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The sustainability and social entrepreneurship fellowship: transdisciplinary and multicultural problem-based engineering education

Gordon Krauss [1,✉], Chris Rennick [2], Nadine Ibrahim [2] and Sanjeev Bedi [2]

[1] Harvey Mudd College, United States of America, [2] University of Waterloo, Canada

✉ gkrauss@hmc.edu

Abstract

The nine-week Sustainability and Social Entrepreneurship Fellowship at the University of Waterloo addressed urban habitation sustainability in London, Ontario, via a multicultural, trans-disciplinary approach. Undergraduate engineering students addressed housing and transportation environmental and social sustainability, guided by expert lectures and fieldwork. The program highlights the importance of diversity in engineering education and the need for structured cultural and educational management. Students proposed engineering solutions to sustainably improve the housing development process.

Keywords: sustainability, entrepreneurship, multi-/cross-/trans-disciplinary approaches, design education

1. Introduction

The continuous surge of urbanization has positioned cities at the fulcrum of global challenges. Today, urban habitats are not only the dwelling of over half of the global population, but are also accountable for a staggering 70% of global greenhouse gas emissions (Ribeiro, 2019) (IEA, 2021). This trajectory, juxtaposed with the economic vitality of cities, underscores the paradox of urban landscapes (World Bank Group, 2021). Their economic significance remains undeniable; however, the environmental footprint demands a transformative rethink. Adding a layer of complexity, Canada grapples with a profound housing deficit, necessitating an additional 3.5 million homes by 2030 (CMHC, 2023), far beyond the current construction pipeline.

Amidst these multi-dimensional challenges, it became evident that innovative, human-centered, and sustainable urban design solutions were required. Recognizing this urgency and the inherently interdisciplinary nature of urban challenges, a new initiative was implemented in the summer of 2023, The Sustainability and Social Entrepreneurship Fellowship (SSEF). This fellowship emerged as a collaborative effort of two institutions, the University of Waterloo in Canada and Harvey Mudd College in the United States.

Designed as a multi-week, multi-institutional pilot program, the fellowship aimed to infuse an interdisciplinary approach to sustainable urban design. It convened nine exceptional third-year engineering students from globally diverse backgrounds from five nations and five participating institutions (University of Prince Edward Island, University of Waterloo, Harvey Mudd College, Tecnologico de Monterrey, and Khalifa University). These students were awarded a unique opportunity – a nine-week internship to ideate and innovate solutions for sustainable urban futures. The international blend of participants brought a rich tapestry of cultural, academic, and engineering perspectives to the project. The challenge the students faced was clear yet complex. The City of London, Ontario had made

a commitment to address the housing shortage in line with the Province of Ontario's housing objectives as articulated in Bill 23 (Clark, 2022). The City's pledge was ambitious: facilitating the construction of 47,000 housing units by 2031. The student cohort was challenged with crafting actionable solutions to help realize this pledge in a way that was both sustainable, and kind to the population of London.

The Sustainability and Social Entrepreneurship Fellowship shares similarities and some distinctions from well-known academic partnerships in engineering design, community service, entrepreneurship, and sustainability. Exemplar programs selected for comparison include The Engine (MIT) (Gwynne, 2017), Clinic (Harvey Mudd College) (Bright, 1999), and EPICS (Purdue) (Oakes, 2022). Like EPICS work in community service within an academic program, the SSEF focuses on applying entrepreneurial engineering solutions to societal problems. However, the SSEF diverges in emphasizing an international perspective without academic credit, unlike EPICS. SSEF's approach to social entrepreneurship contrasts with The Engine's orientation on financial entrepreneurship incubation related to challenging technical problems and Clinic's industry partnership focus for professional practice, emphasizing environmental sustainability and societal impact more prominently. A distinguishing feature of SSEF is its multi-institutional and multinational framework, purposefully including global participant perspectives, helping develop cultural competence, and incorporation of diverse student training experiences in the design process.

The fellowship prioritized continuous learning and feedback. This paper describes the overarching program design, key insights from the organizing team, and invaluable reflections from the student participants. An integral component of the evaluation process was the exit interviews conducted with each student, shedding light on their experiences, learnings, and recommendations. The Sustainability and Social Entrepreneurship Fellowship is offered as one model of interdisciplinary, sustainable urban design, embracing the spirit of international, cross-cultural collaboration and innovation in engineering education.

2. Background

2.1. Urban population growth and land-use evolution

Over recent decades, the trajectory of urbanization has experienced significant accelerations, posing intricate challenges that demand innovative engineering solutions. Using the United States as an example, current estimates are that urban centers now shelter approximately 83% of the population, a substantial increase from the 64% observed in 1950 (UN, 2018). Forecasts suggest this trend will intensify, projecting 89% of the U.S. and 68% of the global populace to be urban-based by 2050 (UN, 2018). Concurrently, the spatial expansion of urbanized land has seen a 15% augmentation between 2000 and 2010. Predictive models anticipate that urban territories, which currently constitute 3% of U.S. land, will witness a twofold expansion by 2060 (Center for Sustainable Systems, 2023). Such data underscores the importance of integrating urban planning and sustainable infrastructure modules into engineering curricula.

2.2. Environmental consequences of dense urban habitats

The environmental ramifications of urban areas, particularly in relation to their emissions profile, constitute a significant area of concern. Urban centers are responsible for approximately 70% of global emissions (IPCC, 2032), making the design of eco-friendly urban infrastructure a priority. The "urban heat island effect," wherein cities exhibit elevated temperatures ranging between 1-7°F more than surrounding regions, is a direct consequence of urbanization (US EPA, 2020). This phenomenon necessitates advanced materials, energy-efficient architectural designs, and sustainable urban planning—all domains where engineering education plays a pivotal role.

2.3. Transport infrastructure and urban mobility

Urban transportation dynamics have substantially transformed over recent decades, with increases in both passenger-miles on public transit and vehicle-miles traveled. As one example of the impacts of these increases, nearly 8,000 pedestrians were killed on American roads in 2021, with vehicle speeds

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and masses being significant contributors to injury severity (CDC, 2023). These trends underscore the importance of resilient transport infrastructure designs, efficient public transit systems, and integrated mobility solutions which center the human experience. Urban centers have a great potential to play a pivotal role in reducing emissions through the adoption of more sustainable transportation practices (BTS, 2023). City authorities are confronted by challenges posed by the growth in emissions and evolving urban mobility patterns.

2.4. Engineering education: the mandate for sustainable urban development

The increasing complexities of urban environments necessitate a holistic integration of sustainable urban development principles into the engineering education paradigm (UNESCO, 2021). Cities, while being hubs of energy and resource consumption, also present unparalleled opportunities for sustainable interventions. It is crucial that future engineers be trained in the nuances of green building designs, eco-friendly transport networks, and urban greening techniques. With urban sprawl a prevailing concern, engineering curricula must include smart growth strategies to counteract the environmental degradation associated with unchecked urban expansion. The surge in urbanization and its multifaceted challenges command a comprehensive, forward-thinking approach in engineering education (UNESCO, 2021). It is imperative to align academic experience with the evolving urban landscape, ensuring that upcoming engineers are adeptly equipped to foster sustainable, efficient, and resilient urban habitats. The benefits of trans-disciplinary engineering problem-based learning is critical for students to appreciate the complexity of problems for cities and similar systems of systems requiring environmental and societal considerations as well as contributions of politicians, urban planners, sociologists and engineers from other disciplines.

2.5. Evolution of the Canadian housing crisis

The Canadian housing market faces severe affordability issues, with home costs consuming 50% of the median household's budget and being historically high, especially for young Canadians (RBC, 2022). The demand for rentals has spiked increasing rental costs, further challenging savings for home purchases. Addressing this requires federal, provincial, and municipal coordination, weighing the economic and community impacts of their policies. Solutions like increasing housing supply are needed but must be carefully managed to avoid harming existing homeowners through rapid price declines or loan value disparities. Alternatively, raising interest rates could curb inflation but risk financial strain on homeowners with rate-reset loans. Predictions suggest that without intervention, housing prices could plummet, risking a financial crisis (Punwasi, 2022). The government's strategy involves delicate decisions between boosting supply, adjusting interest rates, and ensuring economic stability, all while considering the broader implications of development on communities, sustainability, and the economy. This background provides a broad overview of the complex, multifaceted challenges and transformations the Canadian housing market has encountered, emphasizing the need for judicious policy interventions and market insights. More pressing, however, is the need for additional homes in these communities. This critical need is also an opportunity to reimagine and redefine growth from an emergency reactionary perspective to one of sustainable development. Design approaches may inform policymakers with solution opportunities that are beneficial holistically. Extension of the SSEF in whole or part outside of the specific example of sustainable housing in Canada could be achieved dependent upon identification of a similarly complex problem aligned with the skills and interests of faculty and other participants.

2.6. Design methodologies in engineering education: analyzing constraints and operational considerations

The integration and emphasis on various engineering design methodologies stand as pivotal components for the development of proficient and innovative engineers. A methodical examination of pedagogical frameworks elucidates the challenges and constraints associated with assimilating a myriad of design methodologies (NAE, 2018). These challenges arise due to factors such as limited curriculum

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bandwidth, resource allocation, faculty specialization, and the mandate to interweave foundational educational constructs like teamwork, ethics, and communication into the design pedagogy.

A defining characteristic of design education is its inherent resource-intensive nature. Distinct from conventional lecture-oriented modules, design-centric courses necessitate a relatively higher faculty-to-student ratio to ensure optimal pedagogical outcomes (NAE, 2014). The granular and nuanced nature of design problems demands an augmented level of faculty engagement, thereby emphasizing the need for increased human and infrastructural resources dedicated to such courses.

The tangible dimension of design education, which often progresses from theoretical frameworks to real-world prototyping and applications, further amplifies the resource implications. Engaging in projects that transcend mere conceptual boundaries and materialize into tangible outputs entails substantial financial outlays related to materials, fabrication, testing, and ancillary components (NAE, 2018). This is challenging in civil engineering where the design and development of prototypes can be challenging to construct and some user interactions can be impossible to predict prior to construction.

Such financial commitments, though essential for comprehensive design education, strain institutional budgets. Additionally, the multifaceted nature of design education necessitates the incorporation of broader educational principles, including teamwork, ethics, sustainability, and effective communication (NAE, 2004). The diversity of design methodologies presents complexity, requiring faculty with specialized experiential knowledge (Meyer & Norman, 2020). However, accommodating various design methodologies poses pragmatic challenges related to resource allocation, faculty expertise, and institutional priorities. While it's impractical to train students in all methodologies, leveraging diverse student backgrounds can facilitate the selection of appropriate design tools. The collective training in the topics prior to project selection along with a high level of access to subject matter experts somewhat mitigated the concerns on team member selection with respect to training and participation in multi-disciplinary teams (Cascini, 2017).

3. The SSEF: an international interdisciplinary approach to engineering education and problem solving in urban sustainability

3.1. Fellowship structure

The Sustainability and Social Entrepreneurship Fellowship was a meticulously planned and thoughtfully executed program that spanned nine weeks from June 5 to August 4, 2023. The program incorporated a diverse range of speakers from a wide range of disciplines including Systems Design Engineering, Architectural Engineering, Chemical Engineering, Civil Engineering, Knowledge Integration, Geography and Environmental Management, Peace and Conflict Studies, Mechanical Engineering, and Sustainable Design Engineering who were experts in various aspects of sustainable urban development, design, leadership, and communication. This comprehensive program was designed to provide students with a multifaceted learning experience, and each week was carefully curated to achieve specific educational objectives.

The project was structured into four phases, each encompassing a 2 week-long focus on aspects of urban engineering and sustainability. These phases roughly mapped onto the double-diamond process of Discover, Define, Develop, and Deliver. These were led by expert instructors and featured a broad set of relevant topics. Following these four phases of activity, student teams presented their work during the ninth week of the project.

3.1.1. Phase 1 - Discover: introduction and orientation

The project orientation involved all team members in person or remotely. Specific topics of instruction in the first week included introduction to sustainability, design expertise, climate change, sustainable cities, user needs, life cycle assessment, and energy. As learning outcomes, students will understand the basics of sustainable urban design. This week was instructed via daily technical stream roundtables with consultants like Chris Rennick, Sanjeev Bedi, Gordon Krauss, Nadine Ibrahim, and Kumaraswamy Ponnambalam. Specific highlights included Chris Rennick and Grant McSorley (online) setting the project's creative tone through design process discussion. Kelly Scherr's session on Introduction to

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Sustainable Cities provided a practical perspective. Amy Hsiao's online session introduced material life cycle assessment and information on energy, society, and the environment. Discussions led by Sanjeev Bedi and Gerry Schneider further enriched this foundational phase. The deliverables for the first week was an end of week reflection on the topics of this week.

Specific topics of instruction in the second week included focuses on sustainability, climate modeling in Matlab, municipal governance, renewable energy, energy efficiency, urban engineering, systems modelling and discussions on Bill 23. As learning outcomes, students will apply knowledge in climate modelling and understand the relevant municipal governance. Nadine Ibrahim's sessions on sustainability, Kumaraswamy Ponnambalam's exploration of Matlab for climate modelling, and Kelly Scherr's online session on Governance and Communications provided a multidisciplinary understanding of urban challenges. Vanessa Schweizer's insights into renewable energy and energy efficiency, along with discussions on Map the System and Bill 23, facilitated by Adriana Ceric and Paul Heidebrecht, addressed practical and political applications. Scott Mathers' Turkstra Talk and Gerry Schneider's discussions provided additional diverse perspectives. The deliverables for the first week was an end of week reflection on the topics of the week and a research presentation.

3.1.2. Phase 2 - Define: real-world exposure and problem selection

Week three had an emphasis on practical learning through field visits, offering students firsthand experience in urban infrastructure management, and additional practical considerations. Specific topics covered in week three included field trips to understand wastewater treatment, transportation, and solid waste management. Visits to the City of London, Toronto, and Waterloo Region, led by Kelly Scherr, Derek Rayside, and Linda Churchill, respectively, highlighted critical areas like water, transportation, energy, and waste management. As learning outcomes, students will deepen their practical knowledge of urban engineering for sustainability through practical exposure to real-world operations. The deliverables for the third week were an end of week reflection on the topics related to sustainable use of water in urban environments.

In week four**, d**iscussions and lectures were led by Mary Wells, Nadine Ibrahim, and Gordon Krauss. Virtual sessions by Kelly Scherr, and discussions by Nasser Abukhdeir, added depth to the learning experience. The week also included sessions with Andrea Atkins on sustainable building science, and Sarah Burch discussed the intergovernmental panel on climate change (IPCC). Student learning outcomes were developing knowledge about and understanding of sustainable building and urban farming. The deliverables for the fourth week included a reflection on sustainable building and a set of mind maps on the sustainable urban living experience. The end of week four was also a significant milestone for the students as they selected their specific area of project focus and the makeup of their teams for the remainder of the program.

3.1.3. Phase 3 - Develop: design, collaboration, and advanced learning

Lecture topics covered in week five included systems modelling, and advanced topics like agent-based models by Rodrigo Costa, and economics of design by Tom Lee. Phase 3 had the students focus on refining their chosen problem and begin researching ways of addressing them. Student learning outcomes for week five included understanding of agent-based modelling and sustainability economics. The week five deliverable was a reflection on agent-based modelling and sustainability economics applications toward their projects. This was the last week with formal presentations as the organizers shifted to more of a mentoring role with the students. Nadine Ibrahim, Kumaraswamy Ponnambalam, and Derek Rayside each took on the role of mentor for one of the three student teams. Kelly Scherr's virtual sessions provided ongoing feedback and evaluation, crucial for the project's advancement and ensuring the students stayed connected to the realities in London.

3.1.4. Phase 4 - Deliver: final presentations

The final phase focussed on preparing the culminating activities. Week six was a transitional week with a focus on how to communicate municipal construction proposals and conclusions to stakeholders and high functioning team behaviours. Student learning outcomes included improved team collaboration and stakeholder communication. The end of week deliverables were an end of week reflection and team

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health assessment. By the end of week eight, students were requested to have a poster which summarized their project, as well as a 20-minute presentation for London city staff. To help students prepare for the final presentations, week seven included interim presentations by the students showcasing the progress of their projects, under the guidance of the three team mentors, Chris Rennick, and Kelly Scherr. Week eight had no scheduled activities, but the team mentors and Kelly Scherr were available to consult with the student teams. On Monday of week nine, the students, team mentors, and organizers travelled to London to present the projects in person to city staff, including the Deputy Mayor. The week also included a showcase of ideas in Waterloo, further demonstrating the impact and innovative solutions generated by the fellowship for internal stakeholders. Expert topic presenters from the beginning of the fellowship were invited to see project outcomes from the students. Lastly, fellowship organizers conducted exit interviews with each participating student, providing valuable feedback and insights.
In conclusion, the Sustainability and Social Entrepreneurship Fellowship provided students with a comprehensive and immersive educational experience. The program was carefully structured to incorporate a wide range of expert perspectives, practical experiences, and collaborative learning opportunities, equipping students with the knowledge and skills needed to address the complex challenges of sustainable urban development effectively.

3.2. Fellowship proposals

The Sustainability and Social Entrepreneurship Fellowship culminated in the presentation of solutions generated by three diverse teams of three students from different institutions, each addressing critical aspects of sustainable urban development. The program not only facilitated an enriched learning experience for the participating students but also contributed valuable insights and novel approaches to the City of London's housing and sustainability objectives. In this section, we outline the distinctive contributions made by each team and the reception of their proposals by the city representatives.

3.2.1. Team 1 - Sustainable Development in London Using Local Climate Zones (climate-oriented solution)

Team 1 tackled the challenge of London's expansion while minimizing the adverse effects of flooding and urban heat islands. They employed Local Climate Zones (LCZs) to identify specific issues and opportunities for sustainable housing growth. Using temperature and satellite data, their proposal aimed to protect vulnerable populations through informed zoning regulations. Their actions would likely result in a reduction in the urban heat island effect by converting impervious surfaces and mitigating stormwater runoff through the implementation of permeable pavements. Additionally, it could lead to a decrease in energy consumption and health risks associated with urban heat islands.

3.2.2. Team 2 - Growing & Greening: Enriching the City of London Using Rooftop Gardens (green space-oriented solution)

Team 2 proposed the integration of green roofs in London to enhance stormwater management, community cohesion, food security, energy efficiency, and ecological diversity. They emphasized the compatibility and benefits of different green roof types and provided numerical predictions for a larger scale of 15 buildings. These predictions include stormwater collection of approximately 6.5 million liters annually, waste diversion of about 70 thousand kg per year, an expansion of greenspace by 8.8 thousand square meters, carbon sequestration of roughly 2,562 kg of carbon annually, and energy conservation amounting to approximately 1,112 GJ annually for the 15 buildings. Their approach aligns with London's sustainable urban development goals and offers concrete quantitative benefits for the city.

3.2.3. Team 3 - Transit & Living for a Kind and Sustainable London (mobility-oriented solution)

Team 3 presented a comprehensive range of transportation solutions for London to address the challenges posed by population growth, car ownership rates, and traffic congestion. While specific numerical data was not provided in their report, their proposal encompassed a holistic view of potential solutions, including transportation infrastructure improvements, enhancements in public transit, and the

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promotion of sustainable transportation options. Their approach demonstrated a commitment to exploring diverse solutions to London's transportation challenges and aligned with the city's goals for sustainable urban development and improved transportation systems. Although the report lacked specific numerical predictions, it offered a wide spectrum of potential solutions for consideration.

The city representatives found the team's approach valuable in terms of understanding the diverse transportation challenges faced by the city. However, they also noted that further specificity in terms of recommended actions and quantified impact would enhance the applicability of the proposed solutions.

Faculty Perspectives and Engagement: Faculty members closely observed the teams' presence in the research space and their interactions with stakeholders, mirroring the city's response to the novelty and utility of the concepts presented. The faculty noted that the teams demonstrated creativity, innovation, and a strong commitment to addressing sustainability challenges from an interdisciplinary standpoint. The city representatives appreciated the collaborative spirit and in-depth research undertaken by the student teams. They expressed optimism about the potential applicability of the proposed solutions in shaping the city's future sustainable urban development initiatives.

The Sustainability and Social Entrepreneurship Fellowship fostered the development of well-rounded engineers equipped to confront the multifaceted challenges of sustainable urban development. The contributions of each team were met with enthusiasm by the city, with a recognition of their innovative and evidence-based approaches. This collaborative endeavor exemplified the potential for interdisciplinary education to drive impactful solutions in the realm of urban sustainability.

4. Future work: enhancing the sustainability and social entrepreneurship fellowship

The Sustainability and Social Entrepreneurship Fellowship has established a flexible platform for interdisciplinary engineering education within the domain of urban sustainability. Feedback from fellows, faculty and program organizers was collected. In the pursuit of program improvement and evolution, several strategic considerations from this feedback warrant attention:

1. Faculty Articulation of Team Expectations: The open and ill-defined nature of this engineering design project resulted in struggles for some teams. They were not always sure what information from the broad training they received should be included in their analysis or how to identify the topics they should address. Increased clarity of expectations and project milestones will help improve team performance in this respect.

2. Proactive Consideration of Cultural Differences: With the program's continued global reach and the subsequent influx of students from diverse cultural backgrounds, proactively addressing and celebrating these variations is imperative. Global cultural training, integrated into the program's curriculum, can promote inclusivity and cultivate an environment conducive to constructive interdisciplinary collaboration. Providing informal time for participant socialization is also important.

3. Program Expansion: Expanding the program's scope to encompass a broader network of institutions and countries represents a logical progression. This expansion would harness a more extensive spectrum of perspectives, training philosophy, and expertise, enabling the program to include more tools to address multifaceted global sustainability challenges.

4. Pre-Arrival Training and Evaluation: The introduction of pre-arrival training and evaluation utilizing online resources can serve as a preparatory mechanism. This anticipatory approach ensures that incoming students possess foundational knowledge aligned with the program's thematic areas, thus enabling a more expeditious transition into in-depth interdisciplinary problem-solving endeavours.

5. Clearly Defined Deliverables and Milestones: Facilitating a structured framework with explicitly delineated deliverables and milestones is pivotal. This framework empowers student teams to methodically track their progress, culminating in well-defined, attainable solutions within the program's temporal confines.

6. Sustainable Financial Model: A sustainable financial model is fundamental to ensuring the program's longevity and continued effectiveness. Identifying a diverse array of funding sources, encompassing partnerships with governmental entities, private industries, and philanthropic foundations, is paramount for securing the requisite resources to facilitate program expansion and sustainability.

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7. Extended Engagement and Synthesis Time: Allocating additional time for student teams to engage more comprehensively with content synthesis and stakeholder interaction is integral. This extended engagement period amplifies the depth and quality of problem analysis and solution generation, ultimately leading to more potent outcomes.

Incorporating these future work considerations aligns with the program's commitment to ongoing refinement and evolution. By addressing faculty engagement, cultural diversity, program expansion, pre-arrival training, deliverables, financial sustainability, and extended engagement time, the program can continue to empower engineering students as drivers of meaningful change in the realm of global urban sustainability.

Additionally, given the different preparation and emphasis of the students' programs across topics such as systems thinking, design thinking, and entrepreneurial skill set and mind set, it is challenging to reflect on the educational development of students collectively or the impact of these topics on the different projects. However, authors observed that design thinking tools played a significant role in defining the current and desired states of sustainable housing with respect to user and stakeholder needs. Moreover, interviewing and observation skills which are closely tied to design thinking helped inform team project selection. Students evaluated projects considering multiple systems inputs and quantify impact to differing degrees. Modelling of impacts of systems is one area the organizers wish to emphasize further in future iterations. Project selection was also informed through value propositions where society and the environment were considered to be customer segments rather than considering customer segments to consist of users or stakeholders exclusively. This approach was especially challenging for students without an entrepreneurship background and will be further scaffolded in future iterations. The authors observed a deep interest in characterizing environmental and societal sustainability through entrepreneurial and other tools to model impact. Notably, quantitative balancing of financial, societal, and environmental costs and benefits proved challenging in an entrepreneurship context.

Qualitative feedback from SSEF fellows in open ended interviews emphasizes a rich learning experience in multicultural collaboration, emphasizing the development of empathy, communication skills, and the ability to integrate diverse backgrounds into problem-solving. Participants highlighted the growth of presentation and teamwork skills, alongside adapting to language differences and incorporating personal and cultural perspectives to enrich project discussions. This environment allowed for sharing and applying solutions from their home countries to address challenges in a Canadian context, fostering a unique exchange of ideas and mutual learning among peers.

5. Conclusions

This study outlines an immersive, multicultural design initiative focused on addressing a Canadian Engineering Grand Challenge, tailored for undergraduate students with diverse engineering design methodology training. Teams were formed to explore and address urban housing development needs amid an existing housing crisis, emphasizing sustainable development. These teams entrepreneurially identified and addressed high-impact problems within the program's timeframe, resulting in proposals that brought significant sustainable development opportunities to the attention of city officials. This endeavor was robustly supported by the University of Waterloo's Faculty of Engineering in collaboration with the City of London, Ontario, Canada. Such project-based learning, with substantial faculty involvement and resource commitment, represents a unique opportunity to evaluate the impact of targeted training and design-focused activities for multicultural student teams.

The cultural and educational backgrounds of the students played a crucial role in their approach to problem-solving and team dynamics. While all teams grappled with a range of environmental issues related to housing, they prioritized those with the greatest perceived impact. The diversity in training and cultural perspectives was both a strength, fostering innovative solutions, and a challenge, particularly in terms of team behavior, mutual expectations, and feedback mechanisms. The varied cultural attitudes towards team collaboration and communication influenced team formation, project management, and the overall workflow. Some teams gravitated towards a more hierarchical structure, while others preferred a collaborative approach, reflecting their cultural norms and educational experiences. The SSEF demonstrated the benefits of a multicultural, interdisciplinary approach to

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problem-solving in engineering education. However, it also highlighted the costs associated with such an approach, particularly in terms of the time and resources required to manage the diversity of perspectives and to ensure effective team functioning.

Looking ahead, the future of this fellowship and its wider dissemination hinges on improving cost efficiency and enhancing information sharing across institutions. This experience underscores the importance of developing structured strategies to better navigate cultural and educational differences, enabling productive collaboration and maximizing the desired outcomes. Implementing these strategies will not only streamline the fellowship's operations but also enrich the learning experience, preparing students for the increasingly globalized and interconnected world of engineering and design.

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References

Bright, A. a. (1999). The Harvey Mudd Engineering Clinic Past, Present, Future. .*Journal of Engineering Education, 88:* https://doi.org/10.1002/j.2168-9830.1999.tb00434.x, 189-194.

BTS. (2023). *Bureau of Transportation Statistic U.S. Vehicle Miles 2021*. Retrieved from U.S. Department of Transportation,: https://www.bts.gov/content/us-vehicle-miles

Center for Sustainable Systems. (2023). *U.S. Cities Factsheet, Pub. No. CSS09-06*. Retrieved from Center for Sustainable Systems, University of Michigan : http://css.umich.edu/factsheets/us-cities-factsheet

Centers for Disease Control and Prevention (CDC). (2023, October). *Pedestrian Safety*. Retrieved 2023, from https://www.cdc.gov/transportationsafety/pedestrian_safety/index.html

Cities and climate change. UNEP. (n.d.). Retrieved from United Nations Environment Programme: www.unep.org

Clark, S. (2022). *Legislative Business Bills.* Retrieved from Ontario Legislative Assembly: https://www.ola.org/en/legislative-business/bills/parliament-43/session-1/bill-23

CMHC. (2023, September 13). *Estimating how much housing we'll need by 2030.* Retrieved from Canada Mortgage and Housing Corporation: https://www.cmhc-schl.gc.ca/blog/2023/estimating-how-much-housing-we-need-by-2030

Gwynne, P. (2017). MIT creates an engine to accelerate startups. *Research-Technology Management, 60(3)*, 7-9.

IEA. (2021). *Internatoonal Energy Agency.* Retrieved from Empowering Cities for a Net Zero Future: https://www.iea.org/reports/empowering-cities-for-a-net-zero-future

IPCC. (2032). *Synthesis Report of the IPCC Sixth Assessment Report (AR6) Longer Report.* Retrieved from Intergovernmental Panel on Climate Change (IPCC): https://www.ipcc.ch/report/sixth-assessment-report-cycle/

Meyer, M. W., & Norman, D. (2020). Changing Design Education for the 21st Century. *She Ji: The Journal of Design, Economics, and Innovation*, *6*(1), Pages 13-49. https://doi.org/10.1016/j.sheji.2019.12.002

NAE. (2004). *The Engineer of 2020 Visions of Engineering in the New Century.* Washington, DC: The National Academies Press. https://dx.doi.org/10.17226/10999.

NAE. (2014). *Remarks at the NAE Workshop on Pathways for Engineering Talent.* . Retrieved from National Academy of Engineering: https://www.nae.edu/Projects/Continuum/nov19webcast/123918.aspx

NAE. (2018). *Understanding the Educational and Career Pathways of Engineers.:* . National Academy of Engineering. Washington, DC: The National Academies Press. https://dx.doi.org/10.17226/25284.

Oakes, W. C. (2022). Community-Engaged First Year Learning Community Paper presented at 2022 First-Year Engineering Experience. . *2022 First-Year Engineering Experience.* East Lansing, Michigan: ASEE https://peer.asee.org/42220.

Punwasi, S. (2022, March 18). *Canadian Real Estate Prices Expected To Drop 24%, Can Crash 40%: Oxford Economics.* Retrieved from Better Dwelling: https://betterdwelling.com/canadian-real-estate-prices-expected-to-drop-24-can-crash-40-oxford-economics/

RBC. (2022, March). *Housing Trends and Affordability*. *RBC.* Retrieved from RBC Economics Research.: thoughtleadership.rbc.com

Ribeiro, H. R. (2019). Effects of changing population or density on urban carbon dioxide emissions. *Nat Commun 10, 3204* , https://doi.org/10.1038/s41467-019-11184-y.

UN. (2018). *World Urbanization Prospects: The 2018 Revision*. Retrieved from United Nations Population Division (2018) : https://www.un.org/en/desa/2018-revision-world-urbanization-prospects

UNESCO. (2021). *Engineering for sustainable development: delivering on the Sustainable Development Goals.* Retrieved from UNESCO : https://www.unesco.org/reports/engineering/2021/sustainable-development

US EPA. (2020). *Learn About Heat Islands.* Retrieved from U.S. Environmental Protection Agency: https://www.epa.gov/heatislands/learn-about-heat-islands

World Bank Group. (2021, April 22). *Advancing Climate Action through an Urban Lens.* . Retrieved from World Bank Group: www.worldbank.org

worldbank.org. (n.d.). Retrieved from World Bank Group Urban Development Overview.: Retrieved from www.worldbank.org.

https://doi.org/10.1017/pds.2024.293 Published online by Cambridge University Press