Advances in Engineering Education

2022: VOLUME 10 ISSUE 1

Localized Engineering in Displacement: An Alternative Model for Out-of-School Youth and Refugee Students to Engineer their own Solutions for their own Communities

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ABSTRACT

Displaced learners, uprooted because of conflict, poverty, or other major traumas, are often shut out of opportunities to learn engineering. At the same time, fragile contexts demand engineers' expertise, but experts and their engineered solutions are often called in from outside the community. In this article, we examine engineering learning as a vehicle for development in displaced communities by expanding the representation of engineers to explicitly include refugees and formerly homeless youth. We describe an alternative, co-created approach to providing authentic engineering learning through a framework called Localized Engineering in Displacement. Grounded in principles of critical pedagogy and social justice, this framework is structured to integrate technical content, professional skills, and engineering design, all focused on needs identified by the local students themselves. The Localized framework encompasses the curriculum itself, the collaborative attitudes and humility of partners involved, the prioritization of local engineers' learning pathways, the pedagogical capacity building of local instructors, and the institutional partnerships required to recognize and implement students' work. In addition to describing our framework and situating it in the literature, we document two major program outcomes: empowered identity and community impact. Refugee learners and former street youth in the community develop their self-image as engineers, especially after being in positions of low levels of agency or control over their lives. The keystone to the program is our collaboration with local learning spaces (usually in-country implementing NGOs) and community institutions to invest in long-term implementation of solutions. We discuss multiple aspects of community impact, including the engineered products that student members of low-resource communities create, ongoing community teacher development, and collaborative research.

Key words: Nontraditional students, human centered design, critical pedagogy

INTRODUCTION AND MOTIVATION

Displaced learners, whether some of the millions of refugee students or homeless/unaccompanied youth forced to leave their homes, are often shut out of formal pathways to learning. For example, of adult refugees eligible for postsecondary education, only 3% have access to enroll in higher education programs, compared to about 36% of comparable youth globally (UNHCR 2020). Further, limits to higher education quality make displaced learners' opportunities an even scarcer resource. Displaced learners are uprooted, cut off simultaneously from their home communities as well as from ownership in their new communities. When individuals and communities are displaced, deep and specific knowledge is dislocated. Displacement and dis-localization of technical knowledge then means that when engineering solutions are needed, they must be imported and are thus often decontextualized. That is to say, in contexts of displacement, engineering expertise is typically brought in from outside the community, and local knowledge is not centered.

"Fragile contexts" (spaces where basic functions in security, governance, and social service are not met) often demand engineers' expertise, whether for infrastructure, supply chain provision, housing, sanitation, or other pressing issues. However, engineers and engineered solutions are often delivered from outside of the displaced community, often from or in coordination with wealthier countries in the "Global North" (Kang and Medie 2018; King 2004; Curioso and Mechael 2010). Besides providing solutions that are decontextualized, this structure reinforces existing power dynamics and contributes to a cycle of dependency. As a recent example, the Azraq refugee camp is touted as the first completely solar-powered camp. Through a partnership with IKEA, the UN High Commissioner for Refugees (UNHCR) installed what will eventually be a 2 MW solar plant (UNHCR and IKEA Foundation 2017). UNHCR documentation readily provides statistics on how much money it saved because of the sustainable energy installation, but refugees still informally describe insufficient power to meet their needs, and refugee households' choices about electricity usage are highly regulated and severely restricted. In this case, refugees themselves were not part of the decision-making or oversight process to determine how much power would be generated and how it would be distributed. Therefore, we examine engineering learning as a vehicle for development in displaced communities while at the same time expanding the representation of engineers to explicitly include refugees and youth experiencing homelessness. In this article, we propose an alternative, co-created approach to providing authentic engineering learning opportunities through a pedagogical framework called Localized Engineering in Displacement. Grounded in principles of critical pedagogy and social justice, this framework is structured to integrate technical content, professional skills, and engineering design, all focused on needs identified by the local students themselves. Readers can see how this novel framework has been implemented in multiple settings

to determine how it could be adapted in their own work. Our impact-focused engineering education framework proposes re-centering and re-localizing displaced students. In our framework, students experiencing displacement are not just a community to be impacted by someone else's design for them, but are instead *learners, leaders,* and *citizens.*

Our goal of re-centering displaced young people places them in a tripartite role of engineering learners, classroom and community leaders, and engaged citizens by offering introductory engineering courses as a vehicle for community development, and this reconfiguration of the authority of displaced youth themselves has led to both immediate and sustained impact. In this paper, we provide a framework integrating a curricular and pedagogical approach, partnership ecosystem, and learning pathway. Our partnership ecosystem and learning pathway reveal a complex sociopolitical architecture of communities hosting displaced people, which requires collaboration across multiple actors to advance education initiatives. Therefore, we propose a framework that is not merely grounded on specific institutions or partners. Instead, we strive for sustainable and scalable impact by empowering local learners and other stakeholders as core actors during the co-construction and implementation of our framework.

The impact of our framework can be seen in communities' use of locally-relevant engineering products and individuals' personal growth. Our impact includes learning outcomes, because a major part of our innovation is prioritizing the *learning outcomes of these communities.* This differentiates the approach from traditional models of service learning, which often prioritize approaches where community members are considered external partners or clients in service learning (Felten and Clayton 2011) but that do not center communities and support them on the road to reduced dependency on international agents and self-reliance. Ecosystems that take down barriers and existing power differentials and allow community learners to use their engineering skills would help to further scale our students' impact. Local students, even those who have been uprooted and marginalized, can learn in service to their own communities. In our case, impact is indeed measured by long-term community benefits (papers, use of tools, livelihoods), but immediate student outcomes are also crucial measures of impact.

BACKGROUND AND LITERATURE

Engineering in development has a complicated history of trying to deliver appropriate technical solutions. We provide background on traditional models of service learning, issues with international development and humanitarian engineering, and asset-based frameworks. We also provide background literature on our specific implementation contexts and on the education theory that informs our framework.

Existing Development Frameworks

Service learning

Service learning has a long history of fostering growth for the university students who are able to access it. These programs have documented growth in terms of students' attitudes, skills, values, and knowledge of a variety of content areas (e.g., Eyler, Giles, and Braxton 1997, and many others), even helping to embed ideas of democracy and active citizenship (Giles and Eyler 1994). But, to whom are these programs in service? Often, the most well-resourced students are more able to access these programs; further, at a macro level, these are often programs at higher-resourced institutions from the Global North. While many programs do successfully focus on and expand privileged students' awareness of global inequality, they do not prioritize the students and community *experiencing* that inequality (as noted by Ruyle, Boehm, and Lagoudas 2016; Nieusma and Riley 2010; and others).

This contrast is particularly clear in international service work. Indeed, the dynamics of engineer versus served community during international service by engineers or engineering students from North America can reinforce colonialization (Riley 2007) and similar lopsided relationships. While both benefits and drawbacks have been demonstrated for international placements, cross-national phenomenographic research points out that placements may not be inherently good or bad, but must be problematized; local communities may not always benefit, and they may in fact be exploited, so potential liabilities for communities are paramount and require humility and recognition of complexity (Vandersteen, Baillie, and Hall 2009).

One way to bridge the distance in power, resources, experience, and types of expertise between the community and privileged outsider is by connecting local communities to "nearer neighbors", local engineers with credentialed expertise, to collaborate on solving a local technical problem. A small number of programs have attempted this. One example is a domestic version of Engineers without Borders implemented in Colombia. In this case, some of the challenges enumerated in prior cross-national work (e.g., cross-cultural barriers) were surmounted, but others were actually replicated (e.g., clear walls around who is an "expert") (Pineda et al. 2012). In contrast to cross-national humanitarian work, though much less common, "local" humanitarian placements seek to place students in service to a community with which they identify in some way. These may be powerful because they encourage students to be engaged, humble, and aware of needs within their own communities (VanderSteen, Hall, and Baillie 2010). This more localized service approach seeds our framework.

Humanitarian engineering and engineering in development

Beyond service learning, some engineering education programs have emerged that focus more explicitly on humanitarian goals. These programs might include in-depth, context-specific coursework, close examination of development engineering failures, and critical reflection. However, these

same "engineering for development" or "humanitarian engineering" initiatives have rightfully been criticized for still focusing on individual outcomes and technical solutions over the recognition of structural issues (Nieusma and Riley 2010).

In some cases, these programs do thoughtfully engage social justice frameworks, which challenge students to examine the complicated structure of engineering development endeavors. In these frameworks, listening is prioritized, as is a focus on local communities' capabilities (Leydens and Lucena 2014). However, overall, very few humanitarian engineering or service learning initiatives actually incorporate social justice frameworks (Leydens and Lucena 2014).

Lucena and Schneider (2008) provide a helpful history of development in engineering and engineering education, and of particular relevance to our framework is the recent history described. The authors note that historically, development projects (whether for national development needs or cross-nationally) have been very top-down, and that even with calls for more inclusive, participatory methods, implementation of participatory practices has been "elusive" and secondary to technical and professional competencies for engineers or engineering students from the "North" (Lucena and Schneider 2008). Further issues arise in common humanitarian engineering programs' practices. As Riley (2007) points out, competition between privileged students' learning outcomes and the needs of the community fosters uncomfortable tensions, typically resolved in favor of university students' learning. Because programs are often short and students' expertise is still emerging, tasks they perform could be better completed by hiring local workers. She also exhorts engineering educators to generate a clear, collective professional voice as experts in engineering teaching; educators, in their own practice, should push back on the prioritization of only the university students' learning at the expense of the communities where they operate. We respond to many of the calls described in both of these critiques.

We do so by proposing a shift in focus from the learning outcomes of students in the developed world lending their expertise to communities, to a focus on the learning outcomes of students *in these communities* developing expertise and generating localized solutions. Localized Engineering in Displacement (LED) means localizing engineering education for students who are uprooted, students and communities who would otherwise depend on outside solutions. It means local students *learning* and creating solutions for themselves, creating local job opportunities and *leading* decision-making, and becoming engaged active local *citizens*.

Community-Generated Funds of Knowledge Foster Indigenous Innovation

Our approach amplifies the knowledge uniquely held by refugee learners and homeless youth in their understanding of community needs and feasible solutions, key aspects of engineering design. As Schneider, Leydens, and Lucena (2008) point out, typical development approaches in engineering

education often reflect problematic practices of the development industry overall, including by focusing on technical "expertise" held by engineers (or even engineering students) from the Global North rather than the communities (often in the Global South), who are seen only as uninvolved "beneficiaries". The authors argue that community ownership, recognition of community assets, and an understanding of the community as complex are recommended steps (Schneider, Leydens, and Lucena 2008). For example, in "Engineering and Sustainable Community Development," Lucena, Schneider, and Leydens (2010) present a case study by an anthropologist in Mali about a North American engineer who built a new kind of grain mill. The case study discussed the bad practices followed by the engineer, including failure to engage the local "community" while designing the mill, almost non-existent assessment of the social context and cultural impact, ignoring the existing assets of the community, and viewing the community only from a "problems" mindset. The innovation quickly went unused. Lucena et al. (2010) argue that as a result, the engineer would go on to execute similar projects, wasting time, resources, and leaving the communities worse because of the investment in the "development" project.

Birzer and Hamilton (2019) also noted the risk of engineering programs disempowering communities if they do not see quality education as a community benefit. According to Birzer and Hamilton, engineering students placed in temporary positions serving communities (e.g., through service learning programs) often view and communicate these programs as a type of charity. This is worsened if the community being served does not control the services provided, cannot serve and be served by their own actions, or do not understand their positionality as learners as well (Sigmon 1979). Our model builds on these ideas but makes a discrete leap in arguing that the students who should be centered (and the central engineers solving community problems) must emerge from the community itself—not as "beneficiary" or even as "client/owner" but as "solver".

"Indigenous knowledge" as an area of study highlights assets already in the community that are relevant to engineering but may be historically marginalized. In their review of indigenous knowledge in the field of engineering education, Hess and Strobel (2013) point out that their definition of indigenous knowledge includes deep knowledge of the environment. (Note that they define their literature review to exclude "modern mathematics, science and technology". Some of our engineering learners use these tools in their own applications, and they may also draw on non-Western traditions that are still "modern".) As their literature review suggests, indigenous approaches to engineering have existed for a long time, though colonial imposition of engineered approaches or priorities threatens the localized knowledge that communities themselves possess (Hess and Strobel 2013). To resist this, asset-based frameworks instead inform our choice to center and catalyze the abilities and awareness local engineers have. These frameworks focus on the resources that communities hold, rather than the ways in which they are failing. For example, the "funds of knowledge"

approach is defined as engaging the resources, knowledge, and experiences communities already possess (Gonzalez 2005).

Supporting learners in applying the assets in their community is often in opposition to persistent dispossession of the agency of homeless youth and refugees. Homeless youth in Kenya (one of the contexts where we work) report consistent negative interactions with authorities, including police and government (Human Rights Watch 1997); unaccompanied youth who are brought in to court are often charged with vagrancy (a crime of displacement) or classified and held because courts decide that they are "in need of protection or discipline" (Government of Kenya 2001). There is a clear tension between the goal of building agency and the imposition of authority and control over refugees' lives, too, and often under the umbrella of providing protection. There is control over every hour of their schedules from the time they enter a camp and go through a restrictive intake process. For example, in Azraq camp, the purpose of security is articulated as an obligation to protect not only Syrian refugees, but also the Jordanian state and aid workers themselves. Consequently, this complex security protocol leads to contradictory security processes that restrict refugees' freedom and create a sense of a "prison facility" (Hoffmann 2017, p.108). In another case, Kakuma refugee camp restricts the movement of non-refugees in the camp by requiring that they return to UN compounds by 6 pm (UNHCR 2018a).

While a focus on indigenous assets in the community sounds theoretically desirable, intentional action must support the implementation of such a model. Models even from decades ago document that citizen empowerment is a long-term process that involves the scaffolded buildup of "multi-dimensional participatory competence" (Kieffer 1983), in particular in spaces where colonialization and other impositions of authority have suppressed participatory engagement. Similarly, in learning contexts, pedagogies of engagement must be taught to fully support students and prepare them for involvement in their own learning (Smith et al. 2005).

Our Context

In order to build on localized learners' assets, we have to first define where the local community is, as well as where the obligation to solve the problem lies. Displacement is a diffuse context with multiple loci of power. Our students have to navigate this, and it makes questions about oversight and accountability murkier. One study of development education projects defined a local project as one in the same community where the student lives, works, or goes to school, their *own* community; at the same time, though, the same study found that working locally was difficult because problems were "easier" to see in other places (VanderSteen, Hall, and Baillie 2010).

The "local" for our program includes one case that is an alternative school for displaced, former "street youth" (UNICEF's term for homeless/unaccompanied youth forced to live and/or work on the

streets, hereafter "SY") in the rapidly growing urban region of western Kenya. The "local" also includes two cases for refugee learners, both in camp settings. These are cases where refugees are living outside their home countries because of conflict and fear of persecution – one a very recent, planned addition to the desert of Jordan, and the other, a longer standing refugee camp in the arid north of Kenya. The scope of displacement around the world for both SY and refugees is massive: approximately 80 million people are displaced around the world (refugees, internally displaced people, asylum seekers; UNHCR 2020), and separately, UNESCO estimates somewhere between 100–150 million street youth worldwide (United Nations Educational, Scientific and Cultural Organization n.d.).

Homeless/unaccompanied "street youth" (SY)

Homeless students fall higher than other disadvantaged youth on a continuum of cumulative risk, even as they share risk factors (Masten et al. 2015). The UN uses the term "street youth" (SY) or "street children" to describe youth who may or may not be adequately supervised by responsible adults and to encompass both children who work and sleep on the streets (UNICEF 1986). They may have left home for a variety of different reasons; in Kenya, these predominately include post-election violence, insufficient food at home, or abuse. While living or working on the street, SY may have a number of their rights violated by other SY, members of the surrounding community, or police and government authorities. However, long-term stability for SY is possible with a continuity of supports (Masten et al. 2015) and recognition of SY's creativity and demonstrated resilience.

SY often face tacit or explicit barriers to schooling. Because of transience and irregular or interrupted schooling, they may not advance to the next grades with their peers. For SY in our study, they have attended formal schooling for an average of 2 years by the time they are 15. There is often an additional gap between policy and practice for displaced students' education, whether because of discrimination, low preparation for teacher support for displaced learners, or *de facto* barriers and entrance requirements (Rubin 2017). Cultural taboos and community perceptions of SY further contribute to their ostracization in formal Kenyan schools.

In Kenya and around the world, displaced homeless populations are described as problems, as a deficit for the community (Dear and Gleeson 1991). Statistics on SY numbers are reportedly imprecise and likely undercounted (Glauser 2015). Even assessments that specifically look at out-of-school youth struggle to capture the variety of experiences, time students spend in and out of one or more schools, and other complexities (Uwezo 2016). With their reticence to engage with authorities, they are also reluctant to provide information to researchers. On the other hand, they are also the best source of information on their own needs – in fact, our partner school for former SY was begun in response to SY descriptions of a school space that would work better than the drop-in center model typically offered to them.

Refugees living in camp settings

Refugees similarly experience multiple and confounding traumas (Mollica et al. 2001). A refugee is someone who has been forced to flee their country because of persecution, war, or violence and has a well-founded fear of persecution for reasons of race, religion, nationality, political opinion or membership of a particular social group. While much news media focuses attention on Syria, the horn of Africa continues to be an area of massive human migration, with multiple crises continuing to grow (e.g., Democratic Republic of the Congo, South Sudan, Yemen). Most refugees are hosted in nearby countries, which are often already economically strained themselves. For example, 1 in 14 people is estimated to be a refugee in Jordan under UNHCR; if Palestinian refugees are included (who fall under the purview of a different UN body), 1 in 3 people living in Jordan is a refugee (UNHCR 2018b).

Of the refugee learners who are eligible for postsecondary education, only 3% actually have access to higher education programs (UNHCR 2020). In refugee contexts, normative structures and a restrictive interpretation and enforcement of nation-states hamper refugee learners' explicit rights to education and broader empowerment to self-actualize and participate in society (Dryden-Peterson 2016a). Many factors complicate refugees' access to and success in university, including the heterogeneity of refugee needs and experiences in any one given locale (cultural, SES backgrounds, prior schooling, familial relations) and language challenges (Naidoo et al. 2015). These complexities make clear support interventions difficult and are infrequently studied in university settings or at the transition point into higher education.

One highly impactful intervention is financial support, which has been shown to be associated not only with higher direct academic outcomes, but also significantly higher personal safety, group cohesion, and agency (Al-Rousan et al. 2018). For displaced learners, preparation to access and psychosocial support are also necessary to succeed in higher education (Roque et al. 2018). Social capital and community partnerships are necessary and indeed strengthen displaced learners' transitions and persistence in higher education; interpersonal relationships are important, as are pedagogical strategies like providing additional time for tasks and fostering positive perceptions by teachers and flexibility in assessment (Naidoo et al. 2018).

FRAMEWORK AND PROGRAM DESCRIPTION

Description of Our Innovation

Through digital tools, distance coursework, local facilitation, and close partnership with local institutions, the DeBoer Lab has offered introductory engineering courses focused on authentic challenges for displaced learners in refugee camps and schools for homeless youth. The courses

grew out of long-term cross-national collaborations between our research group at Purdue University and international partners. At Purdue, our team comprised a faculty leader and graduate students designing and implementing the course in three stages. In the first stage, we designed the content, assessment, and pedagogy based on locally generated learning objectives. In the second stage, we iterated through exhaustive conversations with international partners to ensure that the structure was culturally relevant and contextually responsive. During the third stage of co-creation, we worked with learners during pre-course workshops as well in early stages of the course to agree on expectations, feedback mechanisms, relevance, class activities, and goals.

Since 2015, we have realized this framework with learning spaces (local implementing NGOs) in Kenya and Jordan. These courses apply engineering design, technical fundamentals in electronics, electrical, and mechanical engineering, and professional communication to local needs that students identify. The results are prototypes and support to implement products that address pressing community challenges, providing short- and long-term impacts in the form of local student expertise, community empowerment, energy and infrastructural independence, and poverty alleviation. For example, students in western Kenya at our collaborating residential school for SY completed a two-year module to design and install a solar photovoltaic (PV) system to power their classrooms and dormitory. Our pedagogy and ecosystem of partnerships is scalable because it empowers local learners and teachers rather than centering engineering expertise at a university in the Global North. Individual and social impacts include engineering mindsets, technical skills applied in an authentic setting, and a broadened perception of who can be an engineer.

As Figure 1 shows, our curriculum targets learning outcomes for engineering technical content, professional skills, and the engineering design process, all grounded on a foundation of a locally-scoped problem identified by our students in the first weeks of the course (Figure 1(a)). Our pedagogical approach uses an integrated framework of Active, Blended, Collaborative, and Democratic Pedagogies, with the Democratic in particular highlighting our localization of engineering education (Figure 1(a)). Our collaborative multi-national team comprises our core research group at Purdue, responsible for developing and overseeing the classes, but it also includes facilitators (local teachers and previous course graduates, who are taking part in continuing education), students at the local learning center, clients in the surrounding community (of which our students are also part), and local universities. We also coordinate with other local and global groups to implement and scale this work, including international university partners, international consortia and policymakers (e.g., UNHCR, UNESCO, CLCC), and funders (Figure 1(b)). Finally, we demarcate a learning pathway tracing from prior knowledge, experiences, motivation, and potential that students bring in to the classroom, through their introduction, the course itself, completion of the course, and implementation of products for the community (Figure 1(c)).

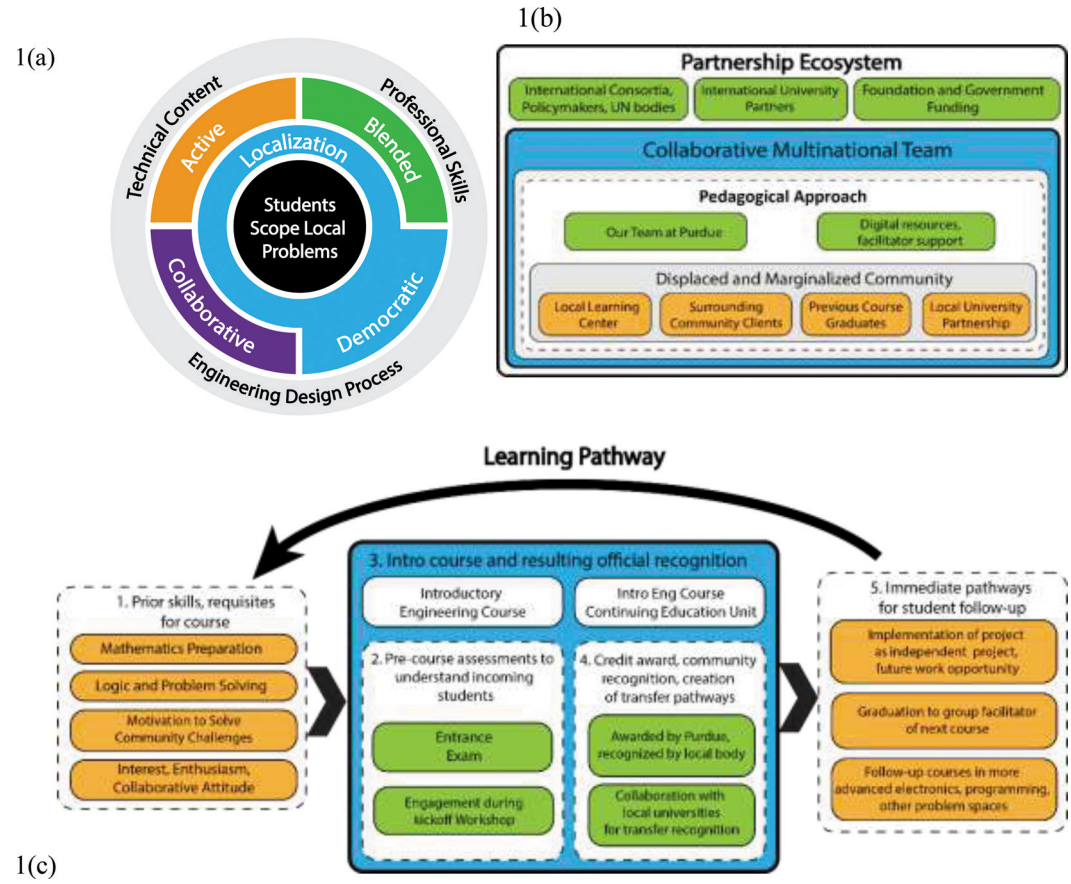


Figure 1. (a) Curriculum and pedagogical approach (b) Partnership ecosystem (c) Learning pathway.

In our framework, long-term learning pathways are sustained through supporting students' opportunities to advance their projects in partnership with local agencies and stakeholders. On the other hand, students are motivated to engage collaboratively in early stages of the course to strategically identify local needs and how to use the skills learned in the course towards problems around them (see Figure 2).

Curriculum and pedagogical approach

Our advance is a curricular and philosophical approach that re-centers displaced learners. The curriculum objectives are co-created with students, so our research group at Purdue uses existing Open Educational Resources and develops additional content that we make available through Creative Commons, targeted to the needs identified by students embedded in their communities. In addition

to curricular materials, the program provides instructor training for local facilitators of face-to-face components of the class; local instructors add important context and foster program sustainability.

Pedagogies: Critical pedagogy and ABCD

We provide more detail in this section on our pedagogy. We integrate four teaching and learning approaches in our "ABCD" framework, and while we briefly define each, we provide more detail on the "Democratic" facet.

Active – active teaching and learning approaches support students in engaging in doing something while learning, which has been shown to benefit university-level learners in STEM (Freeman et al. 2014). However, the expectation of student engagement may be an adjustment for students coming from prior formal learning experiences that were more teacher centered (e.g., Metto and Makewa 2014) and who on a day-to-day basis have their agency suppressed (Parekh 2016).

Blended – blended learning integrates online and face-to-face spaces for students' learning and has been shown to better support students than solely online or solely face-to-face (Means et al. 2009). This may be due to its flexibility to students' needs, which is useful to apply within our framework so that students with limited connectivity and unpredictable schedules can interact with learning resources in multiple ways. This also allows our team to provide videos in multiple languages and communicate concepts in multiple channels (Mayer 2002). We use digital and complementary materials, including multiple backups (e.g., printed paper materials). Digital materials include videos, explanatory slides, and other information that students can download to their phones, and they allow for multiple languages (via subtitles or multiple videos). Internet coverage is often a constraint, so we utilize complementary Whatsapp coverage and communication, and we use remote lab tools for students to access the benefits of hands-on blended tools (Gillet et al. 2001).

Collaborative – collaborative or peer learning describes students working together, teaching each other, and co-constructing new knowledge, which has been shown to lead to higher academic outcomes than even other types of active learning (Chi and Wylie 2014). We include both individual and group work, but the key project that students complete to implement in their communities is done in small teams. This is core to our framework not only because of its support for learning but also because of the social impact of building peer networks, collectivizing solutions, and supporting the creation of a sense of community for students who have been displaced.

Democratic – democratic and critical pedagogy undergirds the philosophy of our program, and we engage critical pedagogy as a way to localize engineering education and solutions for students who have been de-localized and sidelined from the pathway of opportunity for learning engineering.

Critical pedagogy is uniquely suited to support marginalized groups in questioning educational and social power structures and organizing to improve their own conditions. However, because of

education in emergencies' focus on immediate credentials (Dryden-Peterson 2016b) or what Freire calls "banking education" (Freire 1992, p. 72), critical pedagogies have rarely been incorporated into the few higher education or tertiary offerings, let alone engineering courses for displaced groups. In one of few examples of critical pedagogy in refugee settings, a non-formal education program was implemented in Jordan for Syrian learners. However, this example exposed persistent tensions, as students found participatory methods to *hinder* their progress towards efficiently learning material and achieving certification (Magee and Pherali 2019). Indeed, as local host communities struggle and refugees continue to arrive (e.g., in Jordan), teaching philosophies have shifted instruction towards more pragmatism (Cochran 2018).

We engage critical pedagogy in two ways. First, we explicitly support students' agency, both in micro-issues, e.g., students agree together on rules for course management, and in more fundamental ways, e.g., charging them with coming up with solutions to challenges in their community. Second, as the class moves forward and each time we offer the course, we co-create and iteratively improve the course, localizing it based on students' guidance and on course graduates' perspectives, continuing to support their growth as both learners and leaders. Drawing on these two different approaches, our localized framework seeks a more pragmatic instantiation of critical pedagogy by engaging students and facilitators directly in the course structure, decisions, and outcomes. This shift in students' and facilitators' roles as co-designers raises their awareness of responsibility for their new community and their sense of course ownership. In addition, improving learners' and facilitators' engagement in course development accelerates the process of building trust with the local community. Further, their engagement with participatory learning by focusing on solving their own community problems provides an authentic goal and likely a stronger motivation than the examples above of participatory methods that were not as practically centered.

Partnerships and sustaining structures

To implement this program, our research group works closely with local class facilitators, local implementing NGOs, and university partners (Figure 1(b)). These on-the-ground partners are necessary in displacement settings (where UNHCR and local government, e.g., the Jordanian National Police, have legal authority over everything) as well as across our sites to meet local legal requirements for operating educational spaces. For the last 5 years, we have partnered with Tumaini Innovation Center in western Kenya. For the last 4 years, our group has partnered with the University of Geneva and the local refugee-led management team at learning hubs in Kenya and Jordan to offer introductory engineering courses in two refugee camps. Further, we support a model of refugee and student empowerment, training facilitators who are part of the local NGO.

Figure 2. Refugee learners in Kakuma, Kenya engaging in a collaborative activity to create a light-activated alarm as a potential solution to the local problem of security in the learning hub.

Learning pathways

The courses are designed to enable learners to acquire technical, professional, and design engineering skills and to achieve education credits through Continuing Education Units from Purdue. We engage previous course graduates as facilitators to support the growth of local leadership. Learners have the opportunity to work independently on their projects after the class, building them out into implemented community solutions and entrepreneurial opportunities (Figure 1(c)).

Advancing Praxis

We advance praxis by implementing a theory of localized expertise, supporting learners to build where they are at. The idea of "localization" is an important one in engineering, whether it is software engineers discussing software localization, engineering educators working on authentic problems, or multi-national engineering companies discussing the idea of developing globally competent engineers. This quickly becomes problematized in an engineering education setting with uprooted learners. What is the "local"? Is it their home country or region, which they have fled? The camp or residential school where they are now? The host community in which they are embedded that also needs resources?

We demonstrate that we are advancing praxis for engineering education in alignment with literature described above, in particular with Riley (2007). Further, we respond to calls in the "education in fragile contexts" community. The International Network for Education in Emergencies (INEE) defines clear working standards for good practice in education in emergency contexts. These include practices such as psychosocial support, local empowerment, investment in community-based education, mobile solutions, and generation of more research (Burde et al. 2015). Our work directly extends calls for more local empowerment and focus on community-based education, while implementing mobile and adaptable solutions and generating research, including research by local students and facilitators.

TRACKING STUDENT AND COMMUNITY OUTCOMES

Methods to Track Impact

Our framework demands multiple modes of assessment in order to document immediate and sustained impact for both individual and community outcomes. Our work does enable and incorporate scholarly engineering education research, but in this paper, we describe the range of outcomes that a holistic, localized approach can stimulate. We see impact in terms of ***individual*** *graduates' learning outcomes, identities, and entrepreneurial opportunities*, and in ***community*** *engagement, utility derived from engineered products, long-term investment as facilitators,* and *collaborative research*. We track this impact through quality and quantity of students' final projects, their pursuit of independent projects, facilitators trained, joint research papers written with local leaders, and community usage of engineered solutions. We conduct assessments using rubric-based evaluations of final prototypes, analysis of virtual conversations, classroom observations, interviews, ongoing tracking of students' projects, monitoring installation of products for community usage, and collaboration with emergent communities of practice with whom we conduct research and submit publications.

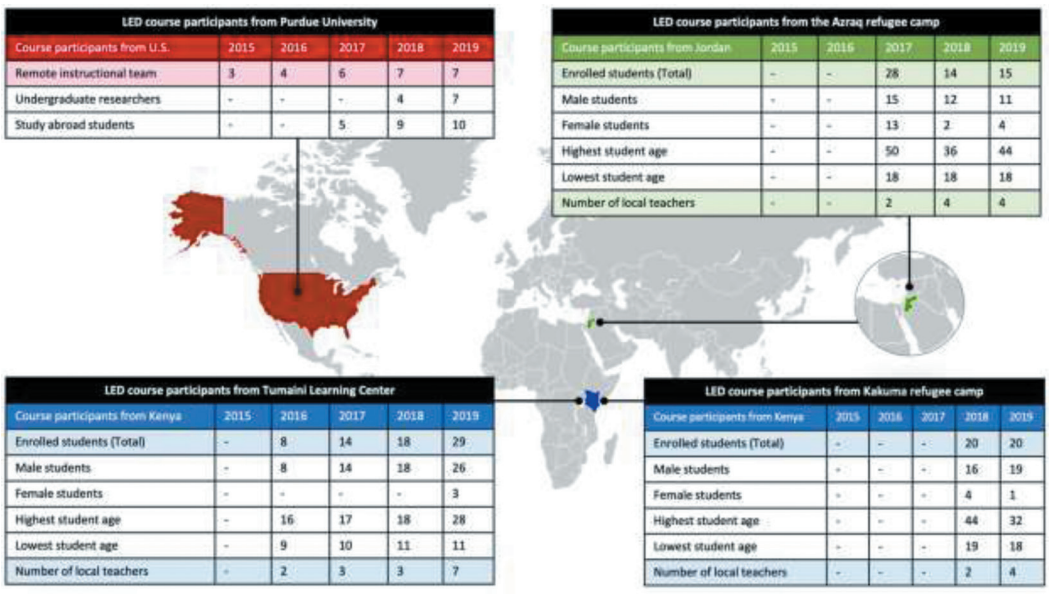
We distinguish our descriptions of outcomes in the next section as illustrated in Table 1, including individual and community impact and immediate and sustained impact.

Table 1. Outcomes illustrating impact.

	IMMEDIATE	SUSTAINED
INDIVIDUAL	• Course credits for completion • Engineering identities (emergent) • Holistic graded rubrics assessing design skills	• Entrepreneurial independent projects • Facilitator credits • Engineering identities
COMMUNITY	• Relevant prototypes and initial usage of installed products	• Community of Practice, mentorship of new teachers and teacher research collaborations • Installed products (usage and maintenance)

Data and Contexts

Data on student experiences and outcomes are drawn from 5 years of consistent and close collaboration. These data comprise 3 different learning sites: the residential school for former "street youth" in the Rift Valley of western Kenya (Tumaini), and two learning hubs for university classes in refugee camps in Jordan (Azraq) and in Kenya (Kakuma). Learners have been displaced from neighboring communities (Tumaini), Syria (Azraq), and a variety of home countries across the Horn of Africa and Great Lakes Region (Kakuma). After multiple years of coursework as of 2021, the impacts described in this paper represent approximately 166 students (69 at Tumaini [with some students repeating], 40 in Kakuma, and 57 in Azraq), learning in 23 different teams, with 19 teacher facilitators (including some previous course graduates; see Figure 3). The broader communities impacted comprise many more relevant stakeholders not reflected in totals here, including the instructional team of professor and graduate researchers at Purdue, undergraduate study abroad groups, undergraduate researchers, and the hundreds of students in the professor's on-campus course who collaborated on projects with the local students in Kenya and Jordan. Figure 3 describes the total number of students and teachers in LED so far. Of note, we focus on core learners in displaced settings, and on the periphery, students in the US gain tertiary benefits.



LED course participants from Purdue University

Course participants from U.S.	2015	2016	2017	2018	2019
Remote instructional team	3	4	6	7	7
Undergraduate researchers	-	-	-	4	7
Study abroad students	-	-	5	9	10

LED course participants from the Azraq refugee camp

Course participants from Jordan	2015	2016	2017	2018	2019
Enrolled students (Total)	-	-	28	14	15
Male students	-	-	15	12	11
Female students	-	-	13	2	4
Highest student age	-	-	50	36	44
Lowest student age	-	-	18	18	18
Number of local teachers	-	-	2	4	4

LED course participants from Tumaini Learning Center

Course participants from Kenya	2015	2016	2017	2018	2019
Enrolled students (Total)	-	8	14	18	29
Male students	-	8	14	18	26
Female students	-	-	-	-	3
Highest student age	-	16	17	18	28
Lowest student age	-	9	10	11	11
Number of local teachers	-	2	3	3	7

LED course participants from Kakuma refugee camp

Course participants from Kenya	2015	2016	2017	2018	2019
Enrolled students (Total)	-	-	-	20	20
Male students	-	-	-	16	19
Female students	-	-	-	4	1
Highest student age	-	-	-	44	32
Lowest student age	-	-	-	19	18
Number of local teachers	-	-	-	2	4

Figure 3. Total course participants and demographics in the LED program over the years.

OUTCOMES AND IMPACT

Immediate Individual Impact: Local Designs and Identities

First, we describe immediate, individual impacts shown in students' design prototypes and their described self-perceptions and goals. Learning outcomes are used as nontraditional gauges of broader impact because we are building local learners' capacities and changing the perception of *who* gets to be an engineer to include SY and refugees. In the class, we conduct rubric-based assessments of students' final projects, using positive rubric scoring (Jonsson and Svingby 2007; Moskal and Leydens 2000) to assess groups' projects and processes. Rubric items include descriptions of problem scope and feasibility of their proposed solution. Across sites, learners focused on relevant needs, provided detailed descriptions of the scope of the problem in their own community, created solutions that prefaced entrepreneurial and job opportunities, and demonstrated a clear awareness of the local market potential for clients.

However, learners also demonstrated a number of areas that needed improvement in order for their engineering projects to be sustainably used by the community. Students often did not provide sufficient data to support their claims, although in many cases, data about the engineering challenge or potential solution were difficult to access, unavailable, or kept out of displaced learners' hands. In addition, students often preferred overly complex solutions. For example, one team (Azraq) identified the problem of transportation around the spread out, dusty camp as a major need; their proposed solution was a model for an electric, solar-powered, self-driving car, with very high cost estimates. The technical possibilities were more interesting and outweighed feasibility, even though these students who are part of the refugee community are best placed to know the limitations of the context.

Finally, students did not fully articulate the downsides of their projects in their final project presentations and in-class formative assessments. This was in large part due to perceptions of articulating "cons" as a detriment, and they focused on *defending* their solution instead of articulating the downsides of their project as an engineering task.

In addition to students' projects, we assess individual, immediate impact by tracking students' goals and descriptions of their images of engineering and the design process. On the entrance examination for the class, students list goals that align with the "currency" approach (Freire 1992; 1968), focusing on having something to do to stave off boredom or practicing language or technical skills as immediately translatable to work. At the end, though, descriptions of goals and accomplishments are more robust and more specific, students talk about community impact and about implementing their work. While still highly engaged with technical accomplishments (Figure 4), at the end of the class, students talked more about process and agency and making impact in the community.

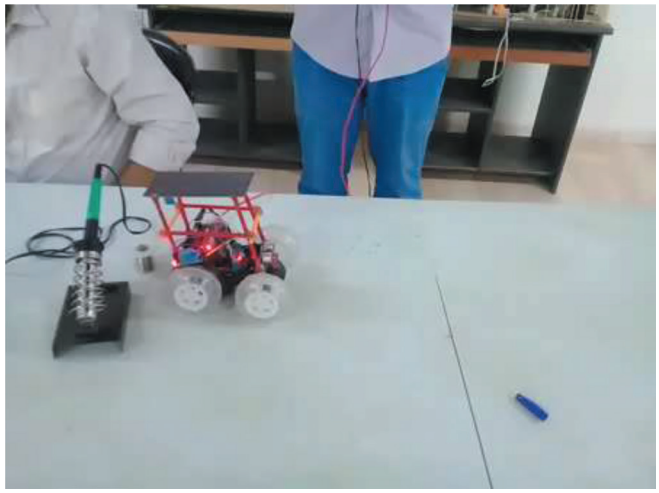


Figure 4. Student video demonstration of conceptual electrical vehicle prototype using alternative plastic and electronic components as a complex technical solution (electric, solar-powered, self-driving car) to the problem of transportation in the camp (https://www.youtube.com/watch?v=2IFvkLYODwY&feature=emb_title&ab_channel=PurdueTeam).

For example, students at the end of the course in Azraq described their ability to apply what they learned to local issues:

> "I know how to identify needs and illustrate several solutions and choose the appropriate one from them. I am able now to show both advantages and disadvantages of each solution and convert them into numbers and choose those that are appropriate for the budget and help a large group of people while being environmentally friendly that is recyclable. I learned a lot about how to evaluate projects, identify problems and obstacles and how to solve them. This is what we applied in the problems which we face in our daily lives and our work."

Further, students were sensitive to and proud of the fact that the UNHCR engineers and other external stakeholders who were authority figures saw their final presentation of projects. One student said, "During the final presentation of the project, we were able to discuss the inquiries that came from engineers and important figures and this gave us more power." Another noted, "People start cheering me on as I kept answering his questions."

Students described not only answering needs in their community, but applying the engineering design process and the skills they learned in class to other areas of work and life:

> "I also learned many concepts especially how to identify problems and the search within the available solutions, and comparing the results and choosing the best available one within the criteria chosen for my projects such as size or cost. I also learned the importance of identifying the need as it is a skill that I used it several time within my working field "education" as I manage with it to convince my direct manager the importance of a project I presented to him and I was only able to get it approved by utilizing some of the concepts discussed in the course. Yes they are engineering concepts but the application is not exclusive to engineering, I can apply it to most life aspects even those that are distant from engineering."

Local students begin with a troubled understanding of themselves as engineers, describing difficulties and not thinking they could solve problems or complete assignments. At the end of the courses, they describe themselves as problem solvers and engineers. They respond, too, that others in the community hold this perception of them, saying things like, "People when they see me now after the course they call me an engineer." Perhaps more importantly, they describe the challenges they persisted through as part of an engineering process, as noted in Figure 5.

As students come to claim their expertise, in parallel, local and global communities must recognize that these students can be engineers and that they bring major assets to their work. This includes recognizing the credits that students accrue as valid and the products they create as useful.

Figure 5. Video "Failure is not a stop but a stage", Kakuma graduate describing his newfound conceptualization of success through the engineering design process (https://www.youtube.com/watch?v=SVXfCS1YerA&feature=emb_title&ab_channel=PurdueTeam).

Immediate Community Impact: Products for the community, by the community

Students created solutions for the needs that they identified for their community within the Localized Engineering in Displacement class. One of the clearest illustrations of the tripartite impact of *learner, leader,* and *citizen* is the solar photovoltaic system at Tumaini. Throughout this process, students not only learned about theoretical aspects behind solar energy, but they got hands-on experience with relevant electronic components and technical aspects of solar systems. Students at Tumaini first identified the problem of unreliable power for their classroom and dormitory building. Over the course of a two-year LED class, former SY took on complex, integrated engineering concepts. They used tablets to access online coursework that our team created, adjusted to their needs and their progress, and completed formative assessments. They worked in teams to complete assignments, addressing learning outcomes regarding the design process, solar science, electricity, teamwork, evalation, and more. In 2018, students completed the design and installation of a 300W solar PV system to power their classrooms and dormitory. This meant planning circuitry, purchasing materials, installation, troubleshooting, and monitoring installation (see Figure 6).

The first module focused on solar photovoltaic systems, and part of the reason the class took so long was that different lessons would be adjusted, moved, and repeated, as students and local teachers determined was needed. The impact of this framework, in empowering local engineers to learn and then

Figure 6. (a) Tumaini team of former SY and an engineering teacher who is currently going through our teacher training (see Sustained Community Impact below) discussing solar installation; (b) Tumaini students at the beginning of their course learning basics of solar PV panels through hands-on activity.

engineer their own solutions, is indeed a longer time frame. This approach takes longer, but we argue that its impact is then both more permanent and more sustainable. Literature concurs that programs grounded in a participatory approach, community empowerment, and centering local capability can lead to long-term impact (e.g., Azaola 2014; Gram et al. 2018; Karim et al. 2014). The students at Tumaini who learned about, designed, and installed their solar PV system were then called upon by community clients as domain experts, which is currently being built into a sustainable livelihood model for the center. The solar PV system has acted both as supplementary source during power cuts (on average 10–15 hours a week) and as a complementary power source along with the local grid providing 5–10 kWh per week. The first course module demonstrated the capability of the learners to lead engineering solutions and build pathways to be solar service providers in the community. Students even developed the expertise and confidence to explain the entire project to the US Ambassador to Kenya (a periphery stakeholder, Figure 7).

We completed the second version of the LED program at Tumaini for five classes within the primary and vocational schools, resulting in five new prototypes addressing various problems. These include a portable solar Peltier cooler for storing fish in the Lake Victoria region for small scale fishermen and a manual briquetting machine for production of charcoal briquettes as cooking fuel for rural communities. The prototypes are currently (as of 2021) under testing and evaluation before scaling further.

Sustained Individual Impact: Independent Projects and Entrepreneurial Opportunities

In addition to immediate impact, we now have multiple years of data from the three sites, and we can gauge more sustained impact for both individuals and communities. We detail individual impact most

Figure 7. One of the senior students explains the principles behind solar power generation to the US Ambassador to Kenya.

clearly in "independent projects", which students can pursue after the class. This is an opportunity for them to take their prototypes and implement them in their homes and in public spaces for the community.

In Azraq, one of the students was motivated by a fire that had broken out in a larger refugee camp in Jordan (Zaatari; ("Four Syrians Killed in a Refugee Camp Fire in Jordan - San Diego Union-Tribune En Español" n.d.)). The fire in Za'atari claimed the lives of a number of people, including a whole family with young children. As part of the independent projects after he graduated from the course, he designed a gas and fire sensor that would cover the standard-issue UNHCR shelters used in Jordan (UNHCR 2016). He recruited team members from his class to help with presentation of the idea to our team and to UNHCR. He and his team were given ownership over the issue and were motivated to solve the issue because of the safety needs of families like theirs (See Figure 8). The shelters previously had no safety alarms. This illustrates the missed perspective of the humanitarian system's identity as an "emergency" solution for only basic temporary needs, when in fact a longer-term development orientation is needed. For example, the most recent "emergency" camps (like Azraq) in Jordan have now been in place for nearly six years. Our students' more immediate, localized motivation is high, but until taking the course, they did not have the space or support to engineer such a solution. This project subsequently won recognition in a local entrepreneurship competition run by MIT; even so, the student has faced barriers to getting it implemented in the camp.

Another ongoing example of sustained individual impact is that of a small-scale wind power generation team in the Kakuma camp. The team came together during class to create a proposal for small-scale wind power for their learning hub. Their presentation impressed the UNHCR engineer who came to observe their final projects in class. Since then, they have gathered data from a site visit to a medium-scale wind turbine outside the camp and have successfully installed a small-scale turbine at the hub.

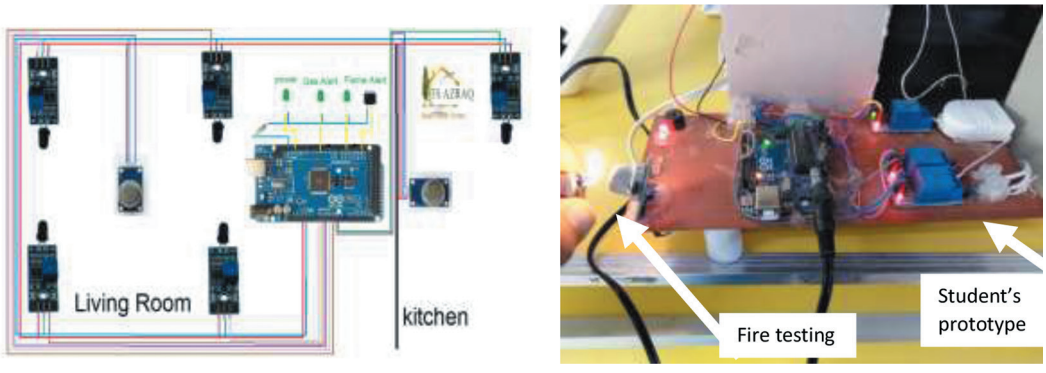


Figure 8. (a) Diagram of student's sensor system tailored to shelter dimensions (b) prototype being tested.

UNHCR engineers expressed enthusiasm for incorporating locally relevant problems into the engineering curriculum. In this sense, UNHCR engineers recognized that by attending the course, learners were able to apply their skills to local issues. Despite initial positive reactions, we noted a lack of recognition during follow-up among other policymakers and local managers. This grew into a significant challenge when students' assets and their capabilities to contribute were not formally recognized or supported in implementing useful solutions.

Another challenge is the lack of recognition of the teaching skills offered through our teaching certification program. Capacity building through ongoing teacher professional development is a critical component of the LED model, and we support training where local facilitators develop skills as instructors. However, local and national policies typically do not recognize these teaching skills, and graduates from our teaching certificate do not have their credits recognized by local agencies. Further, this lack of formal recognition transfers to students' products. While we encourage graduates to become agents of change and tackle local problems, there is little support to fund implementation of their ideas or even permission to access the resources needed to build out their projects.

Sustained Community Impact: Long-Term Maintenance and Local Teaching Capacity

With multiple years of data, we have also observed sustained impact on the community, with the two most notable impacts demonstrated by the community's engagement with our graduates as maintainers and the development of local teaching capacity. First, we see that the community perspective towards our former SY and refugee learners has changed. Where they were previously reticent to recognize our students as learners, leaders, and citizens of their communities, they now recognize their expertise. In Kapsoya (the community surrounding Tumaini), community members now request the students to perform maintenance on the domestic solar PV systems that have become prevalent, as students point out in our interviews (See video in Figure 9).

Figure 9. Student graduate of first engineering course at Tumaini explaining the requests from the community for solar PV installation and maintenance as a result of the LED program (https://www.youtube.com/watch?v=XdZRjKxLinM&feature=emb_title&ab_channel=PurdueTeam).

Figure 10. Two of our graduates from 2018 who became facilitators in 2019 sharing feedback to a student team's biomass briquette machine prototype in Kakuma, Kenya.

The other major measure of impact has been the buildup of local capacity for engineering teaching. From early in our implementation, previous graduates of the course have served as mentors and facilitators for subsequent courses. This has grown to a full course on engineering facilitation with its own credits. As the number of sites has grown, we have connected facilitators across sites, and they shared teaching ideas with each other, including how they explained challenging concepts to their students. Further, we developed a rich Community of Practice (Wenger 1999) of the teachers within our earliest site. They have supported each other and started conducting action research. This has already led to two accepted conference publications on their work that we co-wrote together. Building local and connected knowledge and new research capacity is important. Graduates become facilitators through a participatory process between instructors and students (See Figure 10), which further deepens their understanding, improves the independent projects many are working on in parallel, and builds a cadre of local experts. The CoP further builds research expertise, recognized on a more global scale by the Engineering Education and Engineering Education Research communities.

DISCUSSION

In our discussion, we address ethics of engagement and responsibility to students, communities, and institutional partners, and we describe mechanisms of sustainability and multiple challenges. In Figure 11, we illustrate our process of taking lessons learned in navigating these challenges and

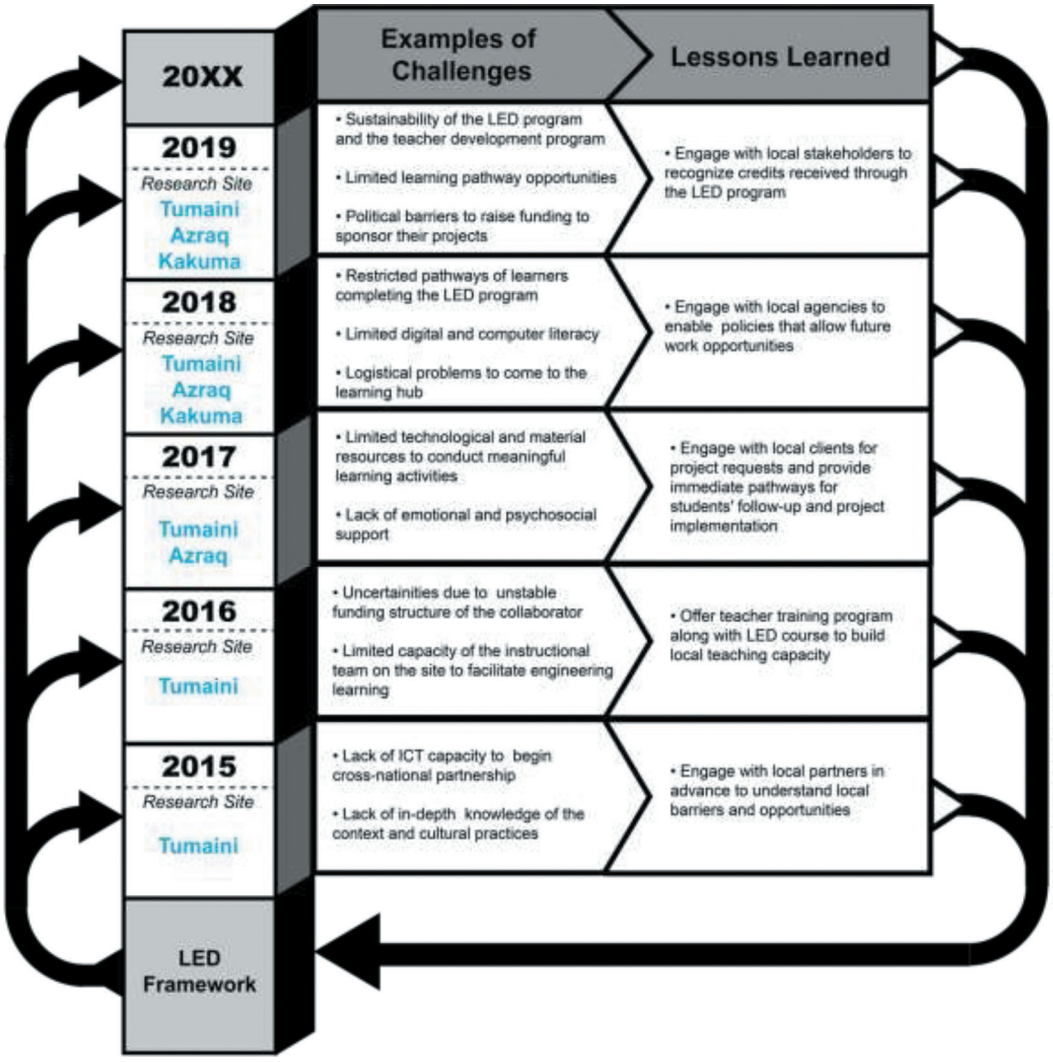


Figure 11. Iterative process whereby contextual challenges help to inform lessons learned and applied to the LED course in subsequent years and in scale-up locations.

adapting the LED to scale to new contexts. The LED program has improved as it has evolved, and we provide in the following section an in-depth discussion of engagement, challenges, and sustainability of the LED across multiple displaced settings.

Challenges

Language

Localized Engineering in Displacement is not simple, and there are a number of challenges associated with the nature of conflict, fragility, and uprootedness. First, language. When learners are

uprooted and come together in a temporary support space or a new community, they are often from different language groups. For example, at Tumaini, street youth have converged on Eldoret from all over Kenya, and while they communicate together via a mix of kiSwahili, English, and a local "slang" version of kiSwahili, their mother tongues vary. In Kakuma, displacement is occurring from multiple countries with a vast number of mother tongues and even variation between colonial languages (English or French). We have adapted by leaning on the strengths of local multilingual students and explicitly recruiting diverse students on the facilitation team (both at Purdue and locally). Covering the spectrum of local languages in an equitable way remains a challenge.

Gender barriers

Despite efforts to balance the gender of participants in recruitment of both students and teachers and to provide tailored support services, we still experienced unequal recruitment and retention. In Azraq, for example, where the population is entirely from Syria, we documented a significant influence of the monocultural social context in family perceptions about female students attending classes with mostly male learners. We also saw from study data that male learners in Azraq placed a higher value on opinions from male peers than female peers when working in teams. We consistently had few women students, and though some successfully completed the course and excelled with their follow-up projects, women students had a higher stop-out rate.

In Kakuma, given the variety of countries of origins and languages spoken in the camp, the multicultural context seemed to positively influence both participation by gender and peer-to-peer collaboration. However, while our observations of gender barriers were more evident in Azraq, we still noticed challenges in Kakuma. For example, our recruitment process revealed challenges for women, whether because of time conflicts with other jobs or a need for nearby childcare. Drawing on our experiences in Kakuma and Azraq, we urge immediate actions to create policies that promote and support displaced women to engage in technical courses when available. We also saw that this challenge was related to both in- and out-of-class factors, and there is a need to understand both classroom practices and family support to better engage women.

Between 2015–2018, Tumaini did not have the space to accommodate and thoughtfully support residential female SY, despite their interest and enthusiasm to learn STEM. Boy and girl SY express different goals and timelines for education, demonstrating gender differences in norms, societal perceptions, and social isolation. Girl students in Kenya, both SY and non-SY, face barriers to education. Girls finish fewer years of schooling (only 5 years in Kenya; Wachira et al. 2015). Overcoming these barriers, in 2019, Tumaini admitted three girls as part of the new vocational school; they immediately took part in the LED program and received certification. The only female student in the electrical wiring class was part of the team that designed an automatic transfer switch for solar and

Figure 12. Stellar graduate at a project site installing electrical wiring system for on-going construction.

grid power sources and is now currently employed with an electrical contractor in Eldoret installing solar PV systems for new buildings (Figure 12). Further, Tumaini has had an overrepresentation of women leading as teachers, though the students have all been boys until last year. These engineering teachers serve as important academic and gender role models for the boys.

Cohesion and host communities

Where does obligation to solve an engineering challenge lie? And, where is community? Another challenge is fostering social cohesion in displacement, which can be difficult for multiple reasons. First, the histories of the groups who have been thrown together has sometimes been one of conflict. Higher education and engineering teaming can serve the important role of building social cohesion, but this is not straightforward in any context, and is even more complex when in some cases, racial, ethnic, or linguistic groups have had violent interactions or been at war before. For example, the area of Tumaini was one of the locations for some of the most intense inter-ethnic conflicts during the post-election violence of 2007. In relation to and exacerbated by the conflict, even today, members of the local community frown upon the presence of street youth because of the ethnicities that they most often represent. However, the engineering solutions developed by the students at the center

in the LED program are perceived by the community as a positive catalyst to further development in the area. The learners, as leaders and citizens, along with the teachers at the center, have intentionally reached out to the local community to bridge the ethnic, economic, and power gap. As a further result, a short-term engineering design thinking program is being developed by one of the teachers and some students to teach other vulnerable youth in the community.

Second, the relationship with the "host" community locally and nationally is often fraught. The vast majority (over 85%) of displaced refugees and internally displaced people are in developing countries. In Kakuma, for example, the local Turkana region is dry, arid, and impoverished, and the local community perceives that resources go more to the refugee community. Refugees around the world are vulnerable to exploitation, arrest or detention, and can be forced to compete with the poorest local workers for the lowest paying and most dangerous jobs. Other opportunities for low-income community students around Tumaini are highly limited, including access to higher education, making relationships more fraught.

Creating positive relationships with host communities involves changing the broader community and organizations' mindsets, including the NGO and UN community. The humanitarian industry sees and fosters dependency (Krasteva 2013), and at the same time, the local community sees displaced people as a problem (Lee and Nerghes 2018; Richmond 2002). Changing this deficit framing on the part of the local and global community is crucial.

Transience and permanence

Camps and street youth schools are supposed to be transitory, transition centers to move students back into a formal system or back to their home countries. The permanence of displacement has become unprecedented, though, with the average amount of time spent in a refugee camp now upwards of 20 years (UNHCR 2018b). Camps in reality are often not a short-term solution, even though they are built and treated as such, further uprooting displaced communities. Our experience implementing the LED program revealed a number of limitations related to the tension between transience and permanence that affected student retention and hampered post-course opportunities and therefore sustainability of the model. For example, in refugee camps, there are constraints on working. With the clear priority of providing food for their families, students often had to seek job opportunities outside the camp. Consequently, some students noted that they had to drop the course because they could not both attend and work, whether because of limited internet or restricted access to enter and leave the camp. Further, in light of the lack of educational and job opportunities within the camp, students often reported frustration and lack of motivation after completing the course since they could not get the necessary support to advance their projects or take advantage of advanced educational opportunities outside of the camps. This strained, unresolved

characterization of displacement as transient or fixed creates uncertainty and ambiguity for our learners and can leave them vulnerable to exploitation.

Lessons Learned and Implications for Humanitarian Engineering

After five years of work on this program, we offer some lessons learned. One important point has been to leverage existing local expertise, both to legitimize our learners and to promote relationships with existing power structures that our students might have to navigate. For example, we calibrate by having UNHCR engineers as invited lecturers during our course, recognizing that our students' implementation ecosystem beyond the classroom is mediated by politics and hierarchy.

We have identified characteristics of the context that need to be understood before scaling our framework. These include language, digital and computer literacy, local infrastructure, teacher professional development, local policies and regulations, and psychosocial factors. Language refers to the language of instruction, which requires appropriate translation and teaching capacity to deal with linguistic diversity. Digital and computer literacy includes the need to provide appropriate training to both learners and facilitators to use educational technology. Local infrastructure includes adequate learning spaces for technical training and connected learning. Teacher professional development means supporting initial training and long-term local capacity building for local face-to-face instruction. Local policy refers to official permission for credit transfers and other requirements of continued learning pathways; these were one of the largest barriers to the scalability of our framework. Finally, psychosocial support and social-emotional learning refer to strategies to support emotional well-being and motivation tailored to the particular needs of students that affect learning performance.

The examples we detail here are currently limited by our experiences in Kenya and Jordan. We do not have the in-depth understanding of contextually available and culturally appropriate resources in every other context, which would be needed to successfully transfer and scale the design and outcomes of our program to all countries, nor is that a reasonable approach. However, we can briefly detail how we have begun to scope our approach in the contexts where we are next scaling this framework – Zimbabwe and the USA. For example, in Zimbabwe, we were approached by two girls' schools and an international NGO to co-develop a curriculum for the learners to design and build a sustainable water supply for their schools. This problem identification emerged from a needs assessment the learners already completed. Our first step together as part of our LED framework is to review the previous needs assessment and subsequently support the learners as they themselves gather data to specifically scope the design space.

Another lesson has been to confront the complexity of emergency settings as needing a longer horizon. We support our students in building more permanent solutions. Displacement now is largely protracted; some two thirds of refugees, 11.6 million, were in protracted situations, with 4.1 million

of them are in exceptionally drawn out situations of 20 years or more, such as Palestinian refugees in Egypt and Afghans in Pakistan. As even UNHCR's camp building handbook has had to recognize, there is a struggle between permanence and the temporary situation that host countries allow. For example, the handbook states, "As it is difficult to predict the life-span of a refugee camp, it is best to plan on a cost-effective, long-term basis" (p. 239). This is contradicted by most host countries' demands that no permanent house or fixed structure is allowed to be built, in order to prevent the camp from turning into a city. Engineered solutions are supposed to be temporary and go up quick. Explicitly confronting the reality that we must move towards a more long-term development solution is crucial. Students need to be prepared to be builders and local leaders when they go back, wherever that might be – otherwise we are faced with a lost generation of engineers.

This study, as a secondary goal, contributes to university-based teams interested in critically engaging in international development collaborations. Specifically, two insights are of interest to this audience. First, we show how the application of distinct pedagogies that are often implemented alone (active, blended, collaborative, and democratic learning) can be integrated in an engineering course that is grounded in critical pedagogy and social justice. We show the role of each pedagogical component during the design process, the sustained pathways to support engineering capstone projects within a complex ecosystem and partnerships, and individual and community impact through independent projects. Our framework also illustrates the complex and interconnected nature of engineering education in displacement so that university teams within a refugee camp or working across teams inside and outside of a camp setting can clearly anticipate potential issues. For example, from a political perspective, our model can help stakeholders identify the different actors who could be involved in course development. We show some of the contextual problems that can arise when trying to translate projects into long-term solutions. We have documented elsewhere other examples of our framework and the ways in which it can be deployed by university teams, with more focus on the international, non-local university. In one example, we describe the way in which a study abroad engages with Tumaini teachers and students, including how US-based students engaged in self-reflection, meaningful learning from the community, cultural humility, flexibility, capacity building and participation, and reverse innovation (Claussen et al. 2019). In another example, we detail how a US-based undergraduate researcher engaged in a collaborative building project with a student at Tumaini, which fostered growth in the US student's ability to enact context-specific and community-centric design and the Tumaini student's ability to see himself as an engineer and oversee the construction processes on site (Napoli et al. 2020).

As our contribution to scholarship, we provide a framework that offers both a curricular and pedagogical approach, partnership ecosystem, and learning pathway. For example, empowerment and scaffolding in our pedagogical approach has been vital. This has included balancing flexible

deadlines and the need to iteratively improve projects through formative feedback with students' limited time and necessary accountability. We have also more clearly integrated technical concepts with the less-familiar design process. Students have been challenged to gather more clear, relevant data to support their initial designs. In addition, our partnership ecosystem and learning pathway call attention to the complex humanitarian architecture in displacement that requires collaboration across multiple actors to advance education initiatives. Therefore, we propose a framework that is not merely grounded on specific institutions or partners. Future research could explore each of the facets of the framework we describe, whether the pedagogy, curriculum, pathways, or partner ecosystem. We achieve sustainable impact by focusing on local students and teams of displaced learners as the core actors of our framework. Further scalability of these learners' collective impact could be achieved by supporting displaced learners to surmount some of the official barriers we have described.

Limitations and Recommendations

The findings and recommendations of our study must be interpreted considering limitations. As mentioned under lessons learned, our examples are limited to our experiences in Kenya and Jordan's fragile contexts. Displacement contexts across the world vary based on the local government, settlement approaches, host community, and emergencies that force people to displace. Therefore, our LED model cannot be generalized without considering the local factors, needs, and assets in these contexts.

Our research efforts discussed in Kenya and Jordan have only evaluated learners who were undergoing the LED program and recent graduates. Therefore, the full impact of the model and its sustainability need long-term evaluation and additional research. Consequently, we recommend three key areas of further research to strengthen scientific evidence and develop new knowledge.

1. Investigating learning outcomes and growth of the learners through constructs of socio-emotional skills and self-efficacy. Understanding the role of engineering in building socio-emotional skills will help integrate psychosocial support (PSS), an essential aspect of educational programs necessary for displaced learners. We also recommend longitudinal investigation of learners' pathways and their ability to see the relevance of LED programs in their careers to understand the impact.
2. Inquiring into the role of technology and learning behaviors to shed light on improving educational technology creation, usage, access, and adaptation in fragile contexts.
3. Investigating the role of teacher development as an approach towards sustainability and scaling the LED program across fragile contexts.

To summarize, ours is an alternative, co-created, multi-institutional approach to authentic engineering learning for displaced communities. Our program focuses on three areas: technical content,

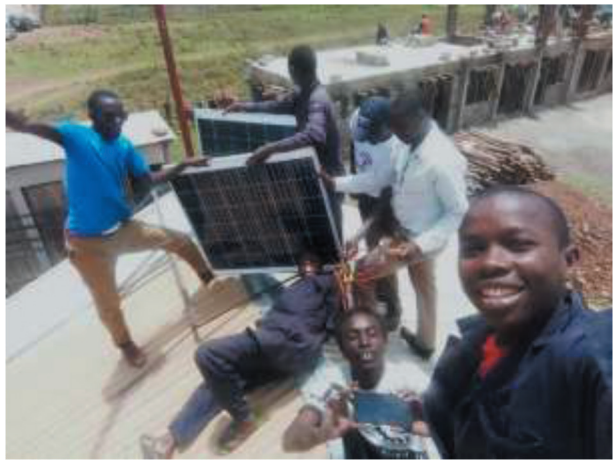


Figure 13. LED module 1 students and teachers at Tumaini installing the final design solution (solar PV system to address lack of reliable power source).

professional skills, and engineering design for needs that refugee learners themselves identify in the beginning of the class. Students are asked to solve an "ill-structured" problem, targeted at a local need in their own community. They use online modules and hands-on practice to learn and practice technical concepts in small groups, replicating the teamwork demanded of engineers today. They have realized impact in their communities with highly relevant solutions that both immediately and long-term address community needs (Figure 13). As our students in displaced settings re-take ownership of their own engineering, we urge policymakers and the discipline of engineering education to similarly recognize these students' assets.

ACKNOWLEDGEMENTS

We would like to gratefully acknowledge first and foremost our students who put their time, energy, and creativity into participating in this program. We greatly appreciate all the work of the whole DeBoer Lab research group at Purdue. We are also grateful to all the partners represented in the impact described – Tumaini, UNIGE-InZone and the local management in Kakuma and Azraq, local university partners, and technology partners whose platforms helped make this class possible. The work represented here was supported in part by funding from Purdue University's Global Engineering Programs and Partnerships group now known as the Shah Family Innovations in International Development (I2D) Lab and the National Science Foundation (NSF). This material is based on work

supported by the National Science Foundation (NSF) under DUE #1454558. Any opinions, findings, conclusions, or recommendations expressed here are those of the authors and do not necessarily reflect the views of the NSF.

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