Leveraging Diversity in Software Engineering Education through Community Engaged Learning and a Supportive Network

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***Abstract*—While a lack of diversity is a longstanding problem in computer science and engineering, universities and organizations continue to look for solutions to this issue. Among the first of its kind, we launched INSPIRE: STEM for Social Impact, a program at the University of Victoria, Canada, aimed to motivate and empower students from underrepresented groups in computer science and engineering to develop digital solutions for society impactful projects by engaging in experiential learning projects with identified community-partners. The twenty-four students in the program came from diverse backgrounds in terms of academic areas of study, genders, ethnicities, and levels of technical and educational experience. Working with six community partners, these students spent four months learning and developing solutions for a societal and/or environmental problem with potential for local and global impacts. Our experiences indicate that working in a diverse team with real clients on solving pressing issues produces a sense of competence, relatedness, and autonomy which are the basis of self-determination theory. Due to the unique structure of this program, the three principles of self-determination theory emerged through different experiences, ultimately motivating the students to build a network of like-minded people. The importance of such a network is profound in empowering students to succeed and, in retrospect, remain in software engineering fields. We address the diversity problem by providing diverse, underrepresented students with a safe and like-minded environment where they can learn and realize their full potential. Hence, in this paper, we describe the program design, experiences, and lessons learned from this approach. We also provide recommendations for universities and organizations that may want to adapt our approach.**

***Index Terms*—Software Engineering Education Diversity and Inclusion, Experiential Learning, Design Thinking**

I. Introduction

Computer science and software engineering university programs have long suffered from a lack of diversity where recruitment and retention of students from underrepresented groups are challenging [1]. Working on society impactful projects has the potential to motivate women and other underrepresented individuals to continue in Science, Technology, Engineering, and Mathematics (STEM) as they are often drawn towards care-oriented and humanistic careers [2]–[4]. Experiential learning, a method employing learning through working [5] has proven to increase confidence and motivation in students to continue and persist to graduation [6]. Engineering programs typically offer a wide breadth of project based courses such as "capstone courses". Such courses offer specific training in skills such as programming, computer algorithms, and agile development. However, these projects are mostly limited to the classroom and likely insufficient to provide a real life experience to students. In addition to academic courses, university engineering programs often require students to complete mandatory co-op internships to obtain their degrees. Depending on *what, how, or where* a student chooses to conduct their co-op, they may be exposed to diverse experiences. Yet, the lack of diversity and potential discrimination towards underrepresented groups in these work environments is an obstacle for them to succeed in engineering [7], [8]. Moreover, potential gatekeeping such as stereotyping in computer science and engineering even unintentionally can have negative effects on whether a minority feels comfortable staying in our field [9]. Ultimately, the lack of diversity can create unwelcoming environments or negatively impact the sense of belonging which can inhibit whether someone from an underrepresented group continues to pursue engineering [10], [11].

In recent years, some universities have begun launching initiatives and protocols regarding increasing diversity, equity and inclusion (DEI) in engineering programs to train faculty, staff, and even teaching assistants [12]. These protocols are a means to help reduce the potential harm that could inflict on a student. However, most programs are limited to spreading awareness through discussions or imposing protocols. Involving students in projects with social and/or environmental causes and allowing them to interact with real clients can increase interest and confidence of students. Hence, we launched the INSPIRE: STEM for Social Impact at our university that aims to foster DEI through community-engaged experiential learning for underrepresented students and support them through a network of like-minded individuals.

As both program organizers and researchers, we share the experiences and lessons learned from students working in this program. The goals of our five-year program include: *(1) developing a network of like minded individuals, (2) motivating students through empowerment, (3) providing experience with realistic and impactful problems through community engagement, and (4) learning to work in diverse teams.* In the first iteration of the program, our twenty-four students from diverse science and engineering backgrounds tackled a number of

social and environmental problems relevant to the community over the course of 4 months. Matched with experienced community partners (local non-profit organizations) and industry mentors, the students were split into 6 community projects for which they endeavoured to design and develop a digital solution. From our initial launch cohort, we report some significant lessons learned from the students' experiences. Afforded an environment where they could develop interpersonal skills and technical expertise, the students learned to work with a diverse group of teammates on problems that had both local and global ramifications. Furthermore, students immensely valued the provided autonomy and gained a sense of empowerment which helped them apply their skills in various aspects. In this experience report we discuss important lessons learned and present recommendations which may be beneficial for future educators implementing diversity centered experiential learning opportunities in other institutions. Section II outlines relevant literature, and Section III offers a detailed description of the Inspire program on which this experience report was written while Section IV highlights the phases students underwent within the program. The novelty of this work is found in Section V which delves into the experiences of our students and Section VI which describes each unique project within the program. Important lessons and recommendations for educators can be found in Section VII, and the paper concludes in sections VIII and IX with suggestions for future works.

II. Background and Related Work

The program aims to engage students from diverse backgrounds in real world projects utilizing experiential learning methods, in particular community engaged learning and design thinking. In this section we discuss the motivation of our program in light of the existing literature.

A. Diversity in Educational Context

Collaborative fields like Computer Science and Software Engineering require teamwork. Facing negative experiences within diverse teams contributes to the attrition of minoritized groups from our fields [13]. Studies suggest students leave STEM fields or choose different careers after graduation due to factors such as level of success and demographic characteristics [14]. Moreover, gender stereotypes often "gatekeep" the field of computer science or software engineering hindering women and other underrepresented individuals' intentions of choosing these field [9]. As such, researchers have tried to introduce new ways of incorporating diversity into education [15]. Furthermore, Diversity, Equity and Inclusion (DEI) initiatives have become popular in recent times [12], however these initiatives are mostly related to hiring/promotional processes and discussions [12]. EUGAIN (European Network For Gender Balance in Informatics), a program in Europe, aims to improve gender balance in Informatics through developing a network [16]. This initiative further introduced various initiatives like a Female Mentorship Program, and academic and social events such as the "Girl Project Ada" [16]. Such programs are beneficial as effectively introducing diversity in classrooms can significantly impact the future workforce [17], [18]. University courses often require students to work in teams [19] which can be leveraged to incorporate diversity. Diversity within a team is beneficial because members provide a variety of perspectives [20]. Therefore, our program employs experiential learning in team work in exploring diversity through experiential learning.

B. Experiential Learning

Experiential learning (EL) is "the process whereby knowledge is created through the transformation of experience" [5]. It is considered to be an effective tool for students to learn about challenging topics that require real experience for sound understanding [21]. EL methods have been used by many educators in software engineering education such as game development [22] and requirements engineering [23]. El-Glaly *et al.* [24] suggested that incorporating EL into curricula inspired students to learn and value the importance of accessibility and take it into consideration while developing software. Thus, the impact of EL in positively enhancing students' learning and attitude towards software engineering education is significant [25]. Community engaged learning (CEL), a form of experiential learning has been an effective method to retain students in courses [26]. In CEL, the community partners actively participate in problem identification and solution ideation [27]. CEL is a popular method in educating computer science students on the social good [28]. However, it is both an empowering and difficult learning process. To support this process, we embedded design thinking in our program to give a primary structure to the students.

C. Design thinking

Design Thinking (DT) has been part of the software development process for a while now [29]–[31]. DT is an iterative problem-solving technique that focuses on users' needs [32]. Involving users as part of the design process has been an essential aspect of successful design [33]. Lindbervet *et al.* [34] stated that design thinking is the process of understanding the clients and building on what we learn from their problems rather than applying what we already know. Studies have shown that students' learning and thinking abilities can be significantly improved through design thinking training [35]. To solve social issues through software engineering, our minds often focus on technological solutions, but these problems should be approached with an open mind [36]. Personal bias often hinders such solution development, so it is important to empathize with end users by overcoming the biases [37]. Hence to guide the students' problem-solving and make their collaborative experience more efficient we utilized IBM design thinking [38]. IBM DT extends the conventional methods by adding more structure in terms of team organization, identifying requirements from end-user feedback and tracking the project progress [38]. Thus, IBM DT was employed in designing the structure and deliverables for the program.

III. Program Overview

A. Motivation and Goal

Retention and the lack of diversity are notoriously difficult problems in computer science and engineering. To address this problem, this program was launched with the vision of inspiring and empowering science and engineering students from diverse backgrounds. In particular, we aimed to create a network where students from underrepresented groups such as individuals of marginalized genders, racialized groups, people with disabilities, LGBTQ2S+ and Indigenous peoples could stay in this field and succeed.

The fundamental idea of the program originated from the principles of self-determination theory [39] which describes the factors that contribute to different types of motivation rooted in three basic needs: *Competence*- a need to be able to effectively handle the environment, *Relatedness*- a need to have close bonds with others, and *Autonomy*- the freedom to make one's own choices. Intensive training was provided for all aspects of the students' projects to provide learners a sense of competence. An emphasis was placed on team bonding activities, and group activities with all teams together to create a sense of relatedness in the program network. Finally, while students received extensive training, the details of their projects were not micromanaged by the program management team, providing a sense of autonomy within an otherwise structured program.

The program secured sponsors and community partners, many of whom were non-profit organizations who actively engaged in helping those in the community that are most vulnerable. By engaging and taking on community impacting projects, the students received industry mentorship and guidance from community experts in a safe, respectable, and inclusive environment. Thus, with the goal of empowering and motivating diverse underrepresented student in science and engineering, we embarked on our first iteration of the five year journey.

B. Recruitment and Project Selection

Considering that a primary objective of the program was to promote DEI and designed to uplift underrepresented students, it was important to recruit students who shared these values and beliefs. To maximize the reach of potential participants an open call was sent through the university platform (i.e., email, social media, etc) 4 months prior to the launch of the program. Over 50 students responded to the open call and were subsequently interviewed through a two step filtering process. The filtering process was designed to test different social aspects such as primary communication skills, conflict resolution, and leadership.

The first step of the interview process consisted of a team activity to test each student's ability to (1) work in a team, (2) overcome any conflict that would occur in that short time span, and (3) self organize the team decisions. Students were broken into teams of 5-6 students and tasked with completing a project that addressed a hypothetical problem and constraints which would require students to demonstrate their skills in these three areas. The second phase of the recruitment was an interview process where each student was interviewed individually on different situational questions. For example, how would they behave under conflicting situation, how would they deal with failure or what would their approach be when conversing with the community partner. At the end of this recruitment process, 24 students were selected to participate in the program. The selected students were offered co-operative education (co-op) credits which would go towards their degree.

In addition to the student recruitment, a critical aspect was selecting the community projects that the students would work on over the course of the four months. Similar to recruiting the students, an open call for the community to propose projects was made. The university has a community engaged learning (CEL) department that was dedicated to establishing relationships between university programs and the community. With the support of CEL department, a large number of prospective community project applications were received. However, a total of six projects were selected. Based on the selection criteria, these six projects were the most pertinent for the students and program. Not only did each project address a pressing social or environmental challenge affecting the broader community, but each community partner also committed to mentoring the students in project specific training such as dealing with brain injury patients and norms of engaging with vulnerable clients.

C. Team formation

The next step consisted of placing the 24 recruited students in their respective teams and pairing them with one of the six community projects. Prior research showed that working in a project that resonates with one's value gives a sense of motivation to work on the project [40]. Thus, each student was asked to fill out a survey to identify their top three project preferences. Based on this preference as well as their academic skills, experiences, and project requirements, each student was placed in a team. Through this process, each team ended up with diverse members in terms of gender, sexual orientation, ethnicity, academic standing and background such that most students had another team member which they could relate to on some level, and thus catalyze the formation of meaningful friendships and bonds. Moreover, each project had a diverse set of end users, making the projects more challenging and motivating at the same time.

D. Demographic

Among the 24 students in the program, 10 identified as female, 12 identified as male, and 2 preferred not to disclose their gender. Furthermore, 19 students came from the undergraduate level and 5 from the graduate level. The students were further diverse in terms of 1) academic background as they came from computer science, software engineering, electrical engineering, mechanical engineering, biomedical engineering, physics, chemistry and business, and 2) ethnicity, including South-Asian, East-Asian, Black, Arab, Hispanic, Indigenous,

and White.

For some of the students, this was their first work-integrated learning experience and most of the students had never worked with a community partner before. To mitigate this, an additional senior experienced student was matched with each project team to help them with any logistical or teamwork issues. Out of the 6 experienced students, there were 5 female and 1 male student and each of them had different engineering and science background. The teams were further matched with industry mentors who guided them on different social and technical issues. Therefore, while each project team had a diverse blend of experiences, skills, and perspectives, all team members had an equal opportunity to work on a project that they were deeply motivated to work on.

IV. Program Timeline

During the four months of the program, the students were instructed to complete 8 phases (2 weeks each). The project timeline comprised from May to August where each team was required to complete each phase of the project in two weeks intervals. At the end of each phase, students were required to present their project progress to the instructional team and other groups. The intention of this bi-weekly presentation was to share the common struggles and challenges with all the teams and create a network where they could support and suggest solutions to each other. The presentations further built confidence in the students. Since the teams were mostly self organized, they were allowed to determine their own deliverables, however some set goals were provided for each phase to help them keep on track. To better understand the goals and activities, we provide a replication package: https://doi.org/10.5281/zenodo.7196558 as well as describe each phase (indicated with P#) as follows:

May

- **P1-Problem Definition:** Students were provided with interpersonal skill training like Diversity, Equity and Inclusion (DEI), professional conduct and communication with clients, conflict resolution, project specific training, design thinking as well as technical skills training like web frameworks, code repositories, and Agile development. Using these skills and their initial communication with the community partner, students were required to finish defining the initial problem.
- **P2-Problem Planning and Framing:** Upon receiving the initial training, students were instructed to meet with their respective community partner and end users to further plan with them and start framing the problem based on collected user data (interviews, focus groups, surveys).

June:

- **P3-Problem Validation/Early Prototyping:** After collecting enough information and framing the problem, students revisited the clients to validate their findings in order to start prototyping.
- **P4-Midterm Presentation:** This was one of the most significant milestones as this was the first major opportunity for students to showcase their work to the public and get feedback from professionals regarding their project.

July:

- **P5-Validation of Prototype:** During this phase, the students reiterated their prototype with the clients before finalizing it for the implementation.
- **P6-Solution Development:** This phase marked the start of the solution development and was dedicated to identifying and learning the required technology.

August:

- **P7-Continued Solution Development:** This phase was fully dedicated to the development of the solution (software) and the students worked in parallel with the clients to make sure the clients were satisfied with the product.
- **P8-Finalizing Solution Development and Documentation:** The final phase of the development process was dedicated to wrapping up the project and creating proper documentation for the clients, so that the client could take this forward and utilize it in their community.

V. Documenting Student Experiences

Throughout the four months of the program, we observed and documented individual and team reflections as well as conducted focus group interviews with the students and community partners. Keeping diversity in mind, we particularly emphasized on analyzing and understanding the students' experience. The purpose was to further improve and utilize the learning for our next iteration. Our aim included identifying whether or not this program instilled a feeling of belonging in the students. The students were provided with workshops on how to reflect on their experience and learning outcome from working on a real-world impactful problem in a diverse team setting.

A. Data Collection and Analysis

As part of the deliverables, the students were instructed to write a 1 page individual reflection and a team reflection (not more than 2 hours of writing) every week based on their project development process and teamwork experience. To guide the students, we provided them with some prompts. For example, *how is the interaction with the community partner, what is their experience working with a diverse set of people, how is the diversity influencing their project, and how are they dealing with adversities*. Furthermore, we conducted two focus groups with each team, once in the middle of program and once at the end. During their first focus group, we gathered information on their developing team dynamic and the project progress. The second focus group consisted of questions related to their software development experience and overall experience throughout the program. We further interviewed the community partners to understand their perspective of working with the diverse set of teams, the program and the product

TABLE I: Documented Data

Project	Individual Reflection	Team Reflection	Focus Group	Community Partner
Nature Sanctuary Visitor Tracking	S1, S2, S3, S4	T1	F1, F2	C1
Women+ Fleeing Violence	S5, S6, S7, S8	T2	F3, F4	C2
Resource Centralization for Brain Injury Survivors	S9, S10, S11, S12	T3	F5, F6	C3
Climate Education for Youths	S13, S14, S15, S16	T4	F7, F8	N/A
Resource Centralization for Urban Environmental Data	S17, S18	T5	F9, F10	C4
Carbon Impact of Websites	S19, S20, S21, S22	T6	F11, F12	C5

received. Hence, by the end of the four months we collected data in the form of approximately 300 individual reflections, 90 team reflections, 12 focus groups and 5 community partner interviews.

Afterwards, we analyzed the data to extract the key lessons and statements that illustrated the student's journey and could be further utilized to improve the program. The analysis process comprised of an iterative discussion cycle and peer debriefing amongst the research team. To avoid assumptions and biases, an external member outside the research team was recruited who reviewed and validated the findings.

In the following sections, we first briefly explain each team's journey to portray their similar as well as different experiences. For convenience, we categorized the data according to the projects in table I where weekly individual reflections are denoted as S# (S1-S22), weekly team reflections as T# (T1-T6), focus groups as F# (F1-F12) and community partner interviews as C# (C1-C5). Although 24 students participated in the projects, 2 students did not consent to their individual reflections being analyzed. We then summarize the common lessons learned from our analysis and propose recommendations for further improvements.

VI. Team Journey

The 4 month program was both an accomplishing and turbulent journey for all the students, as the teams had to overcome various adversities. The first month was heavily dedicated to training and learning about the project specific requirements. Since all the community problems appeared to require technological solutions, the students had to learn different technical skills including programming languages, frameworks, version control, database, API integration, PCB design, geographic information systems, and many more depending on their project. The teams were introduced to design thinking and Agile, as such they extensively utilized these processes in their project management, software development and requirement elicitation. Due to the heavy emphasis on experiential learning, the students mostly developed skills through implementing these skills during the software development process. In addition, the students learned a plethora of soft skills, some of which were unique to their project due to having specific clientele. Table II summarizes a brief description of the community problems and the final solutions developed by the teams. In this section, we highlight some significant points in their journey during this four months.

Project 1: Nature Sanctuary Visitor Tracking

Preserving endangered plant species in the current state of the world is a crucial concern. A local sanctuary posed this issue to one student team; they envisioned an effective method to track visitor activity within the park. Ever since the onset of COVID-19, the nature sanctuary experienced significant increases in the number of visitors, some of whom passed through restricted areas of the sanctuary damaging endangered species. The students were highly motivated *"learning about the history, the ecosystems, and the hopes for the future"* (S2), as it *"brought [them] attachment to the environment"* (S2). Visiting the sanctuary further added to their motivation to work on the project, as one student said: *"Monitoring foot traffic would initially help solidify the hypothesis, which could be used for future planning. ... Having never been there before, I was finally able to connect a place to the name"* (S2).

Furthermore, this project consisted of a hardware component, thus this team was composed of software and mechanical engineering students. The hardware component generated *"slightly stressful"* situations, as one student states, *"Our PCB didn't fit the arduino. ... it is unfortunate that this now means that we have to wait again for more parts to be delivered. I have found this to be the most challenging part of this project. ... We have also been working on our documentation, however it is hard without everything being finalized (final PCB being here, as well as final casing being printed). Hopefully, we can have more productive weeks to come"* (S1). Eventually, the team succeeded in developing the sanctuary tracking devices, allowing them to tally where visitors were exploring within the sanctuary. Describing their experience one student said they *"really enjoyed working with [their] community partner and [liked] making something for [them]"* (F8) and also *"made [them] realize like how much [they] actually know"* (F2).

Project 2: Women+ Fleeing Violence

Homelessness and domestic violence are global issues that first needs to be addressed locally to make a real impact. A coalition comprising local housing, health, and social service providers, nonprofit organizations, all levels of government, businesses, the faith community, people with a lived experience of homelessness (past or present), and members of the public presented this pressing problem to one of the student teams. They envisioned a solution to serve individuals experiencing homelessness, in particular women+ at risk of violence.

TABLE II: Summary of the Projects and the Solutions

Project	Community Problem	Solution
1	Due to the increase in number of people visiting local nature sanctuary, preserving and maintaining specific areas is becoming difficult	An IOT monitoring system to track and visualize where visitors are trekking in the park
2	Women+ fleeing violence and facing homelessness encounter difficulty finding safe and appropriate support, services, and housing	A website that allows support workers to easily find up-to-date available emergency housing and services for women+ fleeing violence.
3	Non-profit supporting brain injury survivors lack a centralized accessible hub to provide patients with relevant services	A mobile application with custom interface directing brain injury survivors towards necessary and appropriate services and support.
4	Youth lack motivation to take climate action due to inadequate knowledge and inspiration	A gamified classroom app that is designed to help teenagers to learn and take action about their personal carbon emissions, climate.
5	Existing climate change data is disorganized and fails to provide informed guidance on potential climate health	An interactive website that centralizes and reports information about regional climate change vulnerabilities.
6	Digital activities is part of everyday life, but people are unaware of the carbon impacts of browsing the internet.	A web application that accurately calculates the carbon impact of web browsing.

The complexity of this project guided this team to conduct a profound user research during the first few weeks of the program which unfolded deeper insights for the project. *"Going through the data and previous research was remarkably interesting to me as I could almost see there is not just one 'user', group or audience, but three different categories considering their stage in their life, or their 'journey' in fleeing violence"* (S8). This sometimes created uncertainty *"[raising] a lot of questions: which phase of these 'users' should [they] focus on? Is what [they] are planning on building viable/usable for either of these people?"* (S8). However, with support and guidance they were able to get back on track. *"We were reassured [by instructional team] that that's a natural step in the Design Thinking process and as we communicated more with our community partner and combed through the data, we started to get a better idea of where to go"* (T2).

Tackling all the challenges made them realize how much they learned from having a diverse team. *"Personally, I have learned about how people from different backgrounds face challenges, work hard, and handle a pivot. We learned it's best to jump into the ocean of information and surf until we find something valuable. Diversity in our group helped us with having talented/experts in every field and we learned from what other members brought to the table"*. The community partner labeled the final product as a *"really good start"* and *"a good traction outside of just [the] client"* (S5). They aspire to leverage the software to *"possibly finding some seed funding"* (C2) so they can fund the *"tech team interested in moving forward with"* (C2) the next stage of the product. The success of this four month project has inspired the team to continue working on it past project completion, thus providing some indication of success of our program.

Project 3: Resource Centralization for Brain Injury Survivors

Acquired Brain Injury (ABI) is a pressing concern as a large number of individuals suffering from it aren't able to find proper care or resources to support them. A local organization providing such resources and services requested a solution that would aggregate and centralize the information into a software which the patients can use comfortably, keeping in mind that individuals with ABI get overwhelmed with too many colors, pictures and moving parts. Provided with this vulnerable set of end users, the key challenge for this student team was identifying the user interface (UI) requirements of individuals with ABI.

Upon receiving initial training on "what ABI was?", "how it effects a person?" and "what accessible means to them?", one student described, *"We learned a lot of new knowledge about brain structure and brain injuries, which ... [lets me] basically understand why and what we need to design and develop the best solution for them"* (S9). As they spent extensive time going back and forth with the ABI patients, the clients *"expressed interest in looking at a prototype and giving [them] feedback on it"* which worked as great source of motivation for the team.

However, coming from first year software engineering and mechanical/electrical engineering, this team had no previous experience in software development, hence *"working with databases or similar things [was] a pretty big challenge"* (T3) for them. Nevertheless, they successfully learned and built what was required, as they mention: *"Some clients were like, Yeah, this is great"* (F6). The community partner expressed immense satisfaction and taking this software to a national level. *"They definitely took what the clients had to say, and applied it to the project. So yeah, I was really impressed with what they've done. ... I can see definitely our clients using it, but also putting it out to other brain injury organizations, even across [the country]"* (C3). This vast impact has motivated the team to continue working on this project which exemplifies one of the key goals of the program of building a network where individuals learn, grow and succeed in their endeavours.

Project 4: Climate Education for Youths

"Today's youth can fundamentally contribute towards solving global climate change concerns". With this goal, this team of students embarked on a journey of finding a solution to

encourage the local youth, in particular teenagers. The current technology advances have reduced youth's attention span [41], as such engaging teenagers was a massive challenge.

To first identify "what the youth of this generation felt about climate change" the team visited local schools to collect data, however the interaction sometimes felt *"daunting"* to them. Moreover, as the schools were headed towards summer holiday but they needed to finish the data collection before that, they felt overwhelmed with the workload, *"Preparing for school visits, organizing activities for the kids, making sure the prototype worked, going over the survey and practicing the presentation. It has been a stressful week and the fact that we needed to come up with a first prototype in such a short time made it more stressful"* (T4). During the school visits oftentimes *"[they] needed to adapt to [their] audience for them to be engaged and get enough feedback from them"* (T4). This process helped the team conceptualize the idea of building a classroom application utilizing gamification techniques and create personalized activities leading sustainable choices.

Reflecting back on their 4 month experience, one of the team members said: *"There was a lot of learning and failure, you know, if you're just given a step by step instructions from your prof how to make an app for whatever reason, then you're not going to learn anything from that. You're just learning how to follow directions, but I think it was really valuable learning how to, like, work in the space we did with, you know, making a quality product out of nothing and actually trying to solve a real problem"* (F8). The initial success of the team has lead them to further work on this project, so it can be fully incorporated in the curriculum of local schools. Thus, working on a real project not only inspired the team to continue working but also contributed to successful network building.

Project 5: Resource Centralization for Urban Environmental Data

To take collective climate actions, the first step comprises of understanding the current state of an area. Although, a lot of information is available online, many of those are either difficult to understand or scattered in different places. Thus, this team was presented with the problem of centralizing regional climate data in an easy to understand way for local community.

This idea originated from the community partner and their vision to educate and empower the community members. Hence, the student team first required to understand the core idea from the community partner, as one student said: *"I think [community partner] has so much background information. Our team kind of had the, like design thinking to kind of work with and I think that structure contributed to kind of like, help make the idea come to life"* (F10). However, the broad vision at times felt daunting to the students. *"The scope of the project from the beginning has been quite extravagant, and even after narrowing it down will be no easy feat for our team"* (S18).

To reduce the scope and validate their assumptions, the students *"spent time reviewing the interview and survey materials"* (S17). The students mention using empathy map, an exercise in design thinking helping them *"give a structured way to deal with all [their] data"* (S18). During this time, they learned various technical skills as well as soft skills. Such as, balancing their group work: *"to optimize efficiency, we split our group into two teams"* (S18). And, leveraging their past experiences for the sake of the project. *"I have taken on a larger project management role, because of my previous experience"* (S17).

In the end, the team was proud of their own accomplishment and the plethora of knowledge they had gained from this experience. *"Yeah if, on the first day, you showed me like a picture of what we created now, I don't think I would have believed that we could do that. But we really like learned a lot in a short amount of time. And then like, did what we set out to do"* (F10. Thus, although initially faced with difficulties regarding scoping, the team successfully negotiated the scope and was incredibly satisfied with their solution.

Project 6: Carbon Impact of Websites

Addressing the carbon emission of web browsing, a lesser known but important climate change factor was the problem stated to this team of students. The student team was paired with a local industry partner who envisioned creating a global platform for companies and organizations to understand and regulate their carbon emission. To achieve this vision, this team of software engineering and electrical engineering students initially received *"lots of guidance"* from a *"tech lead in terms of coding and skill-building"* (S20). One student mentions, *"The community partner has been fantastic to work with. In our case, the community partner, is our mentor/team lead which made it very easy to approach [them] from time to time"* (S22).

Despite this, at one point due to the tech leads absence the team struggled to find team cohesion. *"A challenge that our team has been facing this week is working without our project lead. Some of the instructions that [they] left us we could not follow to the letter due to access issues in our code base. As a team we had to make executive decisions about the implementation of some of our tickets so that the project could move forward"* (T6). However, this experience helped them find equilibrium as they started to rely on each other instead of the lead. *"Our team has become comfortable working independently and relying on each other"* (S19).

Furthermore, the team diversity seemed to hinder the coding process, but soon they acknowledged the benefits of different perspective and how that effects their work. *"We all have our own way of thinking about a problem and solution, thus our implementations do not always align and we have had to figure out how to meld our implementations into a solution that works for everyone. This can cause the project to become less streamlined at times and for there to be more opportunities for repeated code. That being said diversity in our team gives everyone a place to learn and see the project from a different perspective and through that we all become better at the work that we do"* (S19). By the end of the program,

the team realized how much they had evolved due to this process, as one student mentions: *"Working in a team setting [helped] improve my communication skills, which used to be my greatest weakness"* (S20).

All 6 projects had unique experiences in terms of overcoming different kinds of obstacles and pivots. However, they all left with the sense of achievement and learned different aspects of working in a software development team. Comparing the program with a course, one of the students said: *"This is so much better than taking a course. I think because in a course, the projects feels contrived. And I don't feel like the end result actually does anything. I mean, you learn through it. But it's, that's the intention is learning. Where here learning is not the only intention. It's about, you know, building community and making, you know, building interpersonal skills, and really setting ourselves up for the future while also making a product that actually will go out into the world and do some good"* (F12). This quote is a perfect summary of the program's goal of creating a network of like-minded people and contribute to their success through motivation, empowerment, mentorship and curating a safe space in the community.

VII. Lessons Learned

In this section we discuss the lessons learned from analyzing the data collected from the 4-month long projects. As this is the first iteration of a five year program, we intend to use these lessons to improve future offerings of the program, as well as provide actionable recommendations for other educators intending to launch similar programs.

Working on a community project with *real clients* and *community problems* poses an abundance of rewarding yet challenging experiences that students would not otherwise be exposed to until post-graduation employment. The students in our program were provided with a unique combination of working with real clients tackling real problems in diverse teams. Pacing their own projects, resolving conflict amongst themselves, and negotiating with their clients were all challenges that arose during this program. We describe below the lessons based on real experiences faced by the students, which after much reflection, we propose can be supported pedagogically. Table III, summarizes the overall lessons and recommendations.

Lesson 1:

Training on soft skills facilitates building a successful network of diverse individuals in software engineering. In a successful network, people are able to socialize, and support each other outside of work, and develop meaningful relationships. Previous research suggests that such non-professional relationships, even in organizational networks, is critical to companies employing research and development projects [42]. Soft skills are immensely important in building such a community, yet, university students often lack the soft skills that are required to operate in the real workplace [43]. Thus, training in such area is critical, as a lack of adequate training can cause conflicts, customer dissatisfaction and team fall out [44]. This program was the first exposure for many students to work with real clients, therefore we provided them with a number of training sessions covering soft skills such as communication with clients, team management, professional conduct, Diversity, Equity and Inclusion (DEI) and leadership. This was done to ensure successful interactions between students and clients such that positive relationships between them could be built, thus facilitating the growth and strengthening of their networks.

Due to the unique end-users each project catered towards, eliciting requirements from clients and end-users while also behaving in a professional and respectful manner was likewise an important skill to learn. Positive interactions with potential end users also contributed to students learning to successfully expand and integrate into their own networks. As a result of the provided soft skills training, community partners were immensely satisfied with the students as one of them stated: *"I thought they were very organized and professional. And yeah, I thought they did a really great job. For me it like feels very inspiring for the future to interact with a team of young people"* (C1). This suggests a willingness to interact with our students again, which represents that a strong rapport has been established.

As such, the community partners further connected them to individuals who could help them with their project. Describing their experience building connections one student said: *"for me personally was rewarding, challenging. At the same time, the connections are amazing, we couldn't have had those connections and get in touch with them as quickly as possible without [our community partner]. But definitely the communication has been difficult as well"* (F4). This quote implicitly indicates, the importance of communication skills for building connections. Difficulties developing open communication was clearly manifested in our program. One student reflects on *"exercises that [they] did [in one] week [which they] found particularly difficult and self-revealing"* (S19). *"The exercise consisted of writing down one thing [they] wanted one of [their] teammates to start, one thing that [they] wanted them to stop and one thing that [they] wanted them to continue doing"* (S19). However, the student added: *"This exercise has made it clear to me that communicating constructive feedback is something that I need to learn, and I hope that I may learn how to do it kindly"* (S19). This exemplifies the fact that open communication, while difficult to establish, is critical for effective relationship-building, thus justifying a need for soft-skills training to help students build their own professional networks.

Recommendations:

- Dedicate and emphasize a significant time towards soft skill training to help students build connections and develop a supporting network.

TABLE III: Lessons Learned and Recommendations

No.	Lessons Learned	Recommendation
1	Training on soft skills facilitates building a successful network of diverse individuals in software engineering.	- Dedicate and emphasize a significant time towards soft skill training to help students build connections and develop a network.
2	The right amount of guidance empowers students to balance the autonomy and motivates them.	- Provide adequate support to ensure students are not overwhelmed by autonomy. - Consider how skilled the students are becoming and adjust the level of support accordingly.
3	Proper structure enhances the community engagement experience between the students and community partners.	- Provide a guideline to the community partners to mitigate uncertainty regarding how they are expected to interact with students. - Add more instruction and training in communication, negotiation, and scoping skills since many students are engaging with community partners for the first time.
4	Through mentorship and DEI training, students learn to overcome challenges of working in a diverse team.	- Include explicit DEI training throughout the course of the project and emphasize the benefits of working with diverse teammates. - Be prepared to provide mentorship to students as conflict is expected from time to time.

Lesson 2:

The right amount of guidance empowers students to balance autonomy and motivates them While we encouraged our teams to be largely self-organized, this proved to be a delicate balancing act. We realized throughout the duration of this program that not enough autonomy would lead to feelings of being micromanaged. On the other hand, too much autonomy meant that students sometimes felt lost and were facing overwhelming uncertainty. We observed this closely in our cohort, with some students expressing a lot of anxiety and stress early in the semester when faced with independence: *"I would say, the very beginning with the whole, trying to figure out research and stuff on the different keywords, I think we were all kind of in the same boat at that point, trying to like figure out what we're doing"* (F3). Work by Noll *et al.* [39] supports these perception, speculating that individuals with lower competence, such as our students at the start of the term before learning new skills, will not benefit from high levels of autonomy. For this reason, we front-loaded substantial technical, soft skill and DEI training in the program so that every student would receive some initial guidance in a variety of soft and technical skills to increase feelings of competence.

As the term progressed, the contrary was observed through the increase in competence and relatedness of students in the program. Throughout the term, students developed a variety of skills and had the opportunity to bond with their team members. Noll *et al.* [39] suggests that even if individuals lack competence, autonomy can still be motivating if the person experiences high amounts of relatedness. This was observed as team members often helped each other overcome different challenges, or navigate knowledge gaps leveraging their diverse backgrounds and skillsets. One student discusses her team helping one member in particular saying, *"One of our teammates, the younger one, she didn't have any knowledge skills when she started this program with us. And us as a team decided to give her the tools and change that"* (F7). As the term progressed further and students further developed their competence, they expressed an appreciation for autonomy; one student says: *"We're given the space to come together and kind of figure it out what's needed, in my opinion, as a team to kind of figure out how to grow together"* (F11).

With the teams' progressing through changes in their own competence and relatedness, the teaching team required to adjust how much intervention was needed with the team's processes. In other words, we had to adjust the amount of autonomy we allowed. We realized that students built up autonomy over and relied on our guidance less and less as the semester progressed. This meant that the teaching team had to supervise fewer team-client interactions, spend less time assisting teams in deciphering client feedback, and intervene in fewer project pivots as the semester progressed. Thus, incorporate motivating the students to work on their own pace and empower them to succeed.

Recommendations:

- Provide adequate support to ensure students are not overwhelmed by autonomy and monitor student feedback to adapt if necessary.
- Consider how skilled the students are becoming and adjust the level of support accordingly.

Lesson 3:

Proper structure enhances community engaged collaboration between the students and the community partners. In this program, community partners collaboration was crucial to the success of the experiential learning process. Students expressed feeling highly motivated as a result of working in a real project with the community partners. The students felt more accountable to producing a successful final product as this product would be deployed to the community. When comparing the program to a typical course, one student describes *"You just have an imaginary community partner or user requirements, that doesn't change. Over time. It's just solid, they give you a problem statement, and you solve it"* (F4). However they express that in this program, *"the element of getting real people [had] a big role, because what [they] build might actually end up saving lives"* (F4).

Despite real clients being so important to the students' motivation and success, the community partner's vision for the

solution collided with the students' skillsets. For some of the projects, the scope was so large that the students were required to conduct extensive user research in the first two months to define the scope to a workable state as well as consider their own skills and knowledge to set the scope. Project 5 for example, had a somewhat unclear and broader scope as mentioned by one of the students: *"It's clear that the project's scope is significant and, at times, very daunting"* (P17). Thus they negotiated the scope of their project with the community partner. *"Our community partner meetings were also a great success. ... Its been very reassuring knowing how supported we are in this endeavour. ... It has been challenging to scale down the project to a workable yet impactful level. Although we haven't entirely defined our problem, we are honing in on it"* (P18). The community partner for this project 2 mentioned having to bring students back on track as often times they would deviate. *"We seem to have been pivoting and spinning our wheels a little bit more. ... I do know that because of the scope of the existing problem. It was really huge. And to try and keep the team focused on just chunking out something small, as part of it was a task in itself. ... So needing to pull them back to that route. Every so often was interesting"* (C2).

As a solution for such expectation conflicts, the community partners expressed the need for more guidance (written guidelines) regarding how much their involvement should be. Students conveyed similar needs, as one student stated: *"I wish we got more guidance. Because like our community partner was very, very kind to us. And was really happy with all our solution. But, I think it can be a bit hard to work with the stakeholder in mind. ... So I wish we got a bit more help with that"* (F2). To facilitate this improvement, another community partner suggested *"more touch points across groups, offering everybody a chance to get together or something"* (C1). They also expressed that it would have been helpful to *"hear from the other community partners to see how it's going for them"* (C1). Hence, more support is desired by both students and clients to make this collaboration more successful to build a supportive network.

Recommendations:

- Provide a guideline to the community partners to mitigate uncertainty regarding how they are expected to interact with students.
- Add more instruction and training in communication, negotiation, and scoping skills, since many students are engaging with community partners for the first time.

Lesson 4:

Through mentorship and DEI training, students learn to overcome challenges of working in a diverse team. Diversity has the potential to both benefit and hinder team performance [20]. For example, while diversity introduces many perspectives, the sheer amount of perspectives on each task can significantly slow a team's progress as members deliberate on every decision [20]. One student describes a frustrating experience in which they were encountering too many perspectives, saying: *"the most eye opening thing to me is like, how we can have like, the same objectives but like, the same goals but like different ways and like solving the same problem"* (F4). However, the DEI training helped them realize the importance of different views in a team, *"For me, [initially we had the session] on inclusion and the importance of equity diversity. I was like, [is it] that much important? ... Before that. I didn't take it seriously. I thought it would be helpful, but to what extent and also respecting other comments, other people's view, that's also important. So yeah, that session I feel was important and useful for me to feel it like was one of the core things we need to consider in a group"* (F5).

In the early stages, the students would often prioritize their own work as "important" over others which would result in frustration for the other members. For example, in a particular team, *"[One of the team members] started programming but was programming the [same] page [as the other member], [his] own page, which felt very frustrating as it felt like [the remaining two members were] doing the research or lots of presentation"* (S11). This example highlights the teams going through the storming phase of Tuckman's [45] model of group development. However, with adequate mentoring from their industry mentors and instructional team, they soon realized that it was necessary to learn to discard personal biases for the betterment of the project. One student said, *"I have a process or method that I have developed on my own and naturally think it is the best and most efficient system ever, but it's clashing with these other three or 4 [team members]. I have never worked in a group setting before where our views and opinions could differ so significantly on such a small detail, mostly fascinating than something to be concerned about. I do see what they mean and try to understand why that is truly the best solution, most of the time it is, which is really cool to see how the collaboration worked to create the most efficient solution"* (S11).

As a result of the continuous guidance on practicing DEI, soon the students started leveraging their team diversity through efficient work distribution as a student in project 1 describes, *"Being on a diverse team has positively impacted the project development, in that we can all work on different areas. [One member] did a lot of the back end this week, [Another member] electric schematics, [Another member] case design, and I data visualization"* (S11). Diversity was a prominent part of the program, and practicing inclusion in teams was constantly encouraged though training and mentorship. Hence, by the end of the program the students realized how impactful working in a diverse team can be. *"I have found working on a diverse team enjoyable. It has given me the opportunity to learn new things, as everyone is in a different discipline and has different specialties. My ability to learn from my teammates is made possible through the team culture which encourages asking questions, getting feedback from each member and offering as much assistance as possible"* (S2).

Recommendations:

- Include explicit DEI training throughout the course of the project and emphasize the benefits of working with diverse teammates.
- Be prepared to provide mentorship to students as conflict is expected from time to time.

VIII. Conclusion and Future Work

In this paper, we present a pioneering program that aims to motivate students from underrepresented backgrounds to stay and succeed in computer science and software engineering through community-engaged experiential learning. In the first cohort of our program, 24 students from diverse backgrounds divided into 6 teams and matched with community partners designed and developed a solution for a pressing societal and/or environmental problem. Over the course of four months, the students first received soft skill and technical training from the instructor team. Consecutively, they engaged with the community partners in identifying and scoping the problem before conducting weeks of prototyping and solution validation.

From this first iteration there were several key lessons learned and recommendations for subsequent years. First, **soft skills** are critical to the development of a student's confidence and competency which helps students build a network where they feel supported. A **supportive network** enables a setting where underrepresented students can succeed and realize the potential impact they can make in society through software engineering. Second, students find **autonomy** immensely empowering, however they sometimes lack the experience to strike a balance. The imbalance may create sense of uncertainty and students may get overwhelmed. So, it is necessary to keep track of their progress and guide them whenever required. Third, **experiential learning** can be challenging on both student and community partners. Both sides may experience difficulties with expectations about the project and interacting with each other. Preparing a concrete structure and training students on better communication and scope negotiation will help mitigate these challenges. Fourth, working with a diverse team could be both beneficial and challenging. In some instances, students may experience too many voices and ideas, but they benefit from a boon of diverse perspectives with more creative solutions. Facilitating **explicit DEI training** and continuous mentoring for students is paramount for teams to reap the benefits of diverse teams.

The experiences described in this paper represent the first step of our program aiming to help address diversity in computer science and software engineering. Solving the diversity problem is not a small feat and we hope that our program design, lessons learned and recommendations are useful for other universities and organizations looking to help tackle the issue in their own communities.

IX. Acknowledgements

We would like to acknowledge our sponsors, including IBM Canada Advanced Studies and Riipen. We thank all the students who participated in our program and research for their hard work, resilience, and determination. In addition, we acknowledge The Inspire Executive team for their assistance in the program execution and our study.

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