"The Undergraduate Engineering Collaborative Growth Series": a Diversity, Equity, and Inclusion Program Supporting the Empowerment of Marginalized Students

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***Abstract*—The authors present a Full Paper in the Research-To-Practice category. Educational institutions are increasingly looking toward diversity, equity, and inclusion initiatives as a means of addressing inequities with regards to student representation rates and outcomes. We recognize that the field of engineering was historically designed and continues to operate for the benefit of straight, cis, white, affluent men. Often, institutions offer supplemental programming to students who do not embody this set of identities as a means of support, seeking to more effectively integrate them into fundamentally inequitable structures. Typically, due to the top-down nature of this supplemental programming, it presents additional barriers to challenging the existence of these structures or empowering students to enact equity-centered change.**

Alternatively, we sought to design a program for marginalized engineering students that reduced barriers to the expression of their whole selves, including the value of their identities within the engineering educational space. Applying critical and liberative theoretical frameworks, we invited marginalized students to organize within themselves to enact changes to even the most fundamental aspects of the existing educational structure. This program, the Undergraduate Engineering Collaborative Growth Series, was implemented at a large, prestigious research university in the United States and monetarily paid students for the labor associated with their participation. It consisted of a series of workshops that aimed to support the development of a community that recognized commonalities across experiences and organized to meet their collective needs.

This paper discusses the methods used to recruit and select participants for the series as well as outlines facilitation and data collection methods. The collected data forms the basis for ongoing research. In the future, we hope to expand the program to reach more students in more programs at more institutions. In doing so, the intention is to support the empowerment of marginalized students, the best experts in their own experiences, to connect forms of power to action that disrupts the barriers currently preventing them from expressing their whole, authentic selves within engineering academia.

***Index Terms*—engineering education, undergraduate experience, diversity, equity, gender, ethnicity, socioeconomic status, LGBTQ+, theory of liberation, critical theory, focus groups**

I. Introduction

This workshop series for marginalized engineering students took place within the engineering college at a large, prestigious research university in the Midwestern United States. In a prior quantitative study, some of the academic circumstances that hinder working class students and students of color at this engineering college were identified, including underrepresentation, lower likelihood of graduation, increased time to graduation, and lower grade point average [1]. One purpose of this series was to better understand factors that influence these circumstances from the perspective of marginalized students. It is necessary to identify these factors in order to address the sources of the problems at their roots, rather than enacting reactionary initiatives that label marginalized students themselves as the source of problems [2]. Additionally, the authors sought to design a program for marginalized undergraduate engineering students to support their ability to build agency toward the enactment of constructive changes to the educational system.

To address these dual purposes, a team of graduate student and faculty researchers designed a series of events framed

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around the Theory of Liberation, titled the "Undergraduate Engineering Collaborative Growth Series" (UECGS), which took place in four installments over the course of the 2020-2021 academic year. UECGS was funded by an internal faculty grant from the engineering college focused on efforts to expand diversity, equity, and inclusion (DEI). This paper will focus primarily on the methods used to design and implement UECGS, a practical framework which the authors believe is transferable to a wide variety of institutional settings. We will highlight the intentional use of critical and liberative perspectives in the development of the research methods.

II. Theoretical Frameworks

Paulo Freire is considered to be one of the founders of our modern understanding of critical theory [3]. His "Pedagogy of the Oppressed" [4], originally published in 1968, is a manifesto of educational empowerment to resist capitalistic and colonial oppression. In this work, Freire outlines the concept of conscientização, or critical consciousness, the learned ability of individuals to recognize systemic oppression as it exists within society, and the vital role of education in fostering and developing it [4]. Over time, scholar-activists have built on the principles of Freirean critical theory and applied them with a focus on other bases of oppression; critical race theory [5], [6], radical feminism [7], [8], and queer theory [9] focus on experiences of oppression on the primary bases of race, gender, and attractivity, respectively. Using the framework outlined by Bowen et al. [10], the Theory of Liberation is an umbrella theory encompassing all critical theories regardless of foci. As Robin D. G. Kelley wrote,

> "You've got to be able to cross those lines of race, gender, sexual identity, sexual orientation - not to erase those lines or pretend they don't exist but, on the contrary, make them hyper-visible. Radical empathy means working across identity lines by making them hyper-visible in order to recognize specific struggles that people on different sides of those lines experience. This recognition is fundamental for any change" [11, p. 94].

Donna Riley [12] has previously discussed the application of liberative theories in an engineering pedagogical context as a means of helping students identify existing oppressive structures. Agency, however, is a necessary precursor in order to enact change. Allison Godwin defined critical engineering agency as "a student's perception of their ability to change their world through everyday actions as well as [their] broader goals in life" [13, p. 3]. UECGS seeks to support students' collective development of critical engineering agency toward change as well as to introduce students to the concept of change theory. Tuck and Yang have defined theories of change as "belief[s] or perspective[s] about how a situation can be adjusted, corrected, or improved" [11, p. 13]. As an educational program, UECGS applies liberative pedagogy [12] as the theory of change for disrupting oppressive structures within engineering academia.

III. Positionality

The first two authors, as multipli-marginalized engineers themselves, developed UECGS by leveraging lessons from the labor and community organizing experiences they have had during their graduate education. Bowen is a cisgender, heterosexual white woman from a working class background, and Valle, who is queer, is mixed Latinx/white and also from a working class background. They note that UECGS is an attempt to construct a form of engineering education that would have felt more life-affirming than their own experiences in undergraduate and graduate engineering studies. Faculty collaborators, Mondisa, Johnson, Sakamoto, and Powell, provided support in shaping the series and obtaining funding.

IV. Methodology

In the implementation of UECGS, we attempt to engage in a praxis of liberative pedagogy by making space for participants to raise their critical consciousness. We thus apply the Liberatory Engineering Education Model [14] as the methodology for the creation of UECGS. This model combines Mejia et al.'s Freirian critical consciousness model [15] and Hassan's learning-assessment interactions model [16] to visualize pathways through which liberative efforts can be realized despite barriers imposed across domains of power. Using this model, we can construct pedagogical components that combine to reduce the salience of these barriers. The application of the Liberatory Engineering Education Model to this project is shown in Figure 1.

As shown in Figure 1, we employ participatory action research as the methodology of UECGS itself. As described by Israel et al., participatory action research has five key components: "It is participatory ... It is a cooperative and co-learning process ... It is a reflective process ... It is an empowering process ... It achieves a balance between research and action goals and objectives" [17, p. 163]. In accordance with this methodology, the research intends to co-create knowledge between both the researchers and the participants and invoke cooperative, constructive action that builds toward change.

UECGS was formatted as four two-hour workshops with optional feedback and coaching sessions between the workshops. Engineering graduate students were recruited to serve as facilitators and note takers in focus groups at each of the workshops. All programming was held virtually due to the COVID-19 pandemic. The following subsections describe each component of the series. Table I outlines the components of UECGS and maps their connections to the Liberatory Engineering Education Model.

A. Workshop 1: Student Experiences and Collective Visioning

The first event of the UECGS took place in October 2020. The central activity was focus groups with collaborative, facilitated conversations on the following topics: belonging,

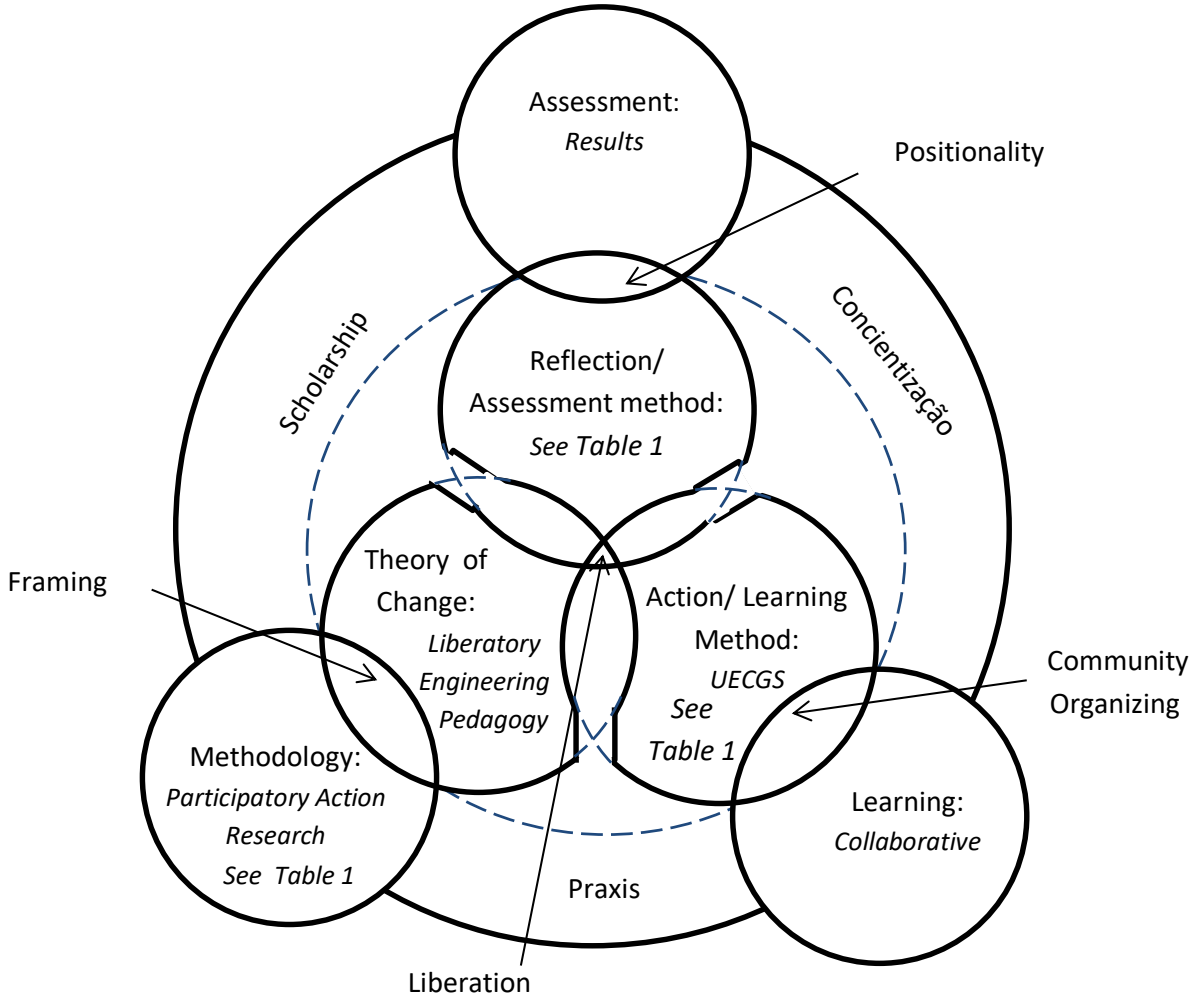

Fig. 1. Mapping of UECGS within the Liberatory Engineering Education Model [14]

TABLE I
METHODOLOGICAL APPROACHES UTILIZED IN EACH COMPONENT OF UECGS AND CONNECTIONS TO THE LIBERATORY ENGINEERING EDUCATION MODEL [14]

Event	Methodological Component	Learning Method	Assessment Method
Workshop 1	Focus Groups Collective visioning exercise	Naming and hearing lived barriers Naming and reading collective visions	Notes and reflections Collectively-written document
Workshop 2	Individual worksheets Focus groups Concept mapping post-workshop	Naming connections between existing theories and personal goals Discussion of connections made Aligning workshop content with participant needs	Worksheet data Notes and reflections Jamboard
Workshop 3	Individual worksheets Focus groups	Developing personal and public narratives Sharing and feedback on personal and public narratives	Worksheet data Notes and reflections
Workshop 4	Individual worksheets Focus groups	Developing pod and power maps Sharing and feedback on power maps	Worksheet data Notes and reflections
1-on-1s	Critical conversations	Sharing, active listening, and reflection	Recordings and reflections

recruitment and outreach, institutional DEI efforts, the classroom environment, mentoring, and conflict resolution. The participants had previously been asked to rank the six focus group topics in their order of preference. Students were put into these focus groups via Zoom breakout rooms with the goal of naming barriers they perceive and experience as well as harms they have experienced resulting from those barriers. The facilitators provided framing questions as needed to keep the flow of ideas coming and encouraged participants to build on each others' statements. They also encouraged participants

to utilize online collaborative Google Jamboards [18], in which students could write notes, draw or paste pictures, or share anything else they wanted to.

After two thirty-minute rounds of focus groups, the students came back into the main Zoom room and engaged in a collective visioning activity. Working from a Google Doc [19], the students wrote statements that they believed were false but wished would become true about the reality of society within engineering. These statements built up rapidly into a bulleted list. The students were also invited to add in sub-bullets below each statement with questions that would need to be addressed and/or directions that we would need to move in as an engineering community in order to bring the vision into reality. This exercise served as a means to envision, prefigure, and theorize an experience that was better fit to engage the students' whole selves into the field of engineering [20].

B. Workshop 2: Theories of Change

The second workshop introduced participants to several theories of change. For each theory, an example was provided of how student movements at the students' university had previously utilized that theory and what tangible changes resulted from that movement. Participants then began formulating methods of applying these theories of change to their current educational environments. They moved into focus groups to connect a particular vision or goal, which they could select from the visioning results in the first event or construct themselves, to the theories of change presented. Participants were also asked to brainstorm skills or tools they would like about to learn about in order to feel more prepared to enact theories of change.

Workshops 2 through 4 also incorporated mood analysis. In each workshop, participants were asked to describe their mood using Brackett's Mood Meter as they entered the workshop and as they were left [21]. This provided a way to gauge empowerment by comparing the feelings participants were bringing with them into the space to those they left with. Documented mood shifts could be used as a tool to provide rapid feedback to facilitators and organizers planning future events.

C. Workshops 3 and 4: Tools for Change

The participant responses about necessary skills and tools from the second workshop directly informed the content of workshops 3 and 4. Bowen and Valle performed thematic analysis on member-checked notes from the second workshop, then performed a mapping exercise to connect interrelated themes in order to determine the content of workshops 3 and 4. Thus, workshops 3 and 4 were used to provide students with an introduction to, examples of, and practice with skills and tools that aligned with their stated needs. The results of our concept mapping are presented in Section VI.B.

D. 1-on-1 feedback and coaching sessions

1-on-1 feedback and coaching sessions took place between the workshops. These sessions were recorded with both video and audio, so it was stressed to participants that it was optional to participate. Participants chose to meet with either Bowen or Valle, and conversations were unstructured, revolving around participants' personal experiences and organizing goals. These sessions were scheduled at one hour in length, but in practice lasted between 30 minutes and 3 hours. The sessions served to provide additional support to students as desired by further situating UECGS within their experiences in the engineering college.

V. Methods

In accordance with the application of critical and liberative frameworks, it was imperative that the event allow the student participants the opportunity to build power collectively, rather than maximize the power and control of the researcher. For this reason, the faculty members on the research team did not attend the events, the events were hosted using a Zoom for Healthcare platform, which does not record video or audio [22], and the identities of participants are not known to the faculty members on the research team. These methods were employed in order to reduce structural barriers that could prevent participants from feeling comfortable sharing their experiences. Because the event was not recorded, note-takers were employed to document the conversations within the focus groups, which serve as a major component of the qualitative data. The events were facilitated by Bowen and Valle, and focus group facilitators and note-takers, henceforth referred to as the facilitation team, were graduate students from the engineering college.

The facilitation team and participants were financially compensated for their labors on this project, in recognition that student DEI work is labor which is frequently rendered invisible [23]. Sharing experiences about harm, be it systematic, institutional, interpersonal, or internal, is an ask for emotional labor, so students must be compensated for that labor with liberative frameworks in mind. Participants in UECGS were compensated $15 per hour for the duration of the events in the series (including any 1-on-1 sessions they attended), and the facilitation team members were paid $20 per hour for their time at the events, for their individual preparation, and for approximately two hours of professional training before the start of UECGS. A professional facilitator was hired to provide the training.

A. Participant Selection

Institutional Review Board approval for the embedded studies was obtained from the institution at which the research was conducted. UECGS was advertised via email through the researchers' existing channels within the university, which included participants in a liberative event organized by a team of graduate student volunteers including Bowen and Valle, identity-based engineering student groups on campus, and a daily newsletter sent out to the student body from the engineering college's student affairs office. Advertisements included a link to an electronic intake form. To communicate the researchers' desire to recruit marginalized students, the

form stated, "we are looking for participants with at minimum one of the following identities: women or non-binary, people of color, family background less than approx. $100,000 per year, LGBTQ+, or other marginalized identity." The intake form contained the following items:

- Name and email address
- Engineering department and year within program
- Gender, ethnicity, race, and sexual orientation (short-answer text response)
- Annual family income (multiple choice options: less than $50,000, $50,000-$100,000, $100,000-$150,000, or above $150,000)
- "Do you have any needs of the space such that you can feel safe engaging with this material? (This can include needs regarding other people's attendance impacting your safety. If such a need arises, we will figure out how to best meet your needs on a case by case basis.)"
- "Some of this material may evoke strong emotions for participants. If an exercise becomes difficult for you to handle, what are your needs from facilitators?"
- "Do you have any accessibility needs you would like us to know about?"
- "Is there anything else you would like the graduate student researchers to know?"

The self-reported identities of the applicants are shown in the left-side pie graphs in Figure 2. In this data, we have grouped the short-answer responses of students' race/ethnicity into the categories shown, and we followed up with the students individually in cases in which we were unsure.

It was decided by the research team and graduate student facilitation team that there should be approximately six participants in each of the six concurrent focus groups. We worried that larger focus groups might negatively impact student comfort and collaboration. In case more students applied than our team could accommodate, we developed a framework to quantify marginalization to prioritize multipli-marginalized student participation. The framework is detailed in Table II. Each applicant is assigned a total marginalization index by summing the point contributions from each aspect of their identity shown in the table. The numerical values attributed to each identity are determined based on the quantitative results in [1]. For example, the results indicate that Black/African American students and students from families making less than $50,000 a year are especially hindered in academic outcomes at this engineering college, so these two groups are assigned the maximum of three points in the marginalization index. In the case of students whose answers were linked to multiple racial/ethnic categories, the one that is rated the highest number of points in the marginalization index is assigned.

As shown in Table II, one point was awarded to applicants who identified as having a disability, either physical or mental, although this was not explicitly asked in the intake form. The researchers added one point to an individual's marginalization index if they self-identified as having a disability in their answers to the long-answer text questions in the intake form.

It is fully recognized by the researchers that a quantitative analysis of marginalization is inherently extremely problematic, as students' experiences with oppression cannot and should not be reduced to a single numerical value. However, this task is undertaken in order to prioritize the participation of students who are multipli-marginalized. We also note that a similar marginalization index was utilized by Settles et al. in [24]. The authors do not intend to use this marginalization index in any analyses of data collected at UECGS events.

B. Facilitating and Note-Taking

The facilitation team was recruited from current graduate students in the engineering college known to Bowen and Valle. A diverse group of students with a variety of experiences in education research and/or advocacy work were asked to support the research in paid roles. 13 graduate students agreed to participate. Of the group of 15 graduate students, including Bowen and Valle, 11 identified as women or non-binary, 6 were non-white, 9 were queer, and 7 grew up in households with annual incomes of less than $100,000 per year. Pie charts showing the demographic distribution of the graduate student team in comparison with those of the study participants and engineering college undergraduate student body are shown in Figure 2. Note that some facilitator demographic information has been aggregated in order to protect anonymity, and annual family income of the facilitation team is self-reported income level when first applied for undergraduate study. Participants are students who attended at least one of the four workshops. From Figure 2, it can be concluded that the facilitation team, while very diverse compared to the overall undergraduate student body, was not as diverse as the selected undergraduate participants.

The graduate student facilitation team first completed the required Human Subjects Research Protections course through the university's Office of Research Ethics and Compliance. They were then professionally trained during a ninety-minute session led by Vidhya Aravind, the Learning Director of We the People - Michigan, whom Bowen and Valle employed due to her extensive experience both conducting and teaching effective facilitation. The training covered topics such as grounding, vulnerability, agency, honesty, multipartiality, and active listening. Also within the training, the graduate students worked collaboratively preparing potential facilitation questions for each of the six focus groups in the first workshop. The formalized facilitation training was imperative to ensuring the creation of inclusive, equitable, and constructive spaces within focus groups.

C. Member-Checking

Member-checking with the participants was employed at various stages in the research, including live-checking during note-taking and approximately a week of open review of the notes after the event. This member-checking process was meant to ensure that participants' identifying information had been adequately anonymized and that the data collected was reflective of what the participants intended it to represent [25].

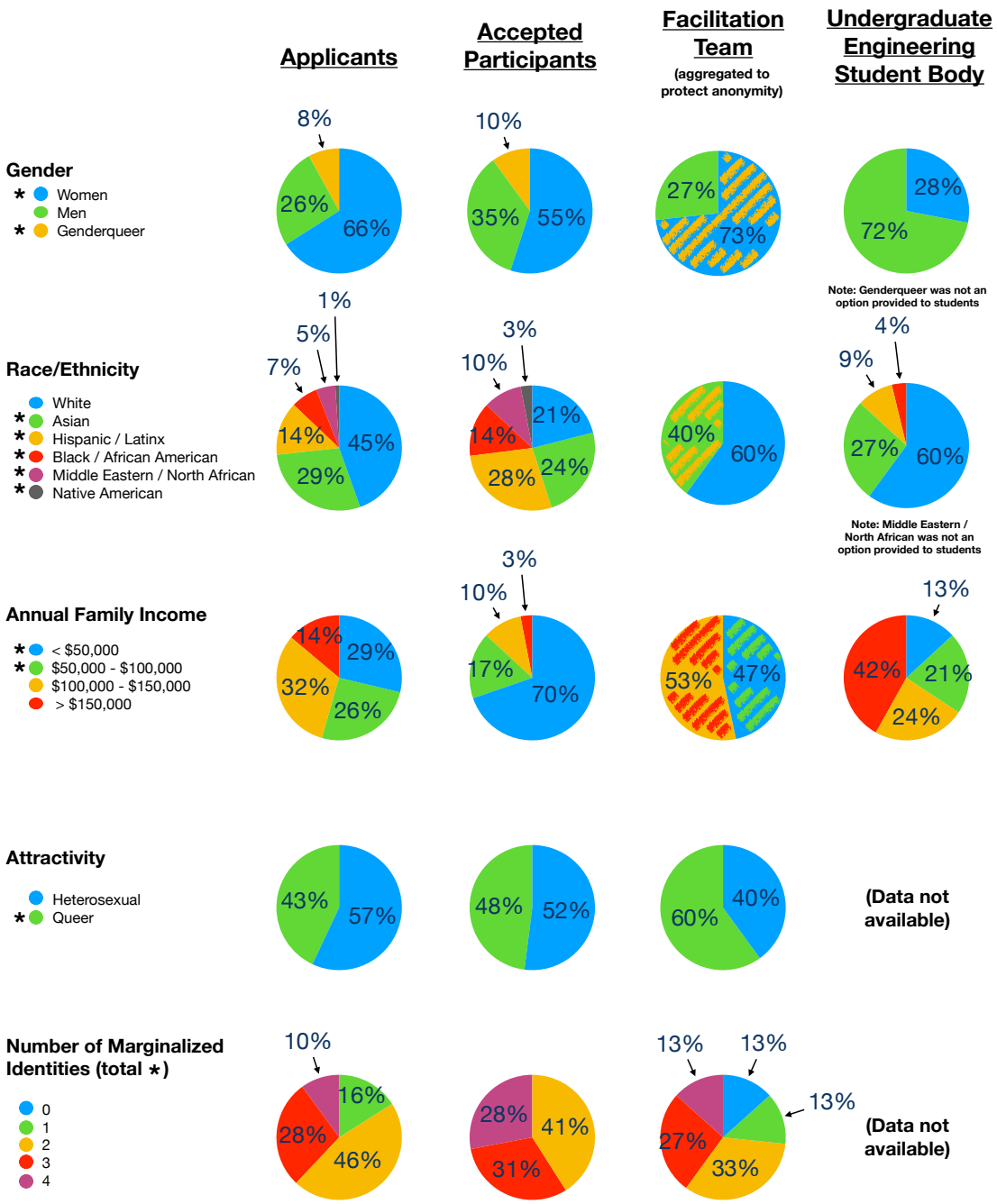

Fig. 2. Demographic composition of UECGS applicants, accepted participants, graduate student team, and undergraduate student body within the engineering college [1]

TABLE II
FRAMEWORK FOR A QUANTITATIVE ENGINEERING STUDENT MARGINALIZATION INDEX (EMPTY BOXES HAD NO POINTS AWARDED).

Identity Aspect	1 Point	1.5 Points	2 Points	3 Points
Gender	Woman		Genderqueer	
Race/Ethnicity	Other non-white		Hispanic/Latinx	Black / AA or Native American
Annual Family Income		$50,000 - $100,000		Less than $50,000
Attractivity	Queer			
Year	5th year +			
Ability	Disability			

Students did choose to participate in the member-checking process, clarifying their statements and deleting details that had the potential to identify them. Follow-up emails were sent to individual participants referring to questionable sections and statements within the notes in order to ensure adequate anonymity as determined by the participants.

Once Bowen, Valle, and all the participants were satisfied with the anonymization, participants' names were switched to pseudonyms they had selected and all the data was copied and pasted into a new document with no file history. Only then were the faculty researchers allowed access to the data. Through this open and transparent process, the researchers are confident that the notes are accurate portrayals of participants' statements during the event and that risk to the individual participants is minimized.

VI. Results and Discussion

A. Participant Selection

The research team's goal was to secure about 30 participants in UECGS, but 90 students filled out and submitted the intake form within only a few days of advertising. We feel that this is an important research result in and of itself. Given the goals of UECGS as articulated to students via the intake form ("the researchers are seeking to better identify the barriers faced by marginalized undergraduate engineering students and provide trainings to equip students to work collaboratively towards change"), we conclude that there is immense desire within the student body for greater agency in enacting student-driven structural change within the engineering community.

Of the students who submitted the UECGS intake form, the average marginalization index was computed to be 3.43 with a standard deviation of 1.65. Based on programmatic capacity, we had to limit the number of participants admitted into the program. Therefore, we chose to admit students who had an index score greater than or equal to 4.00, which resulted in 38 admitted students. Of these students, 31 completed the consent and preparation process and participated in at least one workshop. The demographics of the admitted students who participated in at least one workshop are shown in the pie charts in Figure 2. The last row of pie charts shows how many marginalized aspects of identity are attributed to a student, which are labelled with an asterisk in the figure. For example, a Black, working class, LGBTQ+ woman is defined to have four marginalized identities as shown in this pie chart. From these results, we conclude that our marginalization index was effective at prioritizing the participation of multiply-marginalized students.

B. Data

In this section, we provide examples of some of the data produced in UECGS. The complete dataset will be analyzed in future research.

The visioning exercise at the end of the first workshop established a collective ideal of participants' desired world. While the students only had approximately five minutes to ideate, they filled over three pages with thoughts on their collective vision. Examples of statements generated include:

- No one associates my feelings to any extremes because of my race
- No one assumes I got into a competitive college because of my minority status
- End of cisnormativity
- We have emotionally intelligent students and professors who do not shame or judge people
- Mental health is a real thing with real consequences
- I don't feel like I'm not doing enough if I'm not extremely stressed out all the time
- I feel validated and proud of my academic accomplishments, and prepared for my future after graduation, without comparing myself or competing against other students
- Money shouldn't impact education
- I feel as though my voice and ideas are worth being heard
- People no longer search for a sense of purpose - they naturally know it

During the second workshop, after connecting components from their collective vision to theories of change, participants identified skills and tools they would need in order to feel more confident working toward the enactment of their vision. The research team then mapped these skills and tools, which are represented by the yellow bubbles in Figure 3. They noticed that these items mapped broadly into three categories, storytelling, power-mapping, and first-step organizing, and that the use of the first two of these categories (green bubbles) would help effectively accomplish the third (blue bubble). Thus, the third and fourth workshops were designed to build participants' comfort and skill with the organizing tools of storytelling and power-mapping, respectively.

In the final workshops, participants were first introduced to the concepts of storytelling, "the art of translating values into action through stories" [26, p. 29] and power-mapping, the placement of various actors based on their likely stances pertaining to the organizing goal. Valle shared examples applying these techniques to his own personal experiences and organizing goals. Participants were then provided time to work individually on worksheets that, along with the notes taken by the facilitation team, constitute the data collected for the research from these two workshops. Developed from the work of Ganz, the worksheets provided scaffolding through which the participants developed their own personal narratives (also called stories of self), public narratives (also called stories of self, us, and now), and power maps [26]. Then, the participants shared their stories, organizing goals, and power maps within their focus groups and provided constructive feedback to one another. This gave them practical, tangible opportunities to build confidence around their abilities to organize for change within the engineering community.

As an example of an individual's work within the final two workshops, we introduce Stephen, a trans woman of color

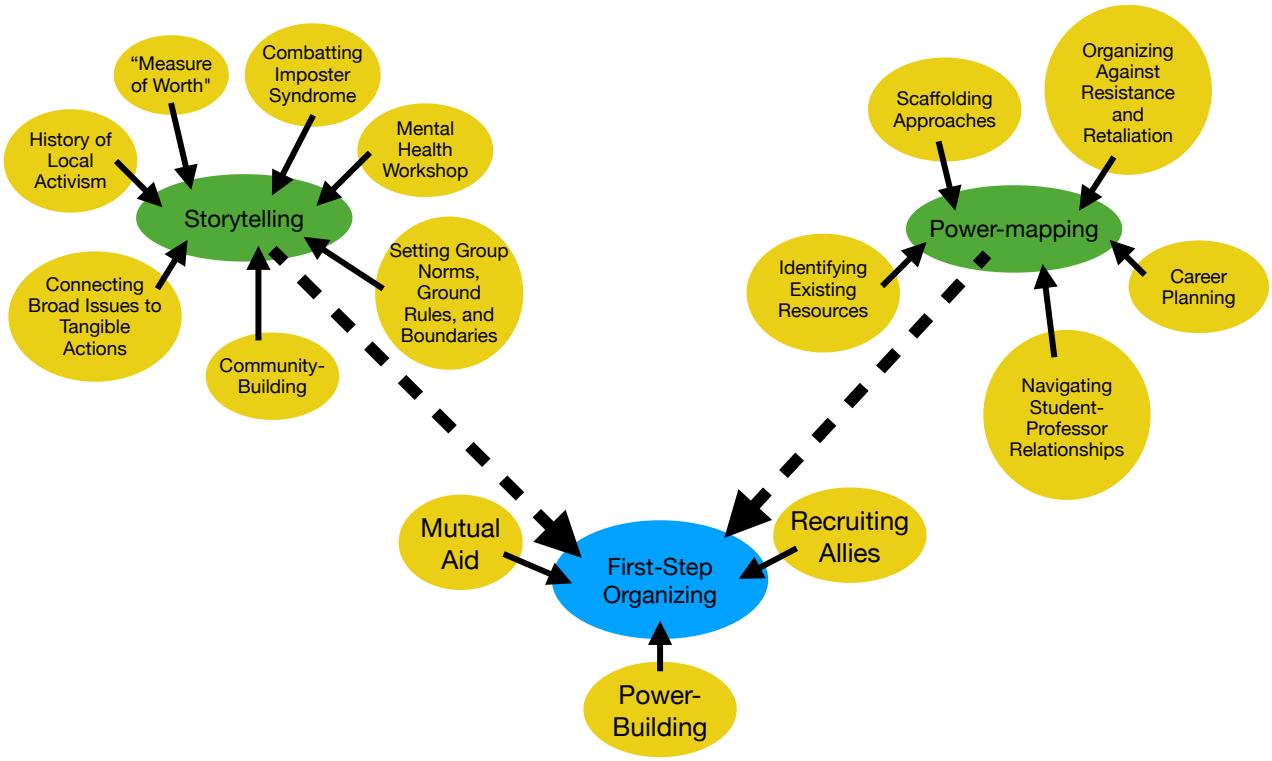

Fig. 3. Graphical depiction of analysis of workshop 2 results.

from a low-income background. In her story of self, Stephen shared that she was raised by strong feminists but had grown up with a male point of view. She saw the action of coming out as trans as intimately connected to her personal value system. Upon developing her public narrative, she articulated the point that male engineers, who currently dominate and control engineering spaces, needed to stand up for gender equality within the field, thus referring to the agency of these already powerful actors. However, upon developing an organizing goal later in the workshop, she wrote the following scaffolded responses (her words italicized):

> We are organizing (who/your constituency):
> *Women and allies in STEM*
> To Achieve (what strategic goal):
> *Gender equality in STEM*
> By (how/your theory of change):
> *Having the older generation establish an equality-based culture that then the younger generations will absorb and develop. Concrete examples: equality seminars required for [graduate student instructors], media portrayals of smart, powerful women in stem, more female professors*

As shown by her organizing goal, Stephen's focus had transitioned. She began the workshop thinking to ask those with social power to behave differently, but she ended it with a goal of empowering those who, like her, were directly affected in negative ways by the current reality to directly change that reality. While building solidarity-focused relationships with other multipli-marginalized students, she had successfully begun to formulate methods for action. Stephen's results are similar to those of other participants, who each had unique perspectives on their organizing goals. However, the participants expressed interest in supporting one another's goals with collective action as they worked toward building a better future for themselves and their peers.

VII. Future Work

Future work is ongoing to analyze the large qualitative dataset that was generated through UECGS. The research team also intends to hold UECGS again during the 2021-2022 academic year and hopes to extend the programming to the graduate student body as well.

VIII. Acknowledgments

The authors would like to thank the College of Engineering where this study was performed for their financial support for this project. We are indebted to our participants and the members of our graduate student facilitation team[3] for their time, effort, knowledge, skills, and empathy that made possible this first implementation of UECGS.

[3]Huge thanks to our incredible team of Sarah Bork, Jeffrey Horowitz, Alex Kate Halvey, Benjamin Silcox, Enrique Rodriguez, Leanne Su, Lea Marlor, Piper Sigrest, Robert Loweth, Alyssa Travitz, Jennie Paik, Shannon Clancy, and Kaylla Cantilina.

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