Workshop on Global Engineering Design for Low-Resource Settings

Lauren Mottel
Lauren Shipp
Menansili Abraham Mejooli
Ghodeejah Higgins
Maleshigo Mabye
Hannah Christine Watkins
Dr. Kimberly L. Bothi

Dr. Kim Bothi has a multidisciplinary background in engineering and social sciences, with research and consulting experience across a range of developing country contexts. She earned a Ph.D. in global community-based resource management from Cornell Unive

Kathryn Alexa Jackson
Dr. Julie Carol Karand, University of Delaware

Julie Karand is an Assistant Professor of Biomedical Engineering at the University of Delaware (UD). Throughout her engineering career, she has tried to integrate global engineering into her work. Most recently, she spent the final year of her PhD at the University of Cape Town, integrating her benchtop cardiovascular research into computational models. In 2018-2019, she spent a year living and working in Tanzania, in East Africa through the Fulbright US Scholar program, teaching and conducting clinical research. Now at UD, her scholarship work includes embedding global engineering opportunities into the engineering curriculum through study abroad programs, new courses, serving as an advisor for UD's Engineers Without Borders, and hosting global design workshops.

Workshop on Global Engineering Design for Low-Resource Settings

Background

Global engineering is becoming more prevalent as technology increases communication and collaboration worldwide [1]. To keep up with the ever-evolving society, global engineers must work on cross-cutting issues and bring a diverse mindset to work nimbly across different environments with changing resources [1,2]. This adaptability requires being comfortable with design skills and being open to new ideas and international relations [3]. The design process is crucial for students to experience and understand how to meet a population's needs and iterate through feasible and culturally appropriate solutions.

Undergraduate engineering curricula have significantly evolved over the years, becoming more hands-on and project-based to allow students to develop, innovate and learn from the design process [4]. However, many curricula still need to implement programs or courses for students to actively engage with global engineering and discover how cultures, settings, and ideologies can impact engineering and design. There have been attempts to incorporate these concepts into humanitarian engineering activities to help students consider marginalized groups and encourage empathy [4,5]. While these programs allow students to think about others, there is still a gap that needs to be filled for students to gain a global perspective on engineering design, especially in low-resource settings. In 2018, Jesiek and colleagues proposed tools for assessing global engineering competencies, which highlights the recent interest in evaluating these skills in our students [6].

For students to have greater exposure to global engineering topics, we developed a weekend workshop open to all undergraduates interested in improving their low-resource medical device design skills. The program allows students to learn from international cultural mentors and develop solutions to real-life challenges. Students are presented with scenarios from current challenges in sub-Saharan African healthcare settings. The program is free for all participants, and under-represented students and those who have not traveled internationally were encouraged to apply.

In November 2021, we held our first workshop to serve as a pilot program. From the first workshop, we learned that the students enjoyed the program layout and especially connected with the open-ended design projects. In our program, Day 1 emphasized general international engineering background and discussion with international cultural mentors. Day 2 focused on team projects, where students designed particular healthcare solutions for a low-resource setting. As we further developed the program, we shortened Day 2 due to student feedback and allowed teams to start working on their projects in the last few hours of Day 1. We also adapted our final presentations into poster sessions, allowing more natural discussion and students to feel more comfortable comparing their project solutions to other teams' solutions. In 2022, we held workshops in March and October, with 32 and 47 participants, respectively, which included students from 9 different institutions spanning five states and territories.

Throughout critical points in the program, students evaluated their learning and provided survey feedback. The program organizers also performed a direct assessment of the student projects. From these data, we found that student learning progressed throughout the workshop. We plan to continue hosting these workshops and believe they positively impact student development and change perspectives in engineering design, allowing them to understand culture's influence on engineering design better.

Methods

Approval: This study was carried out with Institutional Review Board approval from the University of Delaware.

Workshop Scheduling: We held 3 Design for the Developing World workshops during weekends at the University of Delaware in November 2021, March 2022, and October 2022. The November 2021 workshop served as a pilot, and the data discussed in this manuscript reflects results from the March 2022 and October 2022 workshops.

Participant Recruitment: Undergraduate students were recruited for this program from the University of Delaware and other local institutions. Recruitment efforts were placed on women, underrepresented minority students, and those who had not traveled extensively outside the USA. The November 2021 workshop had 26 participants, the March 2022 workshop had 32 participants, and the October 2022 workshop had 47 participants, for a total of 105 participants in the program. Participants attended from 9 different institutions spread throughout five states/territories: Delaware, Maryland, Pennsylvania, New Jersey, and Washington D.C.

Workshop Schedule: The program was held over a Saturday and Sunday during traditional American college semesters, from approximately 10 am to 3 pm each day. The goal of Day 1 of the program was to give a shared background to the participants with the critical goals of introduction to the engineering design process, focus on the end user, discussion with cultural mentors from sub-Saharan Africa, and information on career opportunities in global health. Students chose between 3 projects related to improving healthcare in Tanzania: maintenance of vaccines at refrigeration temperature, simplifying a glucose monitor system, or streamlining the healthcare system for accessibility. They were placed in teams of 2-4 students and started the design process. Day 2 of the program was focused on the student projects, completing the engineering design process and creating a poster and prototype design for their chosen project to present at the workshop.

Mentors: The workshop was run by program mentors and international cultural mentors. These were people with advanced degrees in science or engineering fields. The international cultural mentors all have home countries in sub-Saharan Africa.

Indirect Assessment: Survey questions were created by the workshop development team based on a Likert scale and through open-ended questions [7]. The surveys were given to students when they first arrived at the program, and at the end of days 1 and 2. The questions were based on the workshop's goals: to develop students with a more global and empathetic view towards

engineering design, especially for medical equipment in low-resource settings. Example blank surveys from the October 2022 workshop can be found in Appendix A.

Direct Assessment: Students were evaluated by program instructors at the start of the program, through a brainstorming exercise and at the end of the program during final student presentations. Five instructors (3 international cultural mentors and 2 program organizers) provided feedback from both 2022 workshops using rubrics which can be found in Appendix B. Students were placed in different groups for the two activities. Each instructor provided feedback for all groups in both activities.

An initial brainstorming exercise was completed at the very start of the program, where students were asked to work in groups and write on post-it notes in response to the following prompt: "About 50% of neonatal (newborn) deaths worldwide are due to hypothermia. Some reasons include that newborns lack sufficient body fat and metabolic rates to maintain body temperature. Brainstorm: 1. Possible approaches to avoid hypothermia-related neonatal deaths in developing countries. 2. What additional information do you need?" [8].

The final direct assessment was made by evaluating student projects on one of the following topics: "1. Maintaining the cold chain for delivery of vaccines to rural settings. Many medical products require storage at cool temperatures to maintain molecular stability (4° C to -80° C). These products must be kept cold from the manufacturer to the delivery location. Design a way to maintain the cold chain to deliver vaccines to rural sub-Saharan African settings in a more sustainable, affordable, and convenient method. Choose to focus on designing a method or a device. 2. Streamlining the Healthcare System. People often must wait outside the clinic for long periods from early morning. They often miss a whole day of work. Design a method for shortening wait times at primary healthcare clinics. Choose to focus on a male patient population or an HIV+ patient population. 3. Glucose device adaptation to promote ease of use. Diabetes and blood sugar disorders are issues that often go undetected in sub-Saharan Africa. Traditional monitoring systems using blood glucose meters and testing strips multiple times a day may not be accessible. Children are especially at risk as they might not know how serious complications can be. Design a way to adapt the traditional glucose monitoring systems to help individuals manage their blood glucose levels. Choose to focus on systems for children or adults."

Data Analysis: Data was entered digitally from paper forms and then analyzed using JMP and visualized using GraphPad Prism. Data sets were found to be not normally distributed based on the Shapiro-Wilk W-test. Non-parametric data were compared between the pre-workshop and post-workshop groups using a Mann-Whitney U-test with significance determined at a p-value of 0.05. For direct assessment results, a two-way ANOVA test was used to compare pre- and post-workshop results, blocking by evaluator. Categorical data trends were summarized from open-ended responses and visualized using pie charts.

Results

A total of 64 students attended the 2022 Design for the Developing World workshops and submitted surveys (Table 1). Participants attended the program from various institutions in the Eastern part of the USA, with most students from the University of Delaware (n = 29). "Other"

universities included Rowan University, Delaware State University, Wellesley College, and the University of Pennsylvania. Slightly over half of the students were underclassmen (first- or second-year students), and a third were upperclassmen (third-year, fourth-year, or recent graduates), while the remaining 11% did not provide an answer.

Table 1. Demographics of Participants from the 2022 Design for the Developing World Workshops.

		University							
		Kean U.	Lehigh U.	Rutgers U.	U. of Delaware	U. of Pittsburgh	Other	Unanswered	Total
Grad. Year	Underclassmen	5	3		16	8	3		35
	Upperclassmen	1	3	3	12	3			22
	Unanswered		1		1	1	1	3	7

The participants' majors were also recorded, with two-thirds of students being biomedical engineering or bioengineering majors (Figure 1A). The remaining majors were other engineering disciplines, biomedicine/biotechnology/molecular biology, or the question was unanswered. The question, "I understand how to design with the cultural setting in mind, and I am comfortable working on design projects for settings with varying resources," was asked to all students before the workshop. The ratings were separated by underclassmen and upperclassmen (Figure 1B) and no significance was found between how the two groups rated the question.

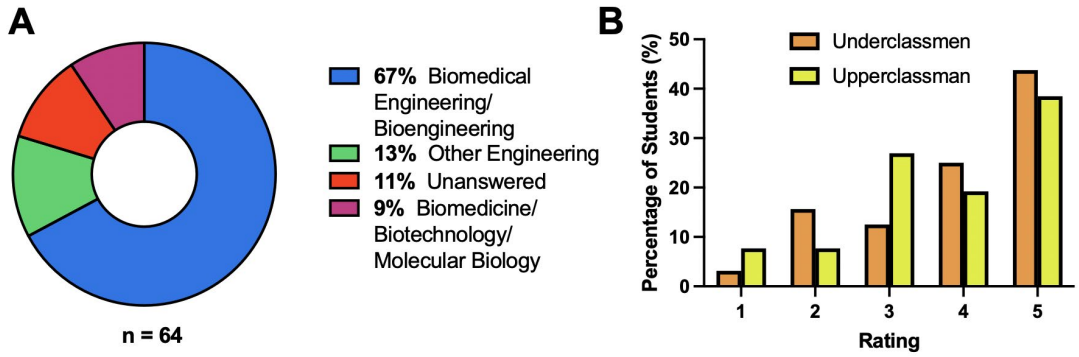

Figure 1. (A) Pie chart visualizing the percentage of majors present in the 2022 workshops, (B) Bar chart representing the ratings (1-5) given to the question "I understand how to design with the cultural setting in mind, and I am comfortable working on design projects for settings with varying resources" by underclassmen and upperclassman at the start of the 2022 workshops, where 1 is 'strongly disagree', 3 is 'neutral', and 5 is 'strongly agree.' These results were not significant between underclassmen and upperclassmen, Mann-Whitney U-test, $p>0.05$.

Students were asked to answer various questions throughout the workshop to gauge how their perspective changed over the two-day period. The ratings were on a scale from 1-5, with 1 being 'strongly disagree' , 3 is 'neutral', and 5 being 'strongly agree.' There were three questions that could be directly compared between pre- and post-workshop surveys and the results of those survey responses are shown below (Figure 2). Given a large variance in the responses, we found

it useful to view the spread of data rather than compare the mean ratings alone. The ratings of Question 3, "I am interested in doing engineering/science that is relevant to global problems," showed a large increase in a rating of '5' by the last day of the workshop (Figure 2A). Question 6, "I am interested in engineering/science that is relevant to sub-Saharan Africa," showed over three-quarters of students rating a '4' or '5' post-workshop (Figure 2B). Question 7, "I understand how to design with the cultural setting in mind, and I am comfortable working on design projects for settings with varying resources," was rated as a '4' or '5' post-workshop by all students (Figure 2C). All three questions demonstrated significance between pre- and post-workshop responses.

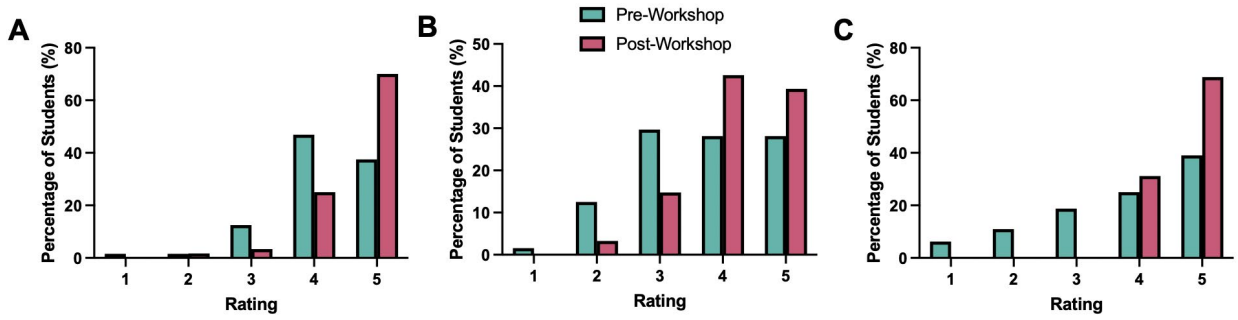

Figure 2. Bar charts representing the ratings (1-5) given to the questions (A) "I am interested in doing engineering/science that is relevant to global problems," (B) "I am interested in engineering/science that is relevant to sub-Saharan Africa" and (C) "I understand how to design with the cultural setting in mind, and I am comfortable working on design projects for settings with varying resources." All questions show significance between the means of pre- and post-workshop responses, Mann-Whitney U-test, $p<0.001$.

Students were also encouraged to answer open-ended questions to reflect on their experiences in a survey. These responses from October 2022 are compiled in Figure 3. A wide range of gained skills were reported amongst participants, with 20% saying they gained experience in the iterative engineering process; this result is in conjunction with increased mindfulness of global communities, where 18% of students were more conscious of end-user populations, and 14% of students felt they expanded their cultural competency (Figure 3A). This reported increase in consideration of end-users also extends to self-reported changes in overall design perspective, with approximately 40% of students stating the importance of collaborating with end-users when designing (Figure 3B). Furthermore, when students were polled on whether this workshop had an impact on their plans going forward, approximately 57% of students reported that they wished to look into researching or working abroad, and 29% of students planned to study abroad (Figure 3C). Overall, across open-ended survey questions, there were strong trends in being able to effectively communicate and work with end users to solve complex global engineering problems, as well as continued interest in working or studying abroad after attending the workshop.

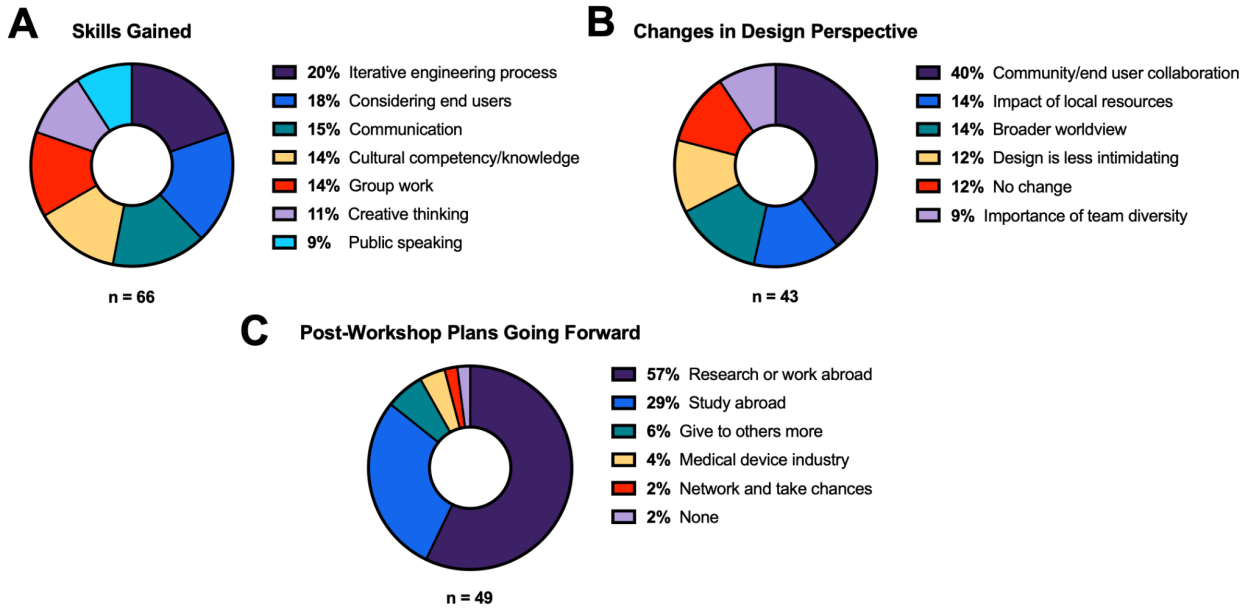

Figure 3. Pie charts visualizing student open-ended survey responses following the October 2022 workshop. Specifically, the following questions are highlighted: (A)"What, if any, skills did you gain from this workshop? (B) "Has your perspective on design changed? If so, name one or more ways." and (C) "Do you plan to do anything differently as a result of attending this workshop?".

Instructors directly assessed two activities during the program using rubrics with a 1 to 4 grading scale, with 4 meaning ‘Yes’ and 1 meaning ‘No’ (Appendix B). The assessed activities were 1) a brainstorming activity at the start of Day 1 of the program and 2) a presentation of their design projects after Day 2. For both activities, the feasibility of the design in a low-resource setting and the cultural context and user-friendliness of the design were the two main criteria on the rubrics. The frequency of scores for each criterion are summarized in Figure 4. Although there was no statistical significance found between the two activities, there were promising trends observed by the evaluators. With regards to the feasibility of proposed designs, the average pre-workshop score was 2.77 +/- 0.71 and the average post-workshop score was 2.92 +/- 0.97; the frequency of ‘4’ scores doubled, increasing from 14% to 31% over the course of the workshop and coinciding with the relative decrease in ‘2’ and ‘3’ scores (Figure 4A). For the consideration of cultural context and user-friendliness of the projects' designs, the average pre-workshop score was 2.87 +/- 0.78 and the average post-workshop score was 2.81 +/- 0.86; the trends remained very similar at both time points (Figure 4B).

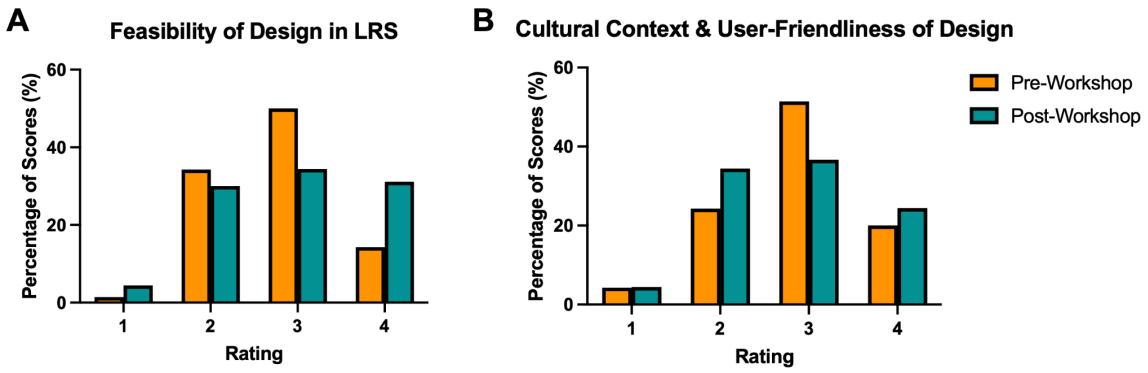

Figure 4. Bar charts showing the distribution of ratings (1-4) given to student group projects by workshop instructors to evaluate the (A) feasibility of their proposed design in a low-resource setting and (B) the consideration of cultural context and the overall user-friendliness of the design at the beginning and end of the workshop. No significant differences between means was found in either metric, two-way ANOVA blocking by evaluator, $p>0.05$.

Finally, students were asked to answer open-ended survey questions to provide constructive feedback on how the workshop was organized (Figure 5). At the start of the workshop, 34% of the participants said they were looking forward to getting more experience with the iterative engineering design process, with 21% of students hoping to build connections by meeting and working with new people (Figure 5A). With regard to student feedback on the structure of Day 1 of the workshop, most students enjoyed hearing from the program organizers and international cultural mentors about their own life experiences (Figure 5B). Despite this positive feedback, 42% of students recommended changing the Day 1 schedule to have shorter presentations, with 28% recommending general adjustments to the allotted time for activities (Figure 5C). For Day 2, nearly half of the students were satisfied with the allocated time to work on projects, followed by the general structure of the day (Figure 5D). One-third of students desired more instructor feedback and collaboration with other teams (Figure 5E).

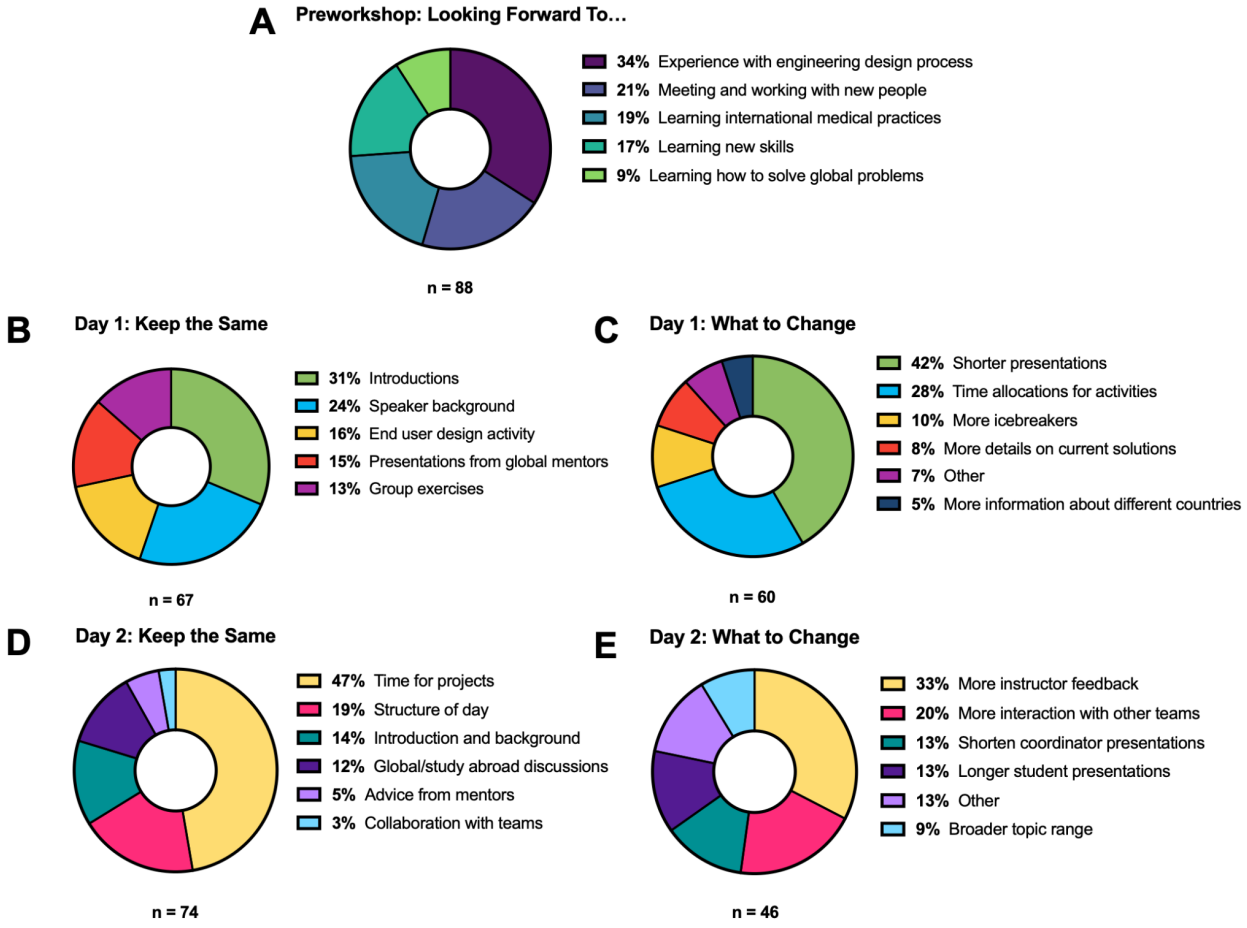

Figure 5. Pie charts summarizing self-reported student feedback from the 2022 workshops, including (A) students' anticipated outcomes at the start of the workshop and (B) features of Day

1 to keep the same, and (C) to be changed. Similarly, (D) features of Day 2 to keep the same and (E) to be changed.

Discussion

The Design for the Developing World (DDW) workshop was created to introduce undergraduate students to medical device design in low-resource settings, an experience many students are not exposed to during their undergraduate careers. Today's undergraduate experience is open to more than formal coursework. In contrast, many universities provide global experiences for their students through organizations such as Engineers Without Borders, Engineering World Health, and a wide range of independent study projects. Many organizations outside the university setting bring together students worldwide to solve today's top engineering challenges, such as the Global Engineering Design Studio [9]. However, many undergraduates may still need to have the opportunity to focus their limited time on these concepts. Our goal was to rapidly expose students unfamiliar with global impacts on engineering design to this complex subject. We received feedback from 64 surveys taken by undergraduate students in the two 2022 DDW programs representing nine different institutions (Table 1). Two-thirds of the students were biomedical engineering or bioengineering majors, and both upper- and underclassmen started the program with similar background knowledge about designing with a cultural setting in mind (Figure 1).

Results from our program surveys indicate that students believe their views changed in 3 key program objectives: an increased interest in solving global problems, an increased interest in engineering or science related to sub-Saharan Africa, and a better understanding of how to design in a cultural context (Figure 2). The students' open-ended responses further highlighted these findings, demonstrating that the critical skills they learned were the iterative engineering process and giving more consideration to product end users. Over 80% of participants also indicated plans to work, conduct research, or study abroad (Figure 3). Program instructors evaluated the student projects before and after the program. There were trends towards higher scores for categories such as the design could work in a low-resource setting and fits the cultural context; however, these data were not statistically significant (Figure 4).

The DDW workshop provides a unique opportunity for undergraduate students to learn and engage with global engineering design outside of the classroom. While many programs introduce undergraduates to engineering design or global health, our goal was to combine these concepts to focus on globally-engaged engineering design for low-resource settings. Many programs also teach engineering design and career development to high school students [10,11]. While this work is vital, a goal for the DDW program was to focus on undergraduate students. This is a pivotal time in their experience as young engineers and often is when they are making decisions about their future careers.

We did find undergraduate global health programs which showed similarities to our workshop. Kienzler and Fontanesi (2016) describe the positive impact made by incorporating a hackathon into their "Introduction to Global Health" undergraduate course at King's College London [12]. Similar to our DDW program, the hackathon involved undergraduate students working in groups to design solutions to global health challenges in one day. Students consulted with post-graduate

volunteers, subject-specific experts, and digital designers as they worked to put together a presentation and create a prototype. Unlike DDW, students were assigned into groups several weeks in advance and were responsible for identifying and refining a healthcare problem of their choice before the hackathon's start. Results indicated that the event demonstrated "the value of interdisciplinary approaches to global health" [12]. This program is unique in introducing students to immersive computer science and software design for global health applications over a semester-long course. However, it does not fully incorporate accounting for low-resource settings and end-user populations to the same degree as DDW.

We also identified an existing program that closely shares DDW's mission of promoting and advancing global engineering design education. Sienko *et al.* (2013) describe a course created for the University of Michigan open to graduate students from any engineering field interested in learning about global health. The course focused on evaluating technologies to "prevent, diagnose, or treat the top ten leading causes of death in low to middle income countries," where student groups researched and presented each cause before brainstorming solutions [13]. One unique aspect of this course is that the possible technology solutions were published in a website compendium that was accessible and searchable by the public. In the future, DDW may seek to find ways to better capture the thought and research the students put into their projects so that subsequent workshop attendees can build on their ideas. Sienko *et al.* (2013) also highlight that the course included an optional one-week trip to Nicaragua where students toured ten rural and urban hospitals and clinics. The student feedback on this trip was overwhelmingly positive, highlighting the synergistic impact of pairing global health projects with physical immersion. Similarly, DDW received sufficient funding from the Whitaker International Program and other supporters to send several students on a trip to South Africa in August 2022, allowing them to appreciate better the stakeholders associated with global health challenges.

Vieira *et al.* (2016) also describe the impact of an engineering design workshop for undergraduate engineering students at a Colombian university to address the high drop-out rate in Colombian engineering programs. They introduce 'learning by design' to help students engage with effective engineering design and practice [14]. The workshop consisted of four 2-hour sessions and proposed the design challenge of using CAD modeling to create a net-zero energy house. Student surveys were supplemented with a Green Building Science Knowledge Test to assess science learning. Overall results suggested that the workshop positively impacted students' knowledge about global energy efficiency, with almost half of the participants emphasizing the importance of the iterative design process, similar to the findings from our DDW program. Further, their workshop is unique in implementing CAD software as a secondary skill for participants to visualize solutions. The use of direct assessments of secondary skills could also be implemented in DDW in the future as an additional means to analyze student learning outcomes. Contrary to the DDW workshop, however, Vieira *et al.* (2016) did not have any global and cultural mentors to speak on their experiences working in low-resource settings abroad to further engage with participants.

Through feedback surveys and discussions, the students in the DDW program demonstrated overall positive thoughts about our program. Before the workshop, most students were excited to gain more experience in the engineering design process. After the first day, their feedback indicated that they most highly valued hearing from others, especially the international cultural

mentors, but also made recommendations for shortening this time frame. On Day 2, they enjoyed the large amount of time they were given for their projects, and would have liked even more collaboration with instructors and their peers (Figure 5). These data suggest that hearing the personal experiences of the international cultural mentors and receiving their feedback on designs were central to creating a positive and intellectually-stimulating impact on the participants' experiences to allow them to not only think critically about design solutions but receive a glimpse of different career paths within global engineering. Moving forward, we plan to make changes to our direct assessment rubrics to measure more holistic takeaways from the students' experiences. Below are two quotes from students responding to an open-ended question asking if the program had changed their view on engineering design "yeah, it definitely has. I don't think I really understood the importance of an end user until now," and "yes!! Now I really understand how important it is to work *with* the users instead of *for* them." Conversations and statements from students similar to this were highly encouraging as they often touched upon a key goal of the program, helping students realize the importance of end-users and their unique cultural contexts.

The student deliverables demonstrated trends toward increased awareness of end-user communities by the end of the program, despite the lack of significance found in the direct assessment metrics. During the initial brainstorming, the students' ideas trended towards straightforward solutions that showed little variety or creativity, primarily emphasizing low cost. In the final projects, students demonstrated cultural understanding from examples that were given during international mentor talks (such as being sensitive to the prevalent stigma surrounding an HIV-positive diagnosis). However, many of the final designs were not novel and tended to be products available on the U.S. market, adapted for a different setting. In addition, since the program only gave students a few hours to work through the entire engineering design process, they would benefit from more time practicing this skill. The organizers and cultural mentors believe that the students gained important skills during this short program and are open to all ideas for continuing this impactful work.

Conclusions

We hosted a series of weekend workshops aimed to introduce low-resource, global engineering design to undergraduate students who may yet to be exposed to the influence of culture on product design. A majority of participants believe the program significantly impacted the way they view engineering design and the importance of collaborating with the end-user. Indirect assessment of student feedback indicates that after attending the program, students better understand how to design with the cultural setting in mind and are more comfortable working on design projects for settings with varying resources. The program evaluators saw improvements in the student work throughout the program, although there were no significant findings from the direct assessment metrics. Given the positive impact of our program on the participants, we hope to continue these workshops and encourage others to embed global and low-resource contexts into their engineering design instruction.

Acknowledgements

Funding for this program comes from a Whitaker International Program Concluding Initiative grant. We sincerely thank Emily Krogstad Mudzwinga, Farai Mudzwinga, Chivonne Moodley, and Sara Aboeleneen for their contributions as speakers and organizers during the workshop programs. Erin Krassan was instrumental in converting the paper surveys into a digital form. Sheila Heen was instrumental in helping to prepare the feedback surveys. We would also like to acknowledge Hannah Bockius and Charise Jeudy, who spoke to the participants about their experiences abroad. Finally, we thank Sue Zatto at the University of Delaware for logistical assistance with hosting the program.

References

[1] T. Hedberg, "The role of the global engineer," *Educating the Engineer for the 21st Century*, pp. 7–13, 2001.
[2] E. Thomas, "What is Global Engineering?," *The Global Engineers*, pp. 1–19, Jul. 2020.
[3] L. Giovannelli and R. Sandekian, "Global engineering: What do we mean by it and how are we preparing our students for it?," *2017 ASEE Annual Conference & Exposition Proceedings*, Jun. 2017.
[4] B. J. Ranger and A. Mantzavinou, "Design thinking in development engineering education: A case study on creating prosthetic and assistive technologies for the developing world," *Development Engineering*, vol. 3, pp. 166–174, 2018.
[5] D. Nieusma, "Alternative design scholarship: Working Toward Appropriate Design," *Design Issues*, vol. 20, no. 3, pp. 13–24, 2004.
[6] B.K. Jesiek, N.T. Buswell, and Q. Zhu, "Global Engineering Competency: Assessment Tools and Training Strategies," ASEE Annual Conference and Exposition, Paper ID 21663, 2018.
[7] D. Stone and S. Heen, *Thanks for the Feedback: The Science and Art of Receiving Feedback Well*. Penguin Books, 2015.
[8] "Global Health Innovation Insights Series". Stanford Byers Center for Biodesign. [Online] Available: https://biodesign.stanford.edu/resources/learning/global-health-case-studies/global-health-innovation-insight-series.html. [Accessed February 13, 2023].
[9] "Global Engineering Design Studio", USC Viterbi (2022). [Online] Available: https://viterbiundergrad.usc.edu/blog/apply-to-join-the-global-engineering-design-studio-2/. [Accessed February 12, 2023].
[10] "Engineers Change the World: A Hands-on Program for Girls 13-18 Years Old", University of Florida (2017). [Online] Available: https://stride.ce.ufl.edu/2017/03/engineers-change-the-world-a-hands-on-workshop-for-girls-
13-18-years-old/. [Accessed February 10, 2023].
[11] L.S. Ryder, J. Pegg, and N. Wood, "A Project-Based Engineering and Leadership Workshop for High School Students," *American Society for Engineering Education: Advances in Engineering Education*, 2012.
[12] H. Kienzler and C. Fontanesi, "Learning through inquiry: a Global Health Hackathon," *Teaching in Higher Education*, vol. 22, no. 2, pp. 129–142, Sep. 2016.
[13] H.K. Sienko, A.S. Sarvestani, and L. Grafman, "Medical device compendium for the developing world: A new approach in project and service-based learning for engineering graduate students," *Global Journal of Engineering Education,* vol. 15, no. 1, pp. 13-20, 2013.

[14] C. Vieira, R. Aguas, M.H. Goldstein, S. Purzer, and A.J. Magana, "Assessing the Impact of an Engineering Design Workshop on Colombian Engineering Undergraduate Students," *International Journal of Engineering Education,* vol. 32, no. 5(A), pp. 1972–1983, 2016.

Appendix A

This appendix includes the survey questions used in the October 2022 program to collect student self-evaluations at the start of the program (pre-workshop), after Day 1 and after Day 2 (post-workshop).

Design for the Developing World
Pre-Workshop Survey

Hi! Completing this survey is 100% voluntary and won't affect your participation in this workshop. Your responses are being collected by the leadership team to help us make the next program better and to assess if our goals for the event were met. Thanks so much for your responses!

For each of the following statements, rate your level of agreement by providing a number between 1 and 5 (non-integer values are ok, e.g. 4.2), where 5 is "strongly agree" and 1 is "strongly disagree."

1. I have brainstormed solutions to a health/medical challenge.
2. I have iterated/refined my ideas for solutions to a health/medical challenge.
3. I have had opportunities to learn about countries in sub-Saharan Africa.
4. I understand how to design with the cultural setting in mind. I am comfortable working on design projects for settings with varying resources.
5. I plan to study or do research abroad.
6. I am interested in doing engineering/science that is relevant to global problems.
7. I am interested in engineering/science that is relevant to sub-Saharan Africa.
8. I have had substantive conversations with people who are from countries other than the USA.
9. What I'm looking forward to most about this weekend is:
10. I'm feeling (a little) anxious about:
11. Anything else you'd like us to know?

Your college or university (optional):
Your anticipated college graduation year (optional):
Your major (optional):

Design for the Developing World: Day 1 Survey

Hi! Completing this survey is 100% voluntary and won't affect your participation in this workshop. Your responses are being collected by the leadership team to help us make the next program better and to assess if our goals for the event were met. Thanks so much for your responses!

For each of the following statements, rate your level of agreement by providing a number between 1 and 5 (non-integer values are ok, e.g. 4.2), where 5 is "strongly agree" and 1 is "strongly disagree."

1. I understand how to design with the cultural setting in mind.
2. I am comfortable working on design projects for settings with varying resources.
3. I am plan to study or do research abroad.
4. I am interested in doing engineering/science that is relevant to global problems.
5. I am interested in engineering/science that is relevant to sub-Saharan Africa.
6. Today I had substantive conversations with people who are from countries other than the USA.
7. Overall, the content covered today was:
    a. was just a repetition of things I already know.
    b. included familiar names and ideas but with useful new context and elaboration.
    c. material that is mostly new to me.
    d. entirely new and unfamiliar to me.
8. When we run this workshop again, what is one thing we should definitely keep the same about Day 1?
9. When we run this workshop again, what is one thing we should we definitely change about Day 1?
10. How can you make tomorrow (even) better than today for yourself and our group?

Rate each of our activities today with respect to each of the following parameters:

	Pace of the session:	Length of the session:	Level/difficult of the material covered:	Presentation of information, including directions for activities:
Early Brainstorming (Giant Post-Its)	● too rapid ● about right ● too slow	● too short ● about right ● too long	n/a	● was always clear & understandable ● was clear & understandable, more often than not ● often unclear, difficult to follow ● totally confusing
International Engineering Presentation	● too rapid ● about right ● too slow	● too short ● about right ● too long	● too difficult ● about right ● too easy	● was always clear & understandable ● was clear & understandable, more often than not ● often unclear, difficult to follow ● totally confusing
South Africa Presentation	● too rapid ● about right ● too slow	● too short ● about right ● too long	● too difficult ● about right ● too easy	● was always clear & understandable ● was clear & understandable, more often than not

				• often unclear, difficult to follow • totally confusing
Tanzania Presentation	• too rapid • about right • too slow	• too short • about right • too long	• too difficult • about right • too easy	• was always clear & understandable • was clear & understandable, more often than not • often unclear, difficult to follow • totally confusing
Wallet Design	• too rapid • about right • too slow	• too short • about right • too long	• too difficult • about right • too easy	• was always clear & understandable • was clear & understandable, more often than not • often unclear, difficult to follow • totally confusing
Day 1 Project Work	• too rapid • about right • too slow	• too short • about right • too long	• too difficult • about right • too easy	• was always clear & understandable • was clear & understandable, more often than not • often unclear, difficult to follow • totally confusing

11. Anything else you'd like us to know?

Your college or university (optional):
Your anticipated college graduation year (optional):
Your major (optional):

Design for the Developing World: Day 2 Survey

Hi! Completing this survey is 100% voluntary and won't affect your participation in this workshop. Your responses are being collected by the leadership team to help us make the next program better and to assess if our goals for the event were met. Thanks so much for your responses!

For each of the following statements, rate your level of agreement by providing a number between 1 and 5 (non-integer values are ok, e.g. 4.2), where 5 is "strongly agree" and 1 is "strongly disagree."

1. I understand how to design with the cultural setting in mind.

2. I am comfortable working on design projects for settings with varying resources.
3. I am plan to study or do research abroad.
4. I am interested in doing engineering/science that is relevant to global problems.
5. I am interested in engineering/science that is relevant to sub-Saharan Africa.
6. Today I had substantive conversations with people who are from countries other than the USA.
7. I thought about how to approach design problems in a new way this weekend.
8. My team, our mentors, and I were able to work together productively and respectfully.

9. What, if any, skill(s) did you gain from this workshop?
10. Has your perspective on design changed? If so, name one or more ways it has changed.
11. Do you plan to do anything differently as a result of attending this workshop (e.g. coursework, extracurriculars, research/study abroad, internships/career development)?
12. High blood pressure often goes undiagnosed in both young and old people in sub-Saharan Africa, and many don't find out until it's too late. Furthermore, many people who are diagnosed with high blood pressure are unable to monitor their blood pressure at home.
    a. What are two possible approaches to these challenges?
    b. What additional information would you like to know in order to develop your ideas?
13. When we run this workshop again, what is one thing we should <u>definitely</u> <u>keep the same</u> about Day 2?
14. When we run this workshop again, what is one thing we should we <u>definitely</u> <u>change</u> about Day 2?

Rate each of our activities today with respect to each of the following parameters:

	Pace of the session:	Length of the session:	Level/difficult of the material covered:	Presentation of information, including directions for activities:
Project Work Before Lunch	● too rapid ● about right ● too slow	● too short ● about right ● too long	n/a	● was always clear & understandable ● was clear & understandable, more often than not ● often unclear, difficult to follow ● totally confusing
Project Work After Lunch	● too rapid ● about right ● too slow	● too short ● about right ● too long	● too difficult ● about right ● too easy	● was always clear & understandable ● was clear & understandable, more often than not ● often unclear, difficult to follow ● totally confusing

Poster Sessions	● too rapid ● about right ● too slow	● too short ● about right ● too long	● too difficult ● about right ● too easy	● was always clear & understandable ● was clear & understandable, more often than not ● often unclear, difficult to follow ● totally confusing

15. Anything else you'd like us to know?

Your college or university (optional):
Your anticipated college graduation year (optional):
Your major (optional):

Appendix B

This appendix includes the direct assessment rubrics used by program evaluators for the initial brainstorming activity and for the final project presentation.

Design for the Developing World: Oct 2022 Workshop
Instructor evaluation of learning outcomes

RUBRIC: Day 1 Design Brainstorming Activity (Hypothermia Post-it Activity)
Rate each group color by the respective items. Made up example: you score the white post it group by writing their color in each metric row in the table:

	Yes (4)	Mostly (3)	To Some Extent (2)	No (1)
Ideas are feasible in low-resource settings				
Ideas & questions consider cultural context; aim to be user-friendly for target population				
Explanation of ideas is clear				
Ideas are creative				

RUBRIC: Day 2 Group Design Project
Rate each group project by the respective items. Made up example: you score team 76 by writing their number in each metric row in the table:

	Yes (4)	Mostly (3)	To Some	No (1)

			Extent (2)	
Design is feasible in low-resource settings				
Ideas have been refined; proposal reflects consideration of possible challenges, roadblocks				
Design considers cultural context; is user-friendly for the target population				
Prototype adds value to presentation of idea				
Explanation/presentation of design is clear				