ENGINEERING INCLUSIVITY BY DESIGN: CO-DESIGNING AN INCLUSIVE INNOVATION WORKSHOP

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Abstract – In North American universities, engineering faculties often exhibit unequal representation, with inclusivity in the curriculum hindered by aspects like elitism and technical social dualism [1]. This project aimed to foster a more inclusive engineering culture by co-designing a workshop with students at McMaster University to appreciate diverse identities and incorporate equity principles into their work. The "Inclusive Innovation Design Challenge" workshop, attended by 55 students, introduced concepts of self-identity and positionality, followed by a human-centred design sprint based on equity-based co-design principles. Participants developed personas and brainstormed solutions to design challenges, enhancing awareness of the value of diverse perspectives.

The outcome was overwhelmingly positive; feedback from a post-workshop survey indicated a shift in participants' perceptions towards their identities and the inclusion of diverse perspectives in design. Ongoing research will evaluate the workshop's impact on integrating these insights into coursework and enhancing the sense of belonging in engineering programs.

Keywords: Equity, Diversity, Inclusion, and Accessibility (EDIA); human-centred co-design; engineering curriculum; workshop; Students as Partners (SaP)

1. INTRODUCTION

Teaching and learning in engineering are constantly evolving with significant progress in developing new strategies to address underrepresentation and ensure all students are set up for success [1] – [7]. This translates into the broader field of design and teaching of design methods, development and approaches. The development of a workshop-based approach to teaching inclusive design works to address the widely accepted and supported awareness that equity, diversity, inclusion, and accessibility (EDIA) and inclusive design must be taught [8], [9]. The workshop we developed strives to help participants integrate principles of EDIA within engineering students' learning experiences by creating a space for the individuals' identities to be discussed and shared with peers. The workshop, through intentional co-designed facilitation, invited participants to complete interactive design exercises focused on equity-driven approaches to design (including Design Thinking, Co-Design, and Liberatory Design) [10]. One of the key components is to raise awareness about the value of students' unique identities and positionality within the classroom and design process [11].

It is well documented in the literature that there are significant barriers to marginalized groups in science, technology, engineering, and mathematics (STEM) fields where design is at the forefront. These barriers exist for many reasons where, despite significant efforts to diversify the field, many disparities remain in representation for intersecting identity groups in particular. In these fields social justice is often overlooked and overshadowed by the idea of meritocracy where education on inclusive design is being highlighted as a gap to fill this need [4]. Multiple institutions are integrating Design Thinking and team-based learning within courses to better prepare students for the human-centered aspects of design and engineering, but the focus on EDIA and inclusive design is less targeted [12]. Workshops with digestive content for students to co-design, engage in peer learning, and gain awareness mitigate some of the barriers to learning class-based content that include grades, pressure to represent, and personal biases.

2. APPROACH

The process of creating the workshop initiated in mid-July 2023, with the aim of integrating EDIA principles within engineering design education. The six-week design sprint culminated in a half-day workshop as part of incoming graduate engineering students' orientation week in September. This initiative prioritized a Students as Partners (SaP) co-design method [13]-[18] involving a

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collaborative effort between two undergraduate students, one graduate student, two recent graduates of the engineering design program, and an engineering Design Thinking instructor. The design and content of the workshop, therefore, reflected a broad spectrum of student perspectives and experiences. The workshop itself was co-facilitated by four members of the design team, including two students and a recent engineering graduate, with the instructor primarily in a supporting role. This allowed for an atmosphere of peer-to-peer training of workshop participants, most of whom had limited experience with EDIA and Design Thinking and reduced the power imbalance (perceived or actual) of an instructor "teaching" the workshop.

2.1. Workshop Development

The workshop was developed based on the initial funding proposal that had been co-written by two members of the design team who had been conducting research on the topic. Additional student and recent graduate members were brought onto the team and tasked with co-designing workshop and participant recruitment materials and assisting with the delivery of the workshop itself.

The development process started with a meeting to outline the workshop's objectives for incoming engineering design graduate students as the initial target audience for this workshop. Initial brainstorming sessions facilitated the identification of key topics to include, focusing on integrating EDIA principles into engineering design. These discussions allowed for an exploration of students' insights into EDIA, which informed the workshop's agenda.

Two sub-groups emerged from the team to focus on distinct aspects of the workshop. The first sub-group of students aimed to introduce foundational EDIA concepts from a beginner's perspective, utilizing students' unique positions and experiences to enrich the learning environment. This first part of the workshop went over important terminology within the EDIA space including Intersectionality, Stereotype Threat, Discrimination, Bias, Imposter Syndrome, and other relevant key terms. It also included EDIA examples in Engineering with real world studies and innovations to drive discussions. Meanwhile, the second sub-group of students aimed to connect EDIA principles with engineering design practices, culminating in an Innovation Workshop centered around the Design Thinking process. This segment was tailored to resonate with the academic interests of incoming design students, encouraging the application of EDIA considerations in their Design Thinking work.

To test and develop these ideas, the students met on a weekly basis with the entire team including the instructor to collaborate on ideas, then twice a week with their sub-groups to co-design workshop materials, content, scripts, and prompts for the workshop. These meetings served multiple outputs: (i) Iterative Testing: Prototypes of workshop materials and activities were evaluated and refined based on feedback, including testing on an instructor and other engineering graduates who offered valuable areas for improvement, (ii) Idea Refinement: Through discussion and collaboration, initial ideas were continuously improved to better meet the workshop's objectives, (iii) Brainstorming: These sessions generated innovative approaches to workshop activities and materials, ensuring alignment with EDIA principles, (iv) Material Creation: Sub-groups dedicated time to the creation and development of specific workshop components, such as Identity Cards, Scenario Cards, and Presentation slides, and (v) Feedback Exchange: Sub-group meetings facilitated a dynamic exchange of feedback, allowing for the immediate integration of suggestions and improvements.

2.2. Workshop Materials

To facilitate participants' engagement with EDIA principles through interactive and reflective activities, materials were designed to not only introduce the foundational concepts but also to immerse participants in scenarios that challenged them to apply these concepts in their student experiences as well as innovative design-oriented contexts. The components included Identity Cards, Scenario Cards, Build Your Character (User Persona), Story Plot (User Journey), Presentation Slides, and Resource Materials (see Fig. 1 for examples). Each element played a critical role in guiding participants through a journey of self-exploration, empathy building, and innovative problem-solving, thereby ensuring a comprehensive and immersive learning experience. Below is an overview of these materials and their intended purposes within the workshop:

2.2.1. Intersectional Design Factor Identity Cards. Participants started their design challenge with an introspective activity using Identity Cards. This set comprises 11 cards, each representing a different aspect of identity, including Gender, Language, Family Structure, Disability, Age, Ethnicity, Sexuality, Race, Economic Status, Geographic Location, and Educational Background. These cards served as a catalyst for participants to reflect upon and share their own diverse identities, fostering a foundation of self-awareness and mutual understanding within the group.

2.2.2. Scenario Cards. To bridge the gap between theory and application, Scenario Cards prompted participants to engage with a variety of student experiences. Options ranged from navigating the cafeteria, studying in the library, attending lectures, to interactions with professors. These scenarios invited participants to explore the dynamics of campus life through a lens of inclusivity and diversity.

Fig. 1 Identity and Scenario Cards designed for participants to use during the workshop.

2.2.3. Build Your Character (User Persona).
In this resource material, participants were encouraged to craft a fictional character, or User Persona, while drawing upon their own identities and experiences for inspiration. This process not only allowed for creative expression but also deepened the understanding of how personal identities influenced design considerations.

2.2.4. Story Plot (User Journey).
Building upon the User Persona, participants mapped out a User Journey or Story Plot for their character. This narrative explored the character's progression through the selected scenario, identifying challenges encountered and current resolutions. The journey map was used to ground the brainstorming activity, in which these stories were reimagined to offer innovative solutions that addressed the identified challenges, showcasing the application of EDIA principles in real-world contexts.

2.2.5. Presentation Slides.
To support the workshop's instructional components, two sets of presentation slides were provided: one covering EDIA concepts and the other focusing on the Design Challenge. The slides were made available for download, ensuring accessibility by allowing changes to slide features, fonts, and note-taking to facilitate personalized engagement and follow-along.

2.2.6. Resource Materials.
A compilation of resources, including articles, tools, and references, were made available to participants. These materials were selected to enhance understanding and provide further reading on EDIA principles and Design Thinking, supporting participants in their ongoing learning journey.

2.3. Participant Recruitment

Students co-designing the workshop took ownership of creating and drafting materials to help recruit participants such as social media posters that were shared by relevant university clubs and organizations and drafting emails to be sent out by the instructor to all incoming graduate students from the Engineering Design program and other relevant graduate programs. The list of student contact information was provided by the department administrators; the email invitation was sent to all incoming graduate students. The emails and posts included a Registration Survey link gathering not just student registration information but also gauging understanding of EDIA and Design Thinking experience to ensure the workshop was catered to the attendees' knowledge levels.

2.4. Workshop Structure and Delivery

The "Inclusive Innovation Design Challenge" workshop was first delivered in September 2023 during orientation week at McMaster University by the collaborative team of students, recent graduates, and the instructor. Students who co-designed the workshop took an active role in delivering and facilitating the workshop with the instructor. The workshop was delivered in two distinct parts. The initial part consisted of an immersive introduction to EDIA concepts, engaging participants in activities designed to deepen their awareness of personal identities, familiarize them with relevant terminology, and encourage reflective thought. It aimed to foster self-awareness among participants about their identity and positionality in the realm of design. This introspection was critical for understanding how personal values and perspectives influence interactions within various contexts. The facilitation of this segment helped attendees recognize the impact of their backgrounds on their Design Thinking processes.

Following this, the second part of the workshop transitioned into a human-centered design innovation challenge, anchored in the principles of equity-based co-design, notably referencing equity-based design frameworks [18], [19]. It was designed to guide participants through the creation of narratives aligned with their identities, the brainstorming of innovative solutions, and collective reflection throughout the process. Noting that there were students who mentioned (through the Registration Survey) that they were unfamiliar with Design Thinking terminologies such as user personas or journey mapping, terms such as characters or story plot were used instead to give a general idea of the objective of these exercises.

This second phase of the workshop was centered around a Design Challenge, emphasizing the student journey and positioning participants as co-designers. This segment started with facilitating the sharing of personal experiences and insights related to EDIA within engineering, design and students' personal experiences, promoting an open dialogue that showed the significance of embedding EDIA considerations throughout the workshop. In the beginning of this challenge, students were given the 'Build Your Character' template of a 'character' to fill out and Intersectional Design Factor card decks adapted from the work of Jones et al [19]. This character mimicked the idea

of a user persona in a Design Thinking Process, and pulled upon selective needs, values, and experiences of group members who chose to share their personal identities with the group. Then, they were given a general scenario that a typical student may go through at university. Using a Journey Map, students were then instructed to first write out their character's story along with challenges or advantages they may face due to their character's identities. Afterwards, using Ideation, this exercise encouraged participants to brainstorm solutions and reconceptualize the experiences of their personas, helping students reframe their character's challenges in unique ways. These resources facilitated a deep dive into the challenges at hand, promoting innovative thought processes aimed at reimagining their student experiences and identities.

Throughout this co-design exercise, participants were encouraged to reflect on the diverse perspectives and challenges experienced by different identities, facilitated by critical questions such as, "How might different identities experience challenges in the given scenario?" Or "How do diverse identities within your group experience this scene differently?" Thereby, the process not only heightened awareness of varied student identities but also fostered critical thinking about design decisions, ensuring that solutions were inclusive and considerate of a broad spectrum of user experiences.

2.5. Subsequent Iterations

Leveraging the insights garnered from the initial September 2023 workshop, subsequent iterations were conducted at the Inclusion, Diversity in Engineering Allyship (I.D.E.A.) conference as well as within a classroom setting in January 2024, targeting undergraduate and graduate students, respectively. These iterations attracted participants from a wide range of academic disciplines, necessitating adjustments to the workshop's structure to accommodate the distinct learning environments and time constraints. In each case, the initial half was spearheaded with a presentation on EDIA terminology - covering ideology, positionality, intersectionality, and discriminatory design, supplemented by practical exercises, based on the character development worksheet, scenarios, and journey map activities described earlier. In these follow-up workshops the "Power Flower" tool [20] was introduced to assist students in exploring and defining identities alongside the Intersectional Design Factor cards, thereby enriching the development of character and persona narratives.

3. OUTCOMES

By co-designing the "Inclusive Innovation Design Challenge" workshop with students (and for a different group of students), the design team was able to create an impactful learning experience that not only conveyed the importance of EDIA in engineering and design but also demonstrated these principles in action through the workshop's content and activities.

The dedication of students and recent graduates in co-designing this workshop was also particularly noteworthy. Students invested additional hours outside of their academic and personal commitments to contribute to the workshop's development and even in contributing to this publication that documents their experiences and the workshop's impact. This investment highlights the students' deep commitment to and belief in the workshop's importance, demonstrating the shared responsibility that equity-deserving students want in making engineering education more inclusive [6], while exemplifying the essence of co-design – where students are not just mere attendees, but also integral to the creation process itself.

This workshop experienced an overall high level of engagement, reaching its maximum capacity with 55 student participants (the given room capacity by administration in which to run the workshop) as shown in Fig. 2. Even after the registration deadline had passed, many students expressed interest in participating. This enthusiastic response demonstrates the workshop's relevance and appeal to the student body. The workshop's success was also gauged through an anonymous post-workshop quality improvement survey, which revealed an overwhelmingly positive reception. In this survey, we posed questions to participants such as: which aspects of the workshop they found most valuable, if the workshop changed their perception of the value of diverse perspectives or their own unique identity in design, and even assessing comfort levels with the EDIA and Co-Design Challenge phases of the workshop. From the responses, a significant majority of respondents acknowledged a transformative shift in their perspective, appreciating the value of their unique identities and the critical role that diverse viewpoints play in the design process.

Fig. 2 Inclusive Innovation Design Workshop participants using the Card Decks to complete their User Persona and Journey Map worksheets.

Similar sentiments were observed during conversations after the subsequent iterations of this workshop in January of 2024 within the IDEA conference as well as the classroom iteration of the workshop. Participants expressed deeper appreciation for the complex interplay of concepts such as the intersectionality of identities in design decisions. Such feedback not only attests to the workshop's immediate impact but also to its potential for fostering a more inclusive engineering community.

In terms of pedagogical outcomes, ongoing research aims to explore the extent to which students are able to incorporate the workshop's teachings into their academic pursuits. A key objective of this inquiry is to assess whether participation in the workshop contributes to a heightened sense of belonging within the engineering program. This aspect of the research is crucial for understanding the workshop's long-term benefits and its ability to cultivate a supportive and inclusive educational environment.

4. DISCUSSION

Although largely a success, in the "Inclusive Innovation Design Challenge" workshop there were a few limitations and challenges we would like to acknowledge, particularly in integrating the aspect of one's identity into design work through the development of characters or personas. This integration is crucial for fostering a deep understanding of inclusive design principles among engineering students. However, effectively incorporating these aspects into workshop exercises proved to be complex, underscoring the need for careful consideration of pedagogical approaches.

We also recognize the inherent vulnerability associated with expressing and sharing personal identities within an academic setting. This acknowledgment signifies the need for creating a supportive environment that encourages open dialogue and mutual respect.

A primary constraint encountered was also timing. The feedback suggested that students required more time to fully grasp and digest EDIA concepts and terminology, particularly for those to whom these concepts were new. Additional time would have not only facilitated a better understanding, but also would have allowed for a more thorough exploration of questions, clarifying uncertainties surrounding these critical concepts. To address this, an intermediate session between the two parts of the workshop (i.e., the EDIA concepts and the Inclusive Innovation Design exercise) could enhance students' comprehension and application of their identities in design processes.

Another challenge for the workshop was getting Instructor participation in the initial September workshop to be co-designers with students in the activities. However, in the IDEA conference iteration, we achieved notable engagement, including the participation of McMaster University's Provost and Vice-President (Academic) and a Keynote Speaker from the IDEA conference. This involvement shows the value of collaborative interactions between students and instructors. Moreover, engaging instructors alongside students facilitates a dynamic exchange that transcends traditional educational hierarchies, fostering a space of mutual vulnerability and respect. This collaboration is pivotal, as it not only challenges power differentials but also models a culture of open dialogue and shared learning, as described in the Students as Partners literature [13]-[19]. Such interactions are crucial for exploring the complexities of identity and inclusivity within design, highlighting the transformative potential of collective engagement in EDIA-focused educational learning.

This integration of the workshop in a conference context also offers a unique lens through which to examine the dynamics of participant engagement and the potential factors influencing it. The IDEA conference, a student-led initiative, stands out as a prime example of how flexible, participant-driven planning can significantly enhance engagement and contribute to the overall success of educational endeavors. For instance, the absence of stringent guidelines or limitations during the planning phase, driven by a student-centric approach, allowed for a highly tailored and responsive event structure. The planning committee, drawing on insights from their peers, effectively catered to participant preferences regarding the day's schedule, timing, and content. Motivational elements such as course bonuses, snacks, and prizes were employed to encourage participation in the conference; however, the core of the conference focused on deepening students' understanding of EDIA. Workshop buy-in was strategically based on connections with the organizing committee and networking at similar events, with many speakers returning from the previous year's conference. This continuity facilitated networking and enriched the planning process for the 2024 conference, and shows the significance of EDIA awareness and promoting widespread student engagement with the subject matter.

4.1. Positionality

As facilitators and creators of this workshop, we acknowledge that our positionality - encompassing our backgrounds, experiences, and biases - may have influenced the workshop's dynamics and outcomes. The diverse composition of our team, which included undergraduate engineering students, recent engineering design master's graduates, an engineering design instructor, as well as a student from a science discipline, brought a wide array of perspectives to the planning and execution of the workshop. This diversity inherently shaped our approach to the workshop content, the methodologies employed, and our interactions with participants. Specifically, the variance in academic backgrounds and experiences among the team members allowed for a richer, more multifaceted exploration of

EDIA principles. However, it also necessitated continuous reflection and adaptation to ensure that our biases did not overshadow the workshop's objective of fostering an inclusive learning environment.

4.2. Future Directions

Post-workshop, a variety of resources were shared with participants to further their understanding and application of the workshop's concepts. The incorporation of these resources into other courses, as exemplified by the classroom iteration of this workshop, represents an ongoing exploration of how to embed EDIA principles within the curriculum effectively without adding undue workload. Ideally, these principles should enhance the curriculum's effectiveness by integrating inclusive Design Thinking into engineering education.

However, there is more work to be done in this area, particularly in assessing the long-term impact of these resources on students' learning and sense of belonging at post-secondary institutions, and their incorporation into other academic and project work. Understanding how students utilize the shared resources post-workshop is vital for evaluating the workshop's effectiveness and guiding future improvements. Conducting research, including focus groups with participants, offers an opportunity to gather direct feedback on the workshop sessions and insights into the practical application of the resources. This feedback would help inform adjustments to the workshop's content and structure, ensuring that it meets the evolving needs of students and the broader engineering community.

Future iterations of the workshop will also aim to more accurately tailor content to the varying levels of knowledge in EDIA and Design Thinking concepts among participants. This customization could involve providing identity cards of varying complexities to match participants' existing understanding, thereby ensuring that each individual's learning experience is both challenging and accessible. Adjusting the scenarios used in the workshop to reflect a broader range of experiences and disciplines is another strategy to tailor the workshop more effectively to different audiences, ensuring relevance and enhancing engagement across a diverse participant base.

The workshop's development and refinement is an ongoing process, with an emphasis on building a network of collaborators committed to advancing EDIA within the engineering education space. Potential collaborators include other academic programs and instructors, university organizations, experts dedicated to EDIA in STEM, and interdisciplinary researchers. Establishing a collaborative network will facilitate the exchange of best practices, support innovation in curriculum design, and promote collective efforts towards creating a more inclusive and equitable learning community.

Engagement with faculty and instructors is also crucial to ensure the relevance of the workshop content to engineering design students. Future efforts to secure faculty buy-in can include demonstrating the workshop's alignment with academic program values and goals, showcasing student feedback and outcomes, and illustrating the workshop's capacity to enhance students' well-being as well as interpersonal skills and critical thinking. Moving forward, it will be essential to engage instructors more consistently, and explore how faculty can integrate EDIA within their teaching in a way that is meaningful for both the learner and educator. By fostering a collaborative and inclusive environment where both students and faculty can potentially co-create learning experiences, this initiative has the potential to challenge and reshape traditional educational hierarchies, promoting a more equitable and participatory model of education.

By considering these future directions, the workshop can continue to evolve and adapt, reinforcing its commitment to integrating EDIA principles into engineering education and fostering a more inclusive and equitable learning environment.

4.3. Conclusion

The Inclusive Innovation Design Challenge workshop demonstrated promising progress towards integrating inclusive design principles into engineering education. Despite encountering challenges such as the complexity of incorporating personal identity into the design process and the need for more time to digest critical concepts, the workshop showcased the transformative potential of collaborative interactions between participants. Engaging students and recent program graduates as partners in the workshop design and planning demonstrated the value of equity-based co-design in fostering engineering student engagement and promoting EDIA awareness. These findings underscore the importance of creating supportive environments that encourage open dialogue, mutual respect, and dynamic exchange, ultimately advancing equity and inclusivity within engineering education.

Acknowledgements

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