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Research Article

Perceptions of Underrepresentation Among Students in STEM Fields: An Empirical Analysis

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Abstract

Gender bias in science has been thoroughly researched and it is well known that women are underrepresented within post-secondary Science, Technology, Engineering, and Mathematics (herein STEM) programs. Limiting women's participation in science carries heavy consequences for both the economy and scientific community. Therefore, gender inequality must be addressed with urgency. This research is focused on the following research questions: 1) are there gender differences in how students perceive the underrepresentation of women in STEM; 2) are there gender differences in student support for initiatives that could enhance gender equity in STEM? Not surprisingly, the results suggest that women consider proportionate gender representation to be more important than men (61.9% vs. 39.6%; χ^2 [2, 158]=7.05, p=0.029, Cramer's V=0.211). Further, when considering their own experiences, 20% of female respondents reported feeling underrepresented at university. These perceptions were more common among women studying STEM subjects than other subjects (33% vs. 14%; χ^2 (1, 339)=16.9, p<0.001, Cramer's V=0.22). Women expressed a greater level of support than men for many programs that would address this issue and a greater level of interest in participating in them. This interest was heightened among women who felt underrepresented. This suggests that women desire opportunities to connect with like peers through outreach and mentorship programs. These solutions require increased levels of resources, as well as the cooperation of those who do not identify as underrepresented individuals. Post-secondary institutions should consider this as they develop new ways of addressing this issue.

Keywords: Underrepresentation, Gender Bias, Students, STEM, Women

1 Introduction

Recent data has shown that although women earn a greater number of post-secondary degrees, they remain underrepresented among STEM degree earners[1]. Within Canada's prairie region, female students are less likely to major in Agriculture, Chemistry and Physics, Computer Science, Engineering, General Science and Mathematics than male students[2]. Within this region, the only STEM subject area where a greater number of female than male undergraduate students declare majors is Biology[2]. Similar findings have been documented within this subject area, across degree levels[3]. This suggests that there is generally a more equal gender distribution within biology, but also that the women earning STEM degrees remain highly concentrated within certain science subjects such as biology and are scarcely found within other disciplines[1]. For example, within the prairie region less than 15% of Engineering majors are female[2]. This is the lowest rate of female representation in any STEM discipline across all of Canada[2]. These statistics suggest that additional efforts are required to address such gender disparities across STEM subject fields.

Failure to address the gender gaps within these fields has many negative consequences for the economy and the scientific community, and therefore the underrepresentation of women in STEM is an issue which should be addressed with urgency. By ignoring the availability of female labour we inhibit the development of scientific knowledge and economic growth within the STEM industry as a whole[4]. This is particularly troubling as new STEM jobs are emerging at an increasing rate and additional labour will be required to fill these positions (Dasgupta and Stout, 2014). Although post-secondary STEM programs can play a critical role in responding to this trend by training the future workforce[2], it remains clear that these institutions have been relatively unsuccessful at closing these gaps. Women's labour is in no short supply as women make up a significant portion of both the student population within post-secondary institutions and the labour market[5]. Therefore, women should play an important role in the STEM workforce[4, 5].

Unfortunately, when women exit STEM programs the knowledge and strengths they bring to the discipline are lost[6]. Women have the ability to make valuable scientific contributions[6] and as underrepresented individuals, their experiences allow them to make unique contributions[7]. Incorporating a greater number of perspectives provides new possibilities for scientific research[7]. Therefore, efforts to increase gender representation should be viewed as a strategy for strengthening diversity within STEM and a way of developing scientific inquiry[6].

Women navigating paths towards STEM careers must complete relevant training within post-secondary institutions. Unfortunately, the climate women enter within many university STEM programs has been identified as a factor which prevents their retention and achievement[8]. Many women report that they have faced gender bias, as well as discrimination and harassment throughout their education[6]. For example, women may be prevented from accessing the same experiences within science and technology throughout their developmental years and continue to see a lack of equal opportunities for women in science throughout their academic careers, which contributes to limited experiences[5]. From an early age boys are socialized in a way that encourages them develop an interest in activities that relate to STEM, whereas girls are socialized to develop an interest in other areas[5]. Therefore, girls may not receive the same exposure to these activities that boys do[5]. For example, this may include learning about technology through video games[5].

Due to the limited number of women in STEM programs, women lack social support which may allow them to deal with adverse situations. The development of interpersonal relationships is considered to contribute to a stronger sense of belonging among STEM students[9]. Further, Rainey *et al.*[9] observed a correlation between a student's sense of belonging within their major and the number of students of that gender studying that major. For instance, male students were more likely than female students to indicate that they felt like they belonged in their STEM major[9]. Furthermore, the underrepresentation of women in STEM creates multiple barriers to establishing successful role model and mentorship relationships[6]. Many female STEM students feel they do not have female role models to look up to throughout their education[4, 6]. This would suggest that women in STEM require additional ways of networking with like peers and role models[4].

Therefore, post-secondary institutions should be interested in taking steps to address unsatisfactory program climates and feelings of underrepresentation among students as this could enhance the quality of the learning environments within the institution. In response to the issue of women's underrepresentation in STEM, many post-secondary institutions have begun to seek out and initiate strategies which encourage and support women's participation in STEM. The present study has two main objectives:

1. to identify factors that influence perceptions of underrepresentation among post-secondary students, which would include gender and program of study;
2. to assess students' interest in initiatives which create supportive networks for female STEM students.

2 Methods

Research Questions
Building on the literature, our work is guided by the following research questions: 1) Are there gender differences in how students perceive the underrepresentation of women in STEM? and 2) Are there gender differences in student support for initiatives that could enhance gender equity in STEM?

2.1 Data Collection

The method employed for this study was the was that of the University of Manitoba Student Equity Survey (UMSES)[10]. The survey addressed a great variety of themes as the overall purpose was to better understand the potential differences in university climate for students in STEM and non-STEM fields. The areas of discussion included: 1) choice to pursue current academic program; 2) anticipated career path; 3) opinion on equity programs in terms of the importance of such programs and predicted participation in such initiatives; 4) perceptions of underrepresentation at university in general and within their program; 5) incidents of discrimination and harassment experienced or witnessed; and 6) General demographic information.

This study specifically addresses opinions on equity initiatives (UMSES discussion point 3), perceptions of underrepresentation (UMSES discussion point 4), and general demographic information (UMSES discussion point 6).

2.2 Description of Variables

The measures included in the survey were designed specifically by the Principal Investigator of the umses, Jenna Rapai as part of her M.Sc. research. Her decisions were informed by a general review of the literature, public information, and personal experiences[10]

The first factor (Factor 1) pursued in analysis was gender. A crude definition of gender which allowed students to differentiate between "Female", "Male", and "Other" gender identities was pursued for statistical purposes. Due to an inadequate sample size of respondents who reported marginalized gender identities, this study cannot account for the experiences of these students. In social research, researchers are

Table 1: *Questions used to measure students' perception of their own underrepresentation in STEM (Perception 1).*

#	Perception Descriptor
1a	Do you feel underrepresented in any of the courses you take?
1b	Do you feel underrepresented in your program?

Table 2: *Common explanations of why women are underrepresented in STEM used to measure students' perceptions (Perception 2).*

#	Perception Descriptor
2a	Male students are disruptive towards female students in learning
2b	Women are more interested in arts than science
2c	Women in STEM are unfairly evaluated at a higher standard
2d	Examples in education biased to males
2e	There is a lack of female professors to act as role models
2f	Males are hostile toward women in STEM
2g	There are not enough female professors who can act as role models for female students in STEM
2h	Hiring committees consist mainly of men
2i	Policy makers consist mostly of men

Table 3: *Community building (CB) initiatives.*

#	CB Initiative Descriptor
CB 1	Outreach within elementary schools
CB 2	Outreach within high schools
CB 3	Read brochure or literature
CB 4	Voluntary workshops for faculty
CB 5	Guest speakers who are members of underrepresented groups speaking about their experiences
CB 6	Voluntary workshops for students
CB 7	Mandatory workshops for students
CB 8	Mandatory workshops for faculty
CB 9	Blogs or Twitter feeds
CB 10	Apply to a specific program to be eligible for scholarships and bursaries

Table 4: *Structural change (SC) initiatives.*

#	SC Initiative Descriptor
SC 1	More opportunities for part-time students
SC 2	Longer library hours
SC 3	Electronic library resources
SC 4	Formalized mentorship programs
SC 5	Centre providing support
SC 6	Conferences

bound by ethics protocols which require a minimum of five similar cases in order for results to be shared. Therefore, this study centers around differences between female and male experiences within the university setting.

The second factor (Factor 2) pursued in analysis was program of study. Students had the opportunity to indicate which academic faculty they were enrolled in. During data analysis the researchers differentiated the responses by "STEM program" and "non-STEM program". The "STEM program" category included the Faculties of Science, Engineering, and Agriculture.

In order to measure students' perceptions of their own underrepresentation (Perception 1, Table 1), questions were asked with options for responses of "Yes", "No", and "Sometimes". "Yes" and "Sometimes" considered indicators of perceptions of underrepresentation. In our analysis, students who answered yes to at least one of these questions are described as "feeling underrepresented". Within this study the focus is limited to examining perceptions of underrepresentation on the basis of gender identity.

In order to measure students' perceptions of the underrepresentation of women in STEM (Perception 2, Table 2), the survey questions addressed common explanations of why women are underrepresented that have been discussed across the literature on the topic. Students then expressed their level of agreement with the statement based on their perceptions of why women may be underrepresented on a likert scale as possible responses ranged from "Strongly agree" to "Strongly disagree".

The survey questions also focused on the importance of various proposed initiatives and students' predicted participation in them. These initiatives were proposed by the original authors of the survey and were based on student initiatives that could be implemented by universities at no or low cost, initiatives that could appeal to all students, and initiatives that are clearly focused on advancing women students in STEM, including initiatives that might require substantial funding.

A first set of initiatives were based on community building (CB) programs (Table 3). Students expressed how important each initiative was with their options ranging from "Very important" to "Very unimportant" and rated their predicted level of participation from "Very likely" to "Very unlikely".

The questions regarding a second set of initiatives also addressed potential changes to the organizational structure (structural changes: SC) of the institution (Table 4). Students expressed how important each initiative was with their options ranging from "Very important" to "Very unimportant" and rated their predicted level of participation from

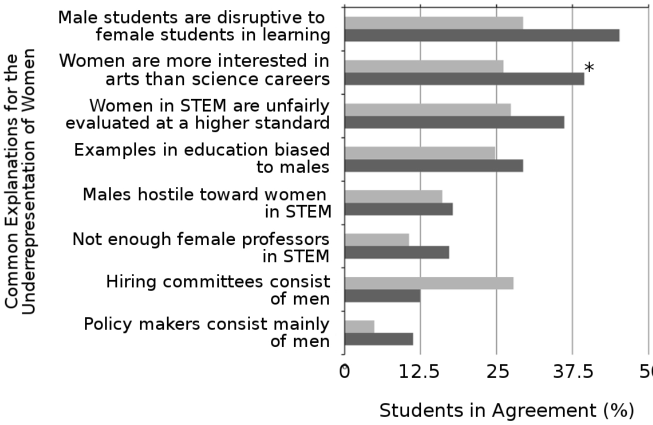

Figure 1: *A comparison of how male (grey bars) and female (black bars) respondents rated their agreement with common explanations of why women are underrepresented in STEM (Perception 2). Each of the common explanations variables were proposed by the original authors of the survey. Significant differences between men and women have been indicated with asterisks (*).*

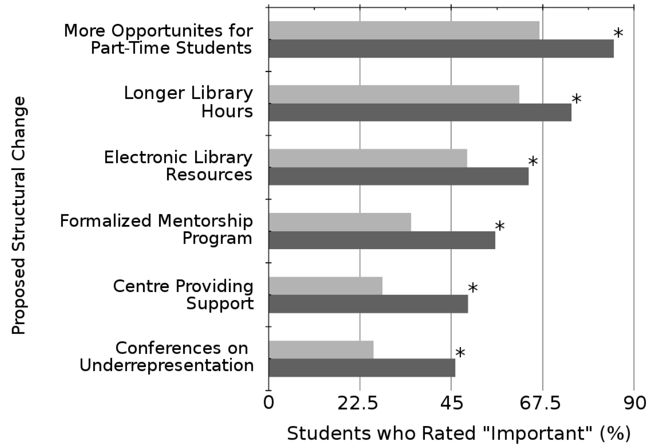

Figure 3: *A comparison of how male (grey bars) and female (black bars) respondents rated the importance of proposed structural changes aiming to address the underrepresentation of women in STEM. Each of the structural initiative variables were proposed by the original authors of the survey. Significant differences between men and women have been indicated with asterisks (*).*

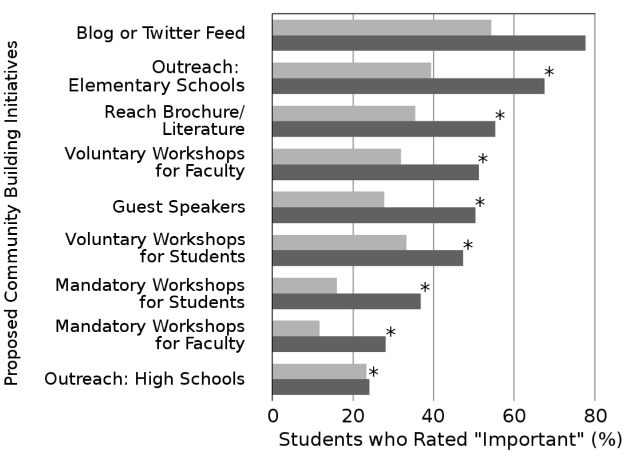

Figure 2: *A comparison of how male (grey bars) and female (black bars) respondents rated the importance of the proposed initiatives aiming to address the underrepresentation of women in STEM. Each of the initiative variables were proposed by the original authors of the survey. Significant differences between men and women have been indicated with asterisks (*).*

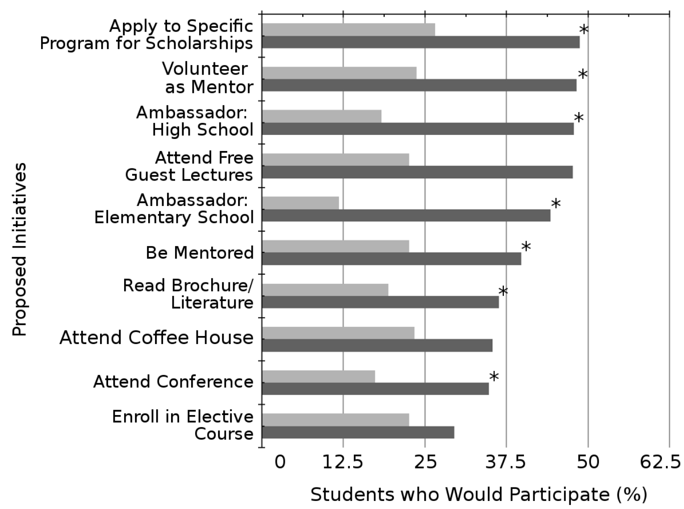

Figure 4: *A comparison of how male (grey bars) and female (black bars) respondents rated their predicted participation in the proposed initiatives aiming to address the underrepresentation of women in STEM. Each of the initiative variables were proposed by the original authors of the survey. Significant differences between men and women have been indicated with asterisks (*).*

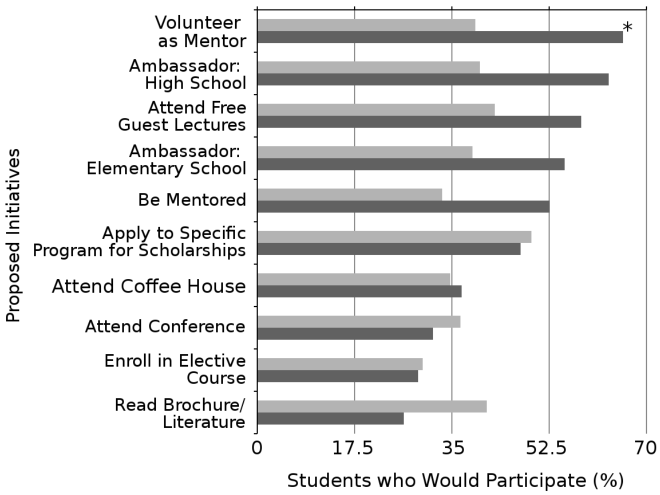

Figure 5: *A comparison of how female STEM respondents who perceive and do not perceive that they are underrepresented rated their predicted participation in the proposed initiatives aiming to address the underrepresentation of women in STEM. Significant differences (p<0.5) between men and women have been indicated with asterisks (*); grey bars: did not feel represented, black bars: felt represented.*

"Very likely" to "Very unlikely".

The sample was composed of male and female undergraduate and graduate students at the University of Manitoba, with a targeted oversampling framework of students within STEM faculties. The gender distribution also included an overrepresentation of female students, with a total of 369 female and 163 male respondents. With regards to recruitment, the email addresses of students currently enrolled in undergraduate programs were obtained by the research team and all respondents were recruited through an email invitation. All of the surveys were filled out online using an online survey program. Once responses were collected, the data was analyzed by the research team using SPSS. Bivariate statistics were generated using chi-square.

3 Results

3.1 Underrepresentation

3.1.1 General Perceptions of Gender Underrepresentation

Students' responses illustrate clear differences in perceptions of underrepresentation within university in general and within their program of study, based on respondent's gender (Factor 1) and status as a STEM vs. non-STEM student (Factor 2). In relation to Perception 1, students' perceptions of how their own identities are represented varied. Overall, 20% of female respondents reported feeling underrepresented at university, regardless of their program of study. However, female students enrolled in a STEM program (33%), were significantly more likely than those in non-STEM programs (14%; χ^2 [1, 339]=16.9, p<0.001, Cramer's V=0.22) to indicate that they feel underrepresented. In relation to Perception 2, students expressed differences in how important they regarded the representation of marginalized identities. STEM students from marginalized groups were more likely to think it is important that their respective identities are proportionately represented. For example, 61.9% of female STEM students thought proportionate gender representation was important, compared to 39.6% of male STEM students (χ^2 [2, 158]=7.05, p=0.029, Cramer's V=0.211).

3.1.2 Opinions on Possible Causes of Gender Underrepresentation

In relation to Factor 1, generally among the STEM population, males and females expressed similar levels of agreement with the proposed explanations of why women are underrepresented (Fig. 1). For example, in response to statements such as "Male coworkers in STEM fields sometimes behave in a hostile way towards women in their fields" (Perception 2f), 26.3% of females and 21.3% of males were in agreement. This difference was not statistically significant.

In response to the proposed explanations of why women are underrepresented, the only significant difference observed between male and female STEM students was Perception 2b, "Women are more interested in arts than science careers". In response to this statement male students (25.0%) were almost two and a half times more likely than female students (10.5%) to agree (χ^2 [2, 157]=12.69, p=0.001, Cramer's V=0.284).

Female respondents who reported feeling underrepresented due to their gender were significantly more likely, than female respondents who did not feel underrepresented on the basis of their gender, to agree with "there are not enough female professors that can act as role models for female students in STEM", (Perception 2g) (42.1% vs. 22.7%; χ^2 [2, 113]=6.6, p<0.05, Cramer's V=0.24).

Among the overall population of students, female students were significantly more likely than male respondents to agree with Perception 2i, that policy makers consist mostly of men (45.2% vs. 29.4%; χ^2 [2, 525]=17.6, p<0.001, Cramer's V=0.18), Perception 2h, hiring committees consist mainly of men (39.4% vs. 26.4%; χ^2 [2, 524]=21.3, p<0.001, Cramer's V=0.20), and Perception 2g, that there are not enough female professors teaching in STEM disciplines (36.1% vs. 27.3%; χ^2 [2, 527]=6.5, p<0.05, Cramer's V=0.11).

3.2 Support for Initiatives

3.2.1 Gender Differences

In relation to Factor 1, support for a number of initiatives aiming to increase gender representation varied greatly between STEM men and women (Fig. 2), with many statistically significant differences. STEM women were significantly more likely than men to indicate that almost all of the initiatives were important. The only exception was reading a university blog or Twitter feed (CB Initiative 9). Roughly a quarter of both men (23.4%) and women (24.1%) who responded indicated that this would be important. Interestingly, among both female and male STEM students the initiatives or programs which were believed to be of the greatest importance were based around outreach, with significantly greater rates of support from female students. Over three-quarters of STEM females (79.0%) and more than half of males (60.4%) thought that CB Initiative 2, outreach programs to high schools, was important in order to promote the participation of a given gender in a field where they are underrepresented (χ^2 [2, 158]=7.01, p=0.030, Cramer's V=0.211), while nearly two-thirds of female students (63.8%) and less than half of males (43.4%) reported that CB Initiative 1, outreach within elementary schools would be important, (χ^2 [2, 158]=7.19, p=0.027, Cramer's V=0.213).

3.2.2 Structural Changes

In relation to Factor 1, it is clear that female STEM students were significantly more likely than male STEM students to support policy amendments related to the structural initiatives (Fig. 3). These suggestions are considered to be "structural" in nature as they would require a higher level of involvement of university administration and would potentially change the organizational structure of the academic institution. When questions center on issues of childcare, for instance, female STEM students were more supportive than male STEM students of SC Initiative 1, providing more opportunities for part-time studies, as it may help students with children to complete their degree in a timelier manner (85.0% vs. 66.7%; χ^2 [1, 206]=9.6, p<0.01, Cramer's V=0.22).

A significantly higher number of female than male respondents also supported SC Initiative 2, extending library hours, in order to assist students with young children 74.6%; χ^2 [1, 208]=4.0, p<0.05, Cramer's V=0.14). There were significant differences observed between female (55.8%) and male respondents (35.1%) in regard to SC Initiative 4, the implementation of formalized mentorship opportunities in programs with gender underrepresentation. Significantly more women than men were in support of such an initiative (χ^2 [1, 207]=8.8, p<0.01, Cramer's V=0.21). SC Initiative 5, the creation of a centre that would provide support for programs with gender underrepresentation, was also thought to be significantly more important among women than men (49.1% vs. 28%; χ^2 [1, 207])=9.6, p<0.01, Cramer's V=0.22)(Fig. 3).

3.3 Participation in Initiatives

3.3.1 Gender Differences

In relation to Factor 1, results regarding respondents' predicted participation in such initiatives also varied greatly between male and female STEM students (Fig. 4). The greatest variances were in response to CB Initiative 2, high school (41.9% vs. 21.2%; χ^2 [2, 157]=9.03, p=0.011, Cramer's V=0.240) level and CB Initiative 1, becoming an ambassador in an outreach program at the elementary school level (37.1% vs. 21.6%; χ^2 [2, 156]=11.32, p=0.003, Cramer's V=0.269). Among female STEM students, half of the proposed initiatives received over 40% of respondents' interest (Fig. 4). Notably, programs that involved "role modeling" were among those that received such levels of support. For example, among the community building initiatives this would include CB Initiative 2, becoming an ambassador in an outreach program to high schools (47.8%), and Initiative 1, becoming an ambassador in an outreach program to elementary schools (44.2%); and among the structural initiatives this would include SC Initiative iv) participating in a formalized mentorship program as a volunteer peer-mentor at the university (48.2%).

Although not shown, female STEM students who thought the proposed initiatives and programs were important were significantly more likely to express an interest in participating in them.

3.3.2 Differences Based on Perceptions of Underrepresentation

In relation to Factor 1, differences in respondents' interest in participating in the initiatives were also analyzed among STEM females who felt underrepresented and those who did not (Fig. 5). Most of these differences were insignificant. However, female STEM students who felt underrepresented were significantly more likely than those who did not feel underrepresented to express interest in SC Initiative 4, by both participating in the formalized mentorship program as a volunteer peer-mentor (65.8% vs. 39.2%; χ^2 [2, 112]=7.6, p<0.05, Cramer's V=0.26) and receiving mentorship from another peer (52.6%), CB Initiative 2, becoming an ambassador in outreach programs both at the high school (63.2%) level, CB Initiative 1, becoming an ambassador at the elementary school (55.3%) level, as well as CB Initiative 5, attending free guest lectures given by members of underrepresented groups (58.3%).

4 Conclusions

We observed that women report feeling underrepresented at the university at a greater rate than men and further, women who study within STEM programs are more likely to feel underrepresented than those who study within other fields.

In response, these women particularly desired the implementation of programs which help to strengthen their social ties within STEM. The results revealed that STEM women overwhelmingly indicated that they would likely participate in mentorships and outreach programs, while many also recognized that there could be structural changes made within the University which would ensure women are supported in STEM programs and are better connected with their like peers. Furthermore, support and predicted participation in the proposed initiatives was also greater among women who indicated that they felt underrepresented themselves, which suggests that these women are eager to find new opportunities to connect with like peers in their programs. Post-secondary institutions should prioritize their role in improving the learning and working climate for their members and should develop a response to women's underrepresentation which considers these findings. Based on these findings we would propose two recommendations to post-secondary institutions.

Firstly, increased support should be provided to underrepresented gender groups. Many of these students are eager to enact change by participating in community building initiatives, but would require resources to establish such programs. There is a large portion of literature which supports the benefits of community building initiatives for underrepresented students in STEM. Recent research by Robnett[11] argues that in order to reduce the negative effects of gender bias, supportive networks can be created through various initiatives targeting women studying in STEM fields. Her recommendations include developing interventions to meet the specific needs of the women in specific STEM programs and partnering with outreach programs. Therefore, discretion over the structure of such programs will be held by each institution. However, in order to insure that the structure reflects the needs of the students who are engaged in the program, post-secondary institutions should seek input from students as they develop these programs. In addition to students' prior notions about STEM fields or the ways students believe they are perceived by their peers, the sense of community within their program is an important factor that influences retention and achievement[12]. There could be many benefits to implementing community building programs which would be received by the student's and post-secondary institutions, including a greater level of inclusivity within University STEM programs, higher rates of enrolment and retention and improved academic performances among women.

In order to ensure that the learning climate within STEM programs becomes a more socially inclusive place for students of all gender identities, men and women who do not feel underrepresented would need to be engaged in this process. Encouraging a broader audience to take part in learning and discussing these issues would require creative efforts. Many STEM students and professors may vary in their understanding of equity, equality and diversity issues; however, in order to effectively carry out solutions, sharing of this knowledge will be critical. For example, one proposed solution could be discussing these issues within the courses that students are taking. This could help to familiarize everyone with the experiences of underrepresented students and ensure information about strengthening gender equity will be communicated in a consistent manner to all.

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