources/ethics/code-ethics

Naval Postgraduate School (U.S.). Center for Homeland Defense and Security, Argonne National Laboratory. (2017, April). *HSx Core Competency: Design Thinking [presentation]*. Retrieved from Homeland Security Digital Library: https://www.hsdl.org/?view&did=803733

Pick, S., & Sirkin, J. (2010). *Breaking the Poverty Cycle: The Human Basis for Sustainable Development.* Oxford University Press, Inc.

The World Bank Group. (2019). *Poverty Home: Overview*. Retrieved from The World Bank: https://www.worldbank.org/en/topic/poverty/overview

Toyama, K. (2015). *Geek Heresy: Rescuing Social Change From the Cult of Technology.* New York: PublicAffairs.

Vaidya, J. (2020, January 20). Interview with Jaykumar Vaidya. (R. Mitchell, Interviewer)

Wangchuk, R. N. (2019, August 26). From Mumbai Slums to US University: This Gritty 24-YO Beat Acute Poverty to Become a Scientist at TIFR! Retrieved from The Better India: https://www.thebetterindia.com/192914/mumbai-slum-boy-beats-poverty-us-university-scientist-inspiring-india/

Appendix I

The following list outlines the questions posed to David Chen on January 31, 2020:

1. What is the nature of the projects that your lab, the BME Design Lab, takes on? Who are the typical stakeholders?
2. What are the advantages and disadvantages of a human-centered design approach to these projects?
3. Is it important for engineers to study design thinking? If so, why?

The following list outlines the questions posed to Jaykumar Vaidya on January 20, 2020:

1. According to the many articles about your story online, you grew up in a slum in Mumbai. What were your goals for your life during this time?
2. What advice would you give to engineers who want to help people out of poverty? How do you think engineers can make a difference with their projects?
3. Looking back on your life, what do you most wish that you had to help you through difficult times? (You can answer this question any way you want, and talk about people, things, programs, and so on).
4. You've told me before about how you have helped people out of poverty in India. Can you talk about how you have done that?
5. How did you start learning about electronics?