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How Diversifying / Updating the Teaching Team Has Positively Affected Teaching

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How Diversifying / Updating the Teaching Team has Positively Affected Teaching

Introduction

Diversity is a key concern for universities, especially in the engineering field. North American universities have been recently pushing for diversity, equity, and inclusion in their education system. The University of Waterloo has diversified the teaching teams in one of its engineering departments by increasing the number of instructors who are women and women of color. This paper examines the difference in teaching and student learning outcomes when this department replaced the teaching team for two courses from Caucasian men to women and women of color with no instructions on how to deliver the courses. It was noted that women professors draw from their work experiences and bring a hands-on learning and a project-based approach. This change was noted in the department of Civil and Environmental Engineering because previously when the courses were taught by men, the course delivery remained consistent with a traditional lecture-based approach. It is important to note that instructors are not given a guide on delivery and examination method when assigned a course to teach. Rather, they are given a course outline with key fundamentals that must be taught in each course. The delivery is designed entirely by the instructor due to academic freedom. The women professors introduced interactive learning and community projects by choosing to take the initiative to redesign the courses. The changes were made in the Architectural (AE) and Civil Engineering (CIVE) programs focusing on the studio and mechanics courses. The AE program focuses on building science and design, bridging architectural concepts and structural engineering meanwhile the CIVE program focuses on infrastructure projects ranging from structures to transportation and water systems. These two programs overlap in their courses and share the same learning outcomes in the first- and second-year mechanics courses. This paper shares in detail the methods in which the mechanics courses were redesigned and the influence of a women teaching team on the students. End-of-term course evaluations were used to assess the success of the projects as well as enhance future courses. This paper aims to investigate and comment through multiple cases, the ways in which the diversification of a teaching team at the University of Waterloo in an undergraduate engineering classroom affects both the delivery of the course material and students' perception of learning.

Background

Research has found that the lack of diversity in science, technology, engineering and math (STEM) is due to the historical and demographic foundations that are not inclusive to women and people of color that these fields were built upon. In their research, Lee et al. [1] and Blackwell et al. [2] both discuss how these factors continue to contribute to the underrepresentation of women and people of color in the STEM industry. This is attributed to the "leaky pipeline" phenomenon where women lose interest in engineering as their career progresses due to continuous barriers such discrimination, inequitable resources and opportunities [2]. This further contributes to the loss of interest in STEM as young women and people of color achieve new milestones in their careers. Fixing the "leaks" in this pipeline, starting with addressing the dysfunctions in educational systems, will help with student retention in engineering classrooms. Hence, diversifying the workforce results in a career path that is not rooted in the current patriarchal norms [3].

In a post-secondary engineering faculty, that would mean the diversification of both faculty and the student body to include more women and people of color. Creating a more inclusive environment that stems from gender, race and ethnic diversity allows for new experiences and knowledge to be introduced [3]. Nielsen et al. highlight how gender diversity contributes to team dynamics by enhancing creativity, decision making, and problem solving when compared to all-men research teams. This is largely due to the ability of women to recognize their team members' expertise as well as their high level of social perceptiveness, resulting in an increase of participation and a decrease in biases amongst team members [4]. Women working in teams also demonstrate higher interactive and co-operative work styles that improve a team's overall processes and management skills. Garcia et al. [5]and Ostergaard et al. [6] found an increase in diverse knowledge and perspectives that originated from different career paths due to the composition of gender-diverse teams.

Some studies also consider that diversity could create discomfort in teams because social identity predicts that the difference in knowledge, and experience can make communication difficult and increase competitiveness [6]. This may be reflected in negative team outcomes that can increase rifts in teams due to gender and raced-based divisions [7]. Milliken and Martins argue that the increase of marginalized people in a team can help eliminate those challenges and decrease perceived discrimination and identity problems while increasing job satisfaction [8]. Thus, making the diversification of teams important not only for equity but also for creating safe spaces that allow for new knowledge and experiences to be explored.

This theory holds true in engineering classrooms as well where the increase of women as faculty is introducing new teaching methods as well as new experiences to reflect upon. Professor Lorraine from Howard University argues that despite the increase of STEM women graduates, many women will not pursue careers in STEM unless they had women mentorship during their undergraduate and graduate experience [3]. The need to diversify engineering faculty to create a holistic "global engineer", is best highlighted in the book Educating the Engineer of 2020 that was published in 2005:

> Student demographics, with greater diversity from the perspective of academic preparation, career aspirations, and ethnic background that require approaches to learning, teaching, and research designed intentionally to respect (and celebrate) this diversity [9].

Based on the literature, when discussing the addition of women to faculty, the course designs changed to include interdisciplinary work and mentorship [3]. Engineering education has developed an expected format for many courses, often founded on course notes or a textbook, supported by lectures, assigned problem sets, and exams or tests. These teaching methods in Western education were created by Caucasian men, both in terms of content of the course and the methodology of teaching that they saw suited their student body at the time. This traditional way of teaching has given us decades of successful engineers in industry, and so there is inherent value in this method. However, the classroom demographics in engineering education have changed from the relatively mono-cultured nature of generations before. The environment in which engineering is taught must become inclusive of women and students of color to avoid the perpetuating a culture of exclusion that is rooted in the “traditional” teaching method.

As the engineering profession diversifies, the teaching styles need to diversify along with it. Lewis states that the engineering profession is especially biased towards men. Men teach as if they are the holder of information, and are transmitting it to students, whereas women think students should define their own learning experiences. This includes but is not limited to questions, evaluations of success and teaching styles [10]. Women are also more likely to invest time into planning their courses and designing active learning opportunities which allow students to participate and engage in the course material and prioritize higher order thinking skills [11]. This is further highlighted by Laird, Garver, & Niskodé [10], where they found that women and multiracial professors spent an average of 10% less time lecturing than their Caucasian men counterparts, and women and faculty of color spent more time on active classroom practices [11]. These active classroom practices break the routine of lecture and reduce student saturation, but they are also beneficial to student engagement and motivation. Identifying where engineering courses can diversify their style of teaching and reintegrate social context can enhance student engagement and motivation as well as improve the engineering profession. Tremblay-Wragg, Raby, Ménard, and Plante also support these findings [11].

Based on the literature reviewed, including women in engineering education is necessary to create career paths that are inclusive. When women engage with engineering education, new knowledge and teaching methods are introduced that allow marginalized students to connect with the field and enhance knowledge retainment. The women in the Civil and Environmental Engineering faculty at the University of Waterloo have made significant changes to their courses drawing from experiences that contribute to these findings. The following sections explore the impact these changes had on the students and the new perspectives that enriched the pedagogy.

An Overview of Course Changes

The AE and CIVE programs in first and second year require the completion of mechanics courses as well as studio courses for the AE program. The mechanics courses for these two programs share identical learning outcomes. Usually, these courses are referred to as AE 104, CIVE 105, CIVE 204 and CIVE 205, where the first number references the year-level of the student cohort, while the remaining numbers refer to the sequence of the course (i.e. 4 is followed by 5). The first AE studio course is referred to as AE 100, to identify that it is a first-year studio course. This nomenclature is used throughout the paper to discuss the changes in each course.

Prior to the assignment of the women professors, the four AE and CIVE mechanics courses were taught using PDF skeleton notes. Students were required to complete the course notes during the lecture period. The students’ knowledge was then tested with a combination of homework assignments, quizzes, midterm examinations, and final examinations. After the women instructors redesigned the courses, several changes were implemented into the course syllabi These changes included hands-on activities and community-based projects to enhance the student’s engagement and knowledge application in the courses. Similarly, The AE 100 studio was handed off to a teaching team of women, which resulted in a shift in the course to focus on end-users and the importance of designing buildings for occupants. These changes can be categorized into three types: Experimental and Demonstrative, End-Users and Social Impact, and Design Project.

Experimental and Demonstrative

The first way in which the courses were updated was by implementing hands-on activities in AE/CIVE 104 and 105. These activities included the analysis of a gothic cathedral, suspension bridges, dams and retaining walls, silos and culverts, arches. In previous versions of CIVE 104, the first-year engineering students were required to complete course notes and report on the lab activities. The woman instructor changed the reporting method to an interactive activity, where students were required to report on these activities by presenting and teaching simple mechanics concepts to middle school students. Students still used hands-on activities in their lesson plans with the middle school students. However, they had to simplify the concepts for the younger students to understand. Students also had to be creative in their lesson plans and produce ways for the younger students to feel the forces and be able to reflect on the benefits of these structures in their community and to society [12]. It is understood from the literature [13] that retention of women in engineering programs increases when they can directly see the impact of the program. This activity gave students' projects value beyond learning in a classroom. This activity was in line with a study completed by Davis and Finelli, where they noted that program retention for women and students of color increases when there is an opportunity to apply their skills in a social setting [13].

The subsequent course, AE/CIVE 105, went through multiple updates that required engineering students' participation. The first iteration included the addition of pre-designed hands-on activities that focused on trusses and hydrostatic loads, allowing the students to better understand the concepts of the course, while also allowing them to learn from hands-on experimentation and report their findings [14]. Similarly in AE/CIVE 204, hands-on activities were introduced that explained concepts in 3-D equilibrium, 3-D moment, beam bending, torsion, and deflection. These activities included simple models and demonstrations to allow students to directly see how different forces can impact a structure. It was evident in the course evaluations that students appreciated the hands-on activities, and they highlighted that the models contributed to their understanding of the concepts. Comments from students in AE/ CIVE 104, 105 and 204 regarding the hands-on activities included:

> I really enjoy the visual representation of concepts explained with tangible tools so we can see concepts in action.
>
> The use of the models during lectures in order to describe certain engineering concepts (i.e Beams, Arches, etc.) is a really good way to describe the different forces.
>
> I like how she shows us real examples of all the concepts by demonstrating it herself with materials. It allows us to see how this can apply in the real world and solidifies our learning.

The end of term course evaluations also showed that students were more engaged and found an interest in mechanics outside the classroom. This was especially noted in the first-year courses where students gained an appreciation and understood the importance of concepts in real world applications.

End-Users and Social Impact

The second iteration of changes for the AE/CIVE 105, included the addition of a community project in which the students had to design a playground for a local elementary school and go through an iterative design process. First, the students met with the end users, elementary school students, and took their ideas for what to include in the playground while abiding by the recommendations from the facility officer and the CSA standards. Second, they performed preliminary designs to show and discuss with the elementary school students on their second school visit. Third, from the forty groups of university students, forty designs were presented to the school principal, parent council and the head of the facilities from the region to select the best ten designs. Fourth, the best ten designs were selected and presented to the kids at the school assembly, where the kids got to vote on their top three designs. Finally, the top three designs then each submitted a poster that was presented in the school fun fair for all members of the community to vote on their favorite design. The top design was then built a year later, with some students attending the opening of the playground as they felt engaged with the project. Through this process, students were able to apply mechanics concepts they learned in class through analyzing various playground structures.

The addition of this project to the course introduced the engineering design process, the impact of end-user feedback and challenges accommodating end-user request while considering safety. It was evident throughout the project that community engagement motivated students and added value to designs beyond the classroom learning experience. This is because students were able to directly see the effects of their designs on the end users. The project also included multiple presentation components where groups were required to present their designs and highlight how meeting with the end-users influenced their design as well as discuss limitations that were influenced by the CSA guidelines. This project was significant for the CIVE students as it was their first project with iterative design and end-user engagement. The end of course surveys reflected that the students enjoyed the engineering design process and found it beneficial to their overall engineering learning:

> The playground project was an excellent and very motivating project. I believe this project contributed exceptionally to the content learned in class.
>
> The playground project was excellent. Not with respect to the application of mechanics, but for the experience of going through an engineering project. It was fun, and great to design something that may be built.

> The playground project is a good opportunity to improve the understanding of the material. Truss activity and fluid statics activities were very helpful and fun to participate

The success of projects that include end-users and social impact can be further examined in the AE 100 studio course. The AE 100 studio course contains many fundamental elements of engineering education that are non-negotiable learning outcomes. The primary deliverables of this course are a series of team design projects, which have remained consistent in format with the all-women teaching team. However, the teaching methods and design focus have been shifted towards a more universal approach, and away from a more traditional style of teaching and learning. For example, in the past, a guided tour of the campus was used to teach students about the buildings around us: how to identify different materials, standard names of building components, and often the visible failures of these components. This guided tour was initially completed by a course instructor, in person, over many hours of the day. During the Virtual Learning period, this tour became recorded videos, which no longer allowed students to touch or approach the building themselves. In the current women-dominant teaching team, the tour is a self-directed audio guide where students are encouraged to listen to the recording but are verbally guided to approach the building and prompted by questions about what they think of the materials. This new format allowed students to take a more personal approach to their learning. The content of the recording still contained nomenclature information, but also pointed out issues of universal design and access, and asked questions about user experience while the students were interacting with the public spaces. The goal of this assignment pivoted from only identifying building materials and differentiating building enclosure types to emphasizing the user’s experience with a building’s design as well as the interests and concerns of various stakeholders. The integration of a teaching team of women in the first-year engineering courses allowed for the addition of community-based learning, where students were able to associate their design decisions with people and clients further emphasizing the impact of their designs.

In addition to the Universal Design content within the audio-tour, the all-women teaching team embedded aspects of equity and user-centered design in all design projects over the course of the term. Students were introduced to topics such as human-centered design and universal design in lectures throughout the term, and then were encouraged to think more critically about the topics. For example, how their design may or may not be accessible to different user groups. The primary example of this was in a project where students were tasked with designing outdoor furniture to be used by visitors on campus. The women professors delivered a lecture on universal design, and why an average European man’s body shape that had been historically used as a standard measure was not representative of all or even most users. The students then received multiple critique sessions from an all-women teaching team and found that student designs were broadly inclusive in nature and showed consideration for users of different sizes or physical abilities. This perspective introduced by the teaching team challenged hegemonic ways of thinking in the hopes that when entering the work force students can create inherently more accessible and inclusive designs, contributing to a more accessible and inclusive society in return.

Additionally, at the direction of the all-women teaching team, more of the assessments were integrated into a consistent learning narrative which was explicitly shared with the students. By showing the students how the small assessments of different skills are related to each other and will feed into improved performance in future assessments, students were more capable of appreciating the value in even the smallest assignment. At the end of the term, the teaching team once again drew the students' attention to the path of learning that they had travelled, reminding them that although there were many small assessments over the term, the final learning outcomes were achieved. This shift was necessary because the format of the Fall 2022 course required many discrete learning outcomes to be fit into the term, including report writing, hand drafting principles, computer-aided drafting, the iterative design process, and presentation skills. In years past, few of the assessments were connected to each other, though the order of delivery was designed to scaffold the skill development as the term advanced.

Interestingly the student feedback from the end of term course evaluation highlighted the benefits of continuous critiques and feedback on their projects. When asked, " What helped them learn best?" The consensus was that the studio critiques were helpful to progress their designs as well as further their understanding of building enclosure and structural concepts.

Design Projects

The second-year courses were further developed by implementing a final transdisciplinary design project that integrated multiple courses. In CIVE 204, the students were tasked with designing a road that would connect two points on a topographic map. The road would include a bridge that would pass over a river at a site of the students' choice. This allowed for diverse designs as the bridge dimensions would change depending on where the students chose to build the road. In addition to applying simple mechanics concepts to design the bridge, students were required to implement analytical skills from their probability and statistics, and transportation principles courses to complete a wholistic design. Models of the bridges were then built and tested. This project provided students the opportunity to see the connection between their courses and real-world applications. Students were able to realize that courses do not work in silos and how what they learn applies to real world examples [15]. Similarly, the AE students in the 205 mechanics course were tasked with designing a pedestrian bridge in a location which the students knew and used on a regular basis. They had to make design decisions, and then work to structurally analyze and design the components of the bridge to fit the design decisions they made previously. The direct application of the course materials in a more creative project allowed students to feel engaged in their structural analysis and less as if it was being forced upon them. Additionally, students came to understand the effect that their aesthetic decisions had on structural sizing and complexity of analysis.

Another design project in AE 204 was integrated with their studio course the same term. In the studio course, students were asked to design a facade for an existing residence building on campus. The students then had to use their mechanics knowledge and design a canopy for the entrance of the building that also integrated with the design of their facade. The objective was to allow them to see the feasibility of their designs. This project gave students the opportunity to practice design that is aesthetically pleasing but also structurally feasible. Thus, emphasizing that they cannot design abstractly without considering the structural integrity of their designs.

The comments from the students in the end of term evaluation highlighted that despite projects of this scale being enjoyable and beneficial to learning, they are time consuming and require a great deal of planning. This is largely because the projects required a design and build phase that was not during timed class time, while juggling other demanding course requirements. The bridge project learning outcomes were not explicitly reflected upon by the students. However, the comments consistently reflected the impact of the hands-on activities and models that were implemented in class.

Discussion

The implementation of Experimental and Demonstrative, End-Users and Social Impact, and Design Project have proven to enhance the students learning based on the student course evaluations. Adjusting the AE 204 course syllabus to include an interdisciplinary final project with the studio course that allowed the students to draw connections between their courses was proved to be highly beneficial to the students by allowing them to create connections from one course to another. discusses how it is important for engineering students to understand the social impact of their work. This emphasizes that students learn about the role that they play in improving the quality of life of all people, and not just those from the same socioeconomic background. Additionally, The AE 105 final project reflects the final project implemented by as both projects asked the students to consider the societal impacts of their design, which allowed the students to understand the impact their designs have on the real-world. These findings were consistent with studies completed by Dumshcat et al. [16] and Mills & Ayre [17]. The courses changes introduced at the University of Waterloo also align with the University of Michigan focusing on diversity and retention in engineering programs. Their conclusion demonstrated that allowing students to participate in research service learning in first year and introducing real world context not only increases diversity and retention in first year-engineering but also improved the marks of underrepresented students [13]. This emphasizes the need to continue the diverse growth of teaching teams, updating teaching and research methods to be more inclusive of women students and students of color which ultimately benefit all students regardless of gender and race.

Interestingly, the hands-on activity and models introduced in CIVE/AE 104, 105 and 204 stuck with students the most. There was an overwhelmingly positive response to the activities as students deemed them engaging resulting in a challenging course like mechanics to be more enjoyable and relatable to the real world. The changes made to these courses were not simply changing evaluation and teaching methods. It was noted in the end of term-evaluations that the students appreciated the woman professor's passion and engagement in teaching as a positive attribute that maintained student motivation throughout the term. Young et al. suggest that more women professors are viewed as positive role models than men professors, and this showed a benefit to all students [16]. Women can often act as role models to students, as they allow students to see someone 'like them' in a higher education setting, and often leads to the attraction and retention of diverse faculty and students [17]. Diverse faculties also yield more diverse ideas and solutions, and by extension, diversify the engineering profession and decreases the implicit stereotyping of science and engineering as masculine field [16]. This highlights the need to further document and investigate the perspectives of women of color that enrich pedagogical approaches of teaching that lead to experimental and inclusive learning outcomes.

Furthermore, the assignment of a diverse teaching team is at the discretion of departmental administrators, relying upon the availability, interest, and capability of faculty to teach a course. That said, even when a more diverse instructional team is assigned to teach a course, there are challenges to be overcome which may prohibit instructors from trying new teaching methods or course structures.

The first challenge to changing teaching methods and course structures is a two-pronged issue: there is an expectation and momentum towards keeping things the same as years past, as well as the large amount of work to overturn the traditional teaching methods. In each of the examples that were given in this paper, the instructor(s) invested no small amount of effort in revising the course(s) to suit their designs. The time and energy required to do these revisions is not always available to faculty who may otherwise be busy with representing a diverse presence on committees. Blackwell et al. found that women in STEM fields face challenges with additional labor, marginalized faulty tend to have higher percentages of their time allocated to services due to the demand to have more women on committees in addition to their assigned tasks as faculty [18]. This adds unfair expectations and additional labor on already marginalized faculty, who are expected to mentor and be leaders in the faulty for marginalized students. Increasing diversity in the faculty would alleviate the pressure from already existing faculty from marginalized backgrounds and ensure that they are not further tokenized and expected to do more labor than their men counterparts. This will give space for women in the faculty to further contribute to their course and enhance teaching methods to be inclusive of students of color.

The second challenge associated with changing the way a course is structured or delivered lies in the risk of student perceptions. As was seen in many of the examples shown earlier in this paper, the changes made to courses were widely appreciated by students, thus instructors received positive feedback. However, the feedback is not always positive when teaching methods change, especially in student groups who often succeed in more traditionally structured classroom environments. This is consistent with the research of Vakil & Ayers which discusses the risk of diversity in teams leading to increased tension towards marginalized team members [7]. It is the risk of negative perception that may hold back instructors from making large changes to a course, especially when the instructor is early in their career and criticism may negatively impact their career advancement.

These challenges complement the limitations in this study that were largely due to the inconsistencies in the end of term course evaluations. There was an administrative change in the questions that students were required to answer which made a direct comparison in the scores of the courses challenging. Hence, the reliance upon students' comments and feedback to gain an understanding on the impact of the women teaching team and the projects on learning. Additionally, when looking at the scores relating to course satisfaction from 2016-2022 there was evident bias against women professors and professors of color. This was further investigated in a study for the Toronto Metropolitan University Faculty Association, formerly known as Ryerson University Faculty Association, stating that course evaluations are a poor method to evaluate learning as they present multiple biases [18]. Similarly, the University of Waterloo investigated student course perception and concluded that there was not enough evidence of historic bias but implemented new course evaluations that focused on course design, delivery and learning experience rather than impressions of the teaching team [19].

Future Work

The work presented in this paper is limited to only one department at one university. Due to the increasing research into issues of equity, diversity and inclusion in the STEM fields and post-secondary classrooms, it is a natural next step to expand the investigation presented here to a broader network of institutions and STEM fields. This research is intersectional, and the authors would encourage further research to collect disaggregated data from instructors of color along with women instructors. Not only does the research require a larger pool of classrooms and instructors, but also a more complete survey of students to deepen the understanding of the impact that these changes may have on student engagement as students advance through their education. Additionally, there is a need to develop a method in which these changes are documented to continuously evaluate the growth that women bring into their courses and faculty positions.

It would also be beneficial to study the long-term effects of a more diverse teaching team on the career pursuits of alumni: does the addition of a more diverse list of instructors feed into the pipeline for a more diverse professional pool?

Conclusion

Women Engineering professors bring a different skill set to engineering education, their teaching methods draw from personal experience as well as the standardized teaching and evaluation methods. Switching to a women-dominant teaching team resulted in the addition of team-focused learning, and application through the design projects. As well, a shift in focus occurred from designing for an “average man" to a more human-centered universal design through community-based projects that emphasized the end-user and social impact. As the engineering student population grows, the need to evolve the teaching methods to represent the classroom is highly needed. This paper demonstrates the successes of these changes and the positive impact they had on the students’ learning.

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