

Article

Perceptions of Barriers to Career Progression for Academic Women in STEM

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Abstract: Gender equity in academia is a long-standing struggle. Although common to all disciplines, the impacts of bias and stereotypes are particularly pronounced in science, technology, engineering and mathematics (STEM) disciplines. This paper explores what barriers exist for the career progression of women in academia in STEM disciplines in order to identify key issues and potential solutions. In particular, we were interested in how women perceive the barriers affecting their careers in comparison to their male colleagues. Fourteen focus groups with female-identifying academics showed that there were core barriers to career progression, which spanned countries, disciplines and career stages. Entrenched biases, stereotypes, double standards, bullying and harassment all negatively impact women's confidence and sense of belonging. Women also face an additional biological burden, often being pushed to choose between having children or a career. Participants felt that their experiences as STEM academics were noticeably different to those of their male colleagues, where many of the commonly occurring barriers for women were simply non-issues for men. The results of this study indicate that some of these barriers can be overcome through networks, mentoring and allies. Addressing these barriers requires a reshaping of the gendered norms that currently limit progress to equity and inclusion.



Citation: O'Connell, C.; McKinnon, M. Perceptions of Barriers to Career Progression for Academic Women in STEM. *Societies* **2021**, *11*, 27. <https://doi.org/10.3390/soc11020027>

Academic Editor: Pooja Sawrikar

Received: 1 March 2021

Accepted: 22 March 2021

Published: 24 March 2021

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Keywords: academia; diversity; gender; inclusion; intersectionality; STEM; women

1. Introduction

Since 1975, governments around the world have grappled with how to foster gender equity [1]. This was mirrored in academia around the same time as women increasingly joined faculties, however largely in non-tenure track (non-permanent) positions [2]. Despite the fact that women have comprised at least half of undergraduate student populations in many countries for several decades [2], their representation at the professorial end of the academic 'pipeline' remains markedly lower. In the European Union, approximately 27% of full professors are women [3]. In the United States of America, women comprise 32% of full professors but this figure hides further inequities: 27% of these women are White, 3% Asian/Pacific Islander and 2% are Black [4]. The challenges experienced by women in general are not experienced equally; there are intersectional challenges to consider. The challenges faced by women are compounded when you consider additional identities such as race, sexual identity, disability or culture. The concept of intersectionality was first coined by Kimberlé Crenshaw in 1989 [5], but gained mainstream recognition and prominence from 2015. The Merriam Webster dictionary included it in 2017, and defined intersectionality as "the complex, cumulative way in which the effects of multiple forms of discrimination (such as racism, sexism and classism) combine, overlap, or intersect, especially in the experiences of marginalised individuals or groups." Marginalised—or minoritised—groups are those who are actively diminished by others rather than naturally existing as a minority [6]. Academia is not an even playing field. It has entrenched systemic inequities, which perpetuate the under-representation of women and other minoritised

groups at senior leadership levels. Other sources of inequity are less visible, but just as tangible, drawing upon ideas of prestige and social capital which combine to give a cumulative advantage to the ‘lucky few’ who are typically not members of minoritised groups [7,8].

The European Commission’s ‘She Figures 2018’ report also finds that these differences are more pronounced in science, technology, engineering and mathematics (STEM) disciplines. The difficulties associated with attracting, retaining and progressing the careers of women in STEM are numerous and well established. Entrenched bias and stereotypes about women’s ability to ‘do’ science and maths [9] are present from as early as kindergarten [10,11] and are reinforced by prevailing societal norms, which position STEM fields as male oriented [12]. Men are stereotypically cast as being competent and assertive [13], which is considered more aligned with the competitive nature of STEM fields [14]. In comparison, women are considered more warm and nurturing [13]. This stereotypical expectation has been shown to bleed into evaluations of women in academia, where they are assessed on their appearance and personality—with the expectation that they should be nurturing and empathetic—rather than their professional abilities [15,16]. If they fail to meet these stereotypical expectations, they can be judged harshly, although studies have also found that female academic instructors are judged significantly more harshly than their male counterparts based on no other difference but their gender [17]. These biases can also be implicit, reinforcing gender stereotypes in all genders, cultures and timeframes [18].

These biases and stereotypes are pervasive in the STEM disciplines [19], especially impacting women, and in particular women of colour [20], non-binary and LGBTQIA* individuals [21]. The resulting sexism, sexual harassment and diminished recognition of their contributions, skills and abilities impedes their progress at all stages of their career [19,22,23]. This is further compounded by having children, with studies finding that women who have children within five to 10 years of completing their PhD are less likely to have tenure, or be in tenure track positions, compared to men or women without children [24]. Even without children, women still shoulder a greater share of domestic duties [24]. The COVID-19 pandemic has further thrown these disparities into stark relief.

The use of lockdowns to attempt to mitigate the transmission of COVID-19 in communities increased the household and child-rearing demands of both men and women [25]. A global study of academics found that this resulted in decreased time available to devote to research across the board; however, this was disproportionately experienced by women [26]. Journal editors reported an increase of 25% in submissions in comparison to the same time the previous year, pre-COVID-19. Yet they also noted this increase was only for male authors; the number of submissions from female authors remained the same [27]. Other journals did see an increase in the number of female authors overall, but this was only for group authorship manuscripts; the number of single authored papers by women fell by 5% [27]. The impacts of this reduced research output will be long lasting. A reduction in research time translates to fewer publications and grant applications, both key metrics in an academic’s argument for tenure or promotion. While gender disparities exist, they are greatly exacerbated by the ‘maternal wall’ [28] or ‘motherhood penalty’, which the existing structures of academia are ill equipped to overcome. These penalties are paid by women, but they have implications for the rest of society.

STEM fields are largely considered critical to national economies [29] and studies have consistently shown that diverse teams are more productive and innovative [30]. However, data compiled by the UNESCO Institute for Statistics in 2019 estimates that women represent 29.3% of the global research and development (R&D) workforce [31]. This varies greatly between regions, with women comprising almost half of all researchers in Central Asia (yet 80% of all researchers in Myanmar), approximately 40% for Latin America and 18.5% in South and West Asia [31]. The greater the number of women in leadership roles in a company, the better the company’s economic performance and outcomes [32]. When women represent at least 30% of a company’s leadership, this improvement in performance is seen irrespective of the size of the organisation [33]. A

2020 study in Australia identified a causal relationship between increasing the number of women in leadership and subsequent company performance [34]. The appointment of a female CEO increased the market value of companies listed on the Australian stock exchange—worth the equivalent value on average of USD \$53.3 million [34]. If these gains are seen in the business world, then surely inclusive and diverse teams would also benefit academic institutions? Certainly studies have found that teams with women have greater collective intelligence, which facilitates problem solving [35], a valuable skill in both research and teaching. So how do women in academia within STEM disciplines perceive of any barriers to their career progression? And do they think these barriers are unique to women? Earlier studies have examined the barriers to career progression for women in STEM [36] but often within the same institution or country (with some exceptions, e.g., [37]), academia in general [38], and in various related aspects such as publication and citations [39] and grant submissions [40]. This study aims to provide a more holistic overview by soliciting the stories, experiences and perspectives of women in STEM from a range of institutions, career stages, and nationalities.

This paper outlines the experiences of women in STEM in higher education and research organisations and explores their perceptions of the differences between genders in this context. The barriers to, and enablers of, career progression are presented, along with suggestions for mechanisms to meaningfully support inclusion and diversity.

2. Materials and Methods

This study sought the input of female-identifying STEM professionals, especially scientists, researchers and science communicators. Participants were recruited through invitations sent via institutional email lists in Australia, the United States of America and Japan, and social media accounts of special interest groups within those institutions (e.g., women in science). Focus groups participants represented a range of STEM disciplines and nationalities. Participation was open to all career stages from masters and PhD students through to full professors, with some focus groups also including researchers, scientists and science communicators from government and industry. The common characteristic between all participants was their self-identification as a ‘woman in STEM’. While recruitment was for ‘female identifying’ participants, none of the participants were asked to disclose any detail about their gender identity. These focus groups intended to explore the experiences and perceptions of being a woman in STEM using an intersectional lens, acknowledging that individuals are “more than the sum of [their] identifiable ‘demographic’ categories”, [41] (p. 5). Similarly, we do not wish to present individual experiences of, say, a female-identifying doctoral student and infer that the results presented apply to all female-identifying doctoral students, as this is patently inaccurate. What we did wish to explore was the prevalence of these barriers throughout a career, arbitrarily broken into early (within seven years of finishing a PhD, including Honours or Masters students), mid (eight–15 years) to late (15+ years) career stages. Consequently, demographic data—beyond these career stages and anything else revealed via participant quotes—will not be reported. The use of ‘woman’ or ‘women’ in this study is acknowledged as presenting an inadequately binary view of gender. However, it is intended to encompass all expressions of female gender identities of the participants in the absence of nuanced detail. Future studies may wish to use a specific gender-identity frame of analysis to explore the issues raised here.

Due to the exploratory nature of this study, the use of focus groups allowed guided yet flexible discussions of experiences. Each focus group had an average of approximately eight participants to ensure that all participants had the opportunity to contribute. Upon arrival, participants were offered refreshments and introduced to each other. The discussion then began by asking participants to talk about their experience as women in science. The order of questions posed to the group after this initial inquiry was largely determined by the flow of conversation and the issues raised. In all focus groups, participants were invited to reflect upon whether they felt gender makes a difference in the experience of becoming a scientist;

what have been some of the barriers to career growth and progression; the top challenges they believe women face in the STEM community, and successful strategies—including leadership—they have seen to manage and/or overcome these challenges.

All focus groups were recorded, in both video and audio only format, and were transcribed using Otter.ai. Both authors manually coded the transcripts using inductive category development [42]. The stories and experiences of participants were used to develop themes and subsequent code categories [43]. While much is known about the barriers that exist for women in STEM and women in academia, this is one of very few studies that included participants of multiple institutions, nationalities and career stages. Inductive category development ensured that the categories were genuinely derived from the stories of participants' lived experience. Both authors discussed the categories half-way through and at the end of the data analysis process to ensure consistent categorisation. Any extracted quotes that the authors coded differently were discussed and resolved, and subsequent coding employed the validated categorical definition. Through this iterative process, relationships between the code categories were clarified, which reduced the number of categories developed overall. Finally, exemplars of each category were identified and extracted from the data [44] and are presented in Table 1.

Table 1. Code categories identified from focus group transcripts with exemplars of quotes used in the qualitative analysis.

Category (and Description)	Sub Categories	Example Quotes
Expectations (Internally and externally applied beliefs of how women should behave and the standards they should meet)	Double standards	This thing where you've got, you know, women who feel they can only succeed by acting like a man. And then everyone hates them, because they're not men.
	Superwoman	I think there's a need for women to be like super women, men can just be researchers. I think the standards that women have to achieve are much, much, much higher than what men have in my opinion.
	Stereotyping	If the woman ... has more authority ... students will say, there's something wrong with her she's a bitch
Confidence (Personal belief in one's ability to achieve reinforced by external cues)	Bullying	I think my confidence has been undermined throughout the whole process. And it's really hard for me to stand up for myself, and to think that I'm good at what I do, and that it's worthwhile, because I've never really been told that ...
	Retribution	I do much more than everybody else, I guess, you sort of feel that what you've had to do twice as much to get this well, not even similar credit. But then refusing to acknowledge what I do, pretending I don't do anything, well, I guess things like bullying, that's what I would call that.
Bullying (Subtle and overt instances of actions which created a sense of reduced personal, mental and/or physical safety, ranging from microaggressions through to assault)		My mentor got kicked off of committees. She was kicked off the graduate admissions committee because she advocated for too many of the mostly women of colour coming in. they didn't like her speaking up all the time and fighting for them

Table 1. *Cont.*

Category (and Description)	Sub Categories	Example Quotes
Credibility (An expectation of different or diminished interests or abilities)	'Being a girl'	I hear a lot, "Oh physics is very, very hard. Only guys do that"
	Underestimated	I get my first grade and it's abysmal ... I decided to go talk to the professor and, you know, tell them, I worked really hard ... do you have any tips of things that I could do to just improve? And he looked at me, he's like, I think you should quit. I don't think you should be there.
	Different tasking	I feel like I'm the first one that my advisor will go to [for secretarial roles] and I feel like that may not be the case if I was a man
Isolation (A felt or actual experience of being alone)	Excluded	All the graduate classes that I attended, ... I was the only girl in my class every time, all the classes, and it would be like I [didn't] exist ...
	Felt 'other'	I cried, and I feel like nobody else would be doing that. And I feel like maybe that's like a male thing to not cry ... it's kind of an isolating experience to look around you and not feel like that people understand what you're going through.
Appearance (Abilities and worth are judged based upon physical appearance; may negatively influence professional interactions)	Objectified	An engineer submitted his comment, believing it's going to another male engineer ... And it says, the product managers are very attractive and make a great addition to the ... office scenery.
	Sexual harassment	... he was making overtures toward me and was talking about subjects that were just not appropriate at all.
Motherhood (Planning to or having children and the subsequent career implications—often externally imposed)		I had a woman chemist at an institution say specifically to me, how will you do this job with three children? ... My husband in all the years interviewing for many of the same positions, sometimes we competed directly head to head for the same positions, never had those questions.
Solutions (Skills, techniques and structures which support the progression of women in STEM disciplines in academia)	Male allies	But it was my other male colleague was the one who was correcting the language and all of a sudden I didn't feel so alone.
	Mentors	I think that to have a role model that you can talk to, a mentor that you can talk about issues and how do you navigate this relationship—it's incredibly helpful.
	Policies	If there were more policies that protected people for reporting harassment, stuff like that, then there would be fewer instances where women need to switch labs because their advisor was discriminatory ...

3. Results

A total of 78 people participated in the 14 focus groups. The focus of this paper is on the experience of being a woman in STEM, and we also wished to better understand whether the often cited solutions to making STEM more equitable were actually seen as effective or not. Results will be presented in two sections. The first describes the dominant barriers to career progression identified in the focus groups. The second outlines participant perceptions of the effectiveness of commonly proposed mechanisms to support equity in STEM.

3.1. Barriers to Career Progression

3.1.1. Different Expectations

The different expectations and double standards women and minoritised groups in STEM face was an overarching theme among all of the focus groups, specifically raised by approximately half of all participants, with many more echoing and amplifying these comments and experiences. Multiple respondents in each focus group brought up having to 'act like a man' to survive in science. Some expanded on that notion, commenting that 'acting like a man' can backfire because they are not adhering to common gendered stereotypes:

"That's the knife's edge we have to go through, right? We don't want the world to be like, well, we just have to act like men. But, on the other hand, we don't want it to be like, we're the special snowflakes that have to be treated nicely, because we're ladies." (8-5)

Other participants specifically mentioned how having to act like a man was a detriment to their relationships, professional and personal:

"You have to play their game. So if you're in a male dominated setting, you have to act like a man, you have to be assertive . . . But it ended up feeling like it was a huge detriment to a lot of other female relationships I had." (7-7)

A smaller number of participants talked about how they did not perceive much gendered discrimination in their work. However, they still felt a need to work harder than male colleagues: "Being a woman I really have not felt discriminated against. But, then I do feel that I have to work harder" (8-2). A late-career stage participant talked about how she did not notice the gender bias in STEM until much later in her career, when she suddenly realised the prevalence of implicit bias in academia and the cumulative negative impact it can have on women's careers:

"There are a handful of experiences of gender related "not nice things" in my life, in my professional life, but on the whole, it's not been bad at all . . . But now . . . I'm starting to really pick up on and see what's going on . . . It's been a really frustrating experience . . . feeling there's a tremendous headwind that we're all facing. And, you know, it's only 10% . . . But if it's a 10% at every single decision along our careers, and . . . every paper [or grant] we ever submit and everything that we ever do, that really accumulates over time to be a pretty strong headwind. And now I'm just mad." (8-3)

Many participants discussed feeling like they had to work twice as hard as their male colleagues to get ahead and that this was reflected in many of the female leaders they saw. This was commonly presented as the idea of being a 'superwoman' and having to be 'perfect' all of the time just to prove to everyone around them that they are meant to be there.

"I noticed a lot of the professors and women in leadership positions tend to be exceptionally good, to the point where one of them was an absolutely insane workaholic. I'm just wondering how she was still alive. And then I found out she also had four kids." (4-3)

Another early career researcher noted that the desire to be 'perfect' held her back from asking for help:

"I question myself a lot. And I think it also stops me from asking for help. And because I have the perception that people need to think I'm perfect, or like that, I'm better at it than and if I admit that I need help, then I'm adding to that, well, you know, look at her, she needs more help than other people." (12-2)

Participants also identified a double standard in what is considered an acceptable range of emotions and communication styles for men versus women. These gendered communication stereotypes place expectations of how women 'should' act, and consequently they were judged on their communication differently to their male colleagues.

"I think men are allowed a little more leeway in what they can do that will be considered assertive versus a woman. She might send an email that some people might say is aggressive. If her name was Christian, maybe it would just be: he wants us to get it done." (6-2)

"I've noticed with my colleagues as well, my female colleagues, you need to be really pushy to get your point across and not have it questioned a lot. Whereas it tends to be that if you're a guy, you get your point across, and everyone says, "oh, fair enough." And then that's it. But so I think that, just generally, if you're, if you're a female, there's a lot more justification required" (2-2)

Gendered stereotypes in communication not only impacted their careers and confidence. Some participants commented on the amount of mental energy and time they have to put into their communications to try and mitigate bias, which is time taken away from research. This was a common theme from early career researchers, to those that were post-tenure.

"I do find myself thinking very carefully before I respond and say something or spending like 30 min on an email that should probably take two minutes ... I know my male colleagues don't necessarily have to do this, but I have to do it. Because if I am direct through an email, if I say, "please do this, or do this", it's like, "oh, she's so demanding". But if I say, "Good morning, I hope all as well, if you don't mind ... by stopping by to do that, thank you, have a great day," there's different responses ... I will throw in a smiley face, because I have gotten feedback that: "Oh, she's so direct, so aggressive"." (6-1)

Double standards in stereotypes also surfaced with respect to evaluations and career advancement. Discussions identified bias in student evaluations and explored how these can negatively impact your career, including getting fewer awards and being evaluated poorly in tenure decisions. These were experienced at all career stages. A late-career researcher mentioned how teaching evaluations did hurt her career and tenure process:

"Females aren't perceived the same by the students. And a lot of our evaluations for our teaching that goes into Privilege and Tenure (P&T) is based on those student evaluations ... I had a horrendous P&T process. And part of that was going up head to head at the same time with a male colleague ... " (9-1)

3.1.2. Confidence

Confidence and imposter syndrome were prominent threads noted by participants in eight of the 14 focus groups. Lack of confidence was often reinforced by personal negative experiences of bias, but also how they witnessed other women in STEM being treated. One early career researcher noted:

"I used to work with a woman who was very, very capable. She's one of the best geologists that we've had. And we would be in a meeting like this, and it would be split 50/50 men and women and yet all of the men would talk over her all the time, and she was by far the best tutor that we had ... And then she started doubting herself ... " (4-6)

Lack of confidence was also exacerbated by the lack of representation of women, especially in leadership roles. Some mentioned how their confidence was shaped by the isolation they experienced due to the lack of other women in similar positions:

"When I was applying to schools ... our department at the time, there were only four female professors listed on the website. And I remember ... part of me was disappointed, but part of me was also like, maybe I don't do this, this isn't what I think women do?" (12-11)

Some participants described how their confidence has decreased as their career has progressed:

"I feel like since I was an undergrad, I've gone down. And then something about a higher degree and recessed imposter syndrome just came with it. I wish I was as confident as I was back then . . . I didn't know half of what I know today, but yet I have twice as much doubt." (4-2)

Others mentioned experiencing subtle comments and microaggressions, and even bullying by more established men and women in STEM fields.

"I've seen the men talking over the women, I've seen men just flat out ignoring them and telling them that they're wrong. I'm now getting really quite angry because I'm mansplained to, like every single day . . . And, now I'm just frustrated because they always seem like they're such innocuous things until we have this conversation . . ." (4-6)

One mid-career researcher talked about how societal bias against women in math and science contributed to her downplaying or hiding her interests and abilities:

"At some point, I developed the impression that being really outgoing or competent in what I was doing, especially in math and science, people didn't like girls who did that. So I learned to kind of be more non-threatening and stay under the radar. And even though I know that I'm very good at what I do, I just kind of try not to step on anyone's toes." (7-6)

And for the women who appeared confident to others, there was also a cost. This could manifest as being unfairly labelled or becoming detrimental to personal wellbeing and safety, as the following quotes illustrate:

"I used to take the approach of the people pleaser. I would do whatever it takes if no one ever calls me [a bitch], because I hate that. And I don't want to be that person. And then, obviously, I've grown up and realize that it doesn't really matter what you do. Somebody is gonna be disapproving. And so I definitely don't embrace it. And I don't go seek it out. But if there's an issue that needs to be addressed, I'll address it. And then if I get called (a bitch) or, you know, other comments, but basically the same sentiment, and I'm like, yes, maybe I am, but you didn't do what you were supposed to do, and I'm not going to let you just get away with it." (6-4)

"Although we come off as confident, it definitely comes with the price . . . I was too embarrassed to tell him that I hurt myself because of the consequences that will come with it. So I still had to keep this up, 'oh, I'm confident I know exactly what I'm doing. I'm just like the guys'." (6-1)

3.1.3. Bullying

Retribution and retaliation for reporting or speaking up against bias was another prominent theme in 10 of the focus groups. A large number of participants experienced something that they wanted to report but did not; either because they did not think they would be supported in the process, or there would be a personal cost and it would be held against them. Many participants talked about ignoring the harassment and moving past it, "acting like it didn't happen," because "it's easier that way". Others mentioned that the consequences of talking would be held against you, be too dangerous, or hurt someone you care about. One later-career researcher commented on the inherent power dynamics in academia that makes it harder to combat harassment:

"Not speaking up about harassment or any issues is more common in academia simply because of the power structure. It's not an employee employer relationship, it's like, this person controls your entire life. The competition is so high . . . that you can't even make the slightest ripple. You know, you have a 2% chance of getting the career you want to begin with. And so if you make the slightest ripple, this person has the power to just completely destroy your career, not just at this company, if it were a company, but like, throughout the entire universe." (8-3)

Many focus group participants spoke of the detrimental effects of the power imbalance that can exist in academia, with supervisors and superiors in particular having the power to negatively impact the careers of women in STEM. This included denying authorship on papers, PhD committee problems, and negative letters of recommendation.

“I would have finished my PhD a lot faster if I didn’t have all that and I would have more papers. So there were plenty of papers that I was not on that I should have been on, because they were being given as awards to the men. And so that was a huge issue throughout my PhD . . . ” (12-13)

This power imbalance can also lead some women to not report harassment, as shown in this quote from a late-career participant:

“There are things that I think just happen and we kind of brush off, especially as you’re beginning your career, because you want to fit in and you don’t know that it’s happening to all the other women around you, because nobody’s talking about it.” (9-4)

Some specifically mentioned not being believed by both male and female colleagues and the detrimental impact it had on them. One participant recounted her experience talking to a male colleague about a mistake he had made in the lab, how he threatened her and her superiors subsequently ignored it:

“He basically confronted me in the laboratory, and screamed and yelled at me and pursued me throughout the laboratory to where I was shaking. And I was told from a woman boss my age “you really need to have thick skin.” There was no report filed at human resources, there was nothing . . . Another woman counterpart, said, “Oh, I work with him. I work with him all the time. And he’s just lovely.” He’s a big guy, like, got in my space, you know, that was just swept under the carpet.” (7-2)

Sometimes women can also use negative experiences to make things better for the women who came after them, as this early career researcher describes:

“All those discriminations are small, small mosquito bites every day . . . Every time she would speak up against something in whatever committee she would be in should be switched off that committee. So I saw her getting switched from one committee to the next, or getting dismissed on committees, administrative committees, again, and again and again. And because she had the guts to stand up and say something. But at the same time, she trained us and the women in her lab, she was like, ‘This is what I’m facing. I’m going to tell you guys the truth, so that but then you have to stand up for where you are’. She taught us very well, she would never let that frustration come down.” (12-9)

A few participants specifically noted being bullied by females in more senior positions. One senior researcher almost excused her previous boss’s behaviour because, as a more senior woman in computer science, she must have faced extreme bias coming up throughout her career:

“There was a woman who was . . . very senior and made my life absolutely wretched when I first started here . . . made me want to quit science, made me go home and cry. But, I will say that I kind of chalk it up to, you know what, you got a PhD in math 40 years ago . . . I’m gonna cut you some slack because I think [that’s] the personality type that you need to have even survived and be where you are today.” (8-3)

Another late-career researcher noted that this bullying might be due to the perception that opportunities were limited at the top:

“They (women) feel like they’re assuming so few spots at the top that we need to compete for them. And I tell them no, we just need to make more spots.” (8-6)

3.1.4. Credibility

A theme that surfaced in all of the focus groups was the idea that “being a girl” carried different societal expectations (e.g., girls are not good at math), and how that surfaced throughout a female scientist’s career in terms of being disregarded or underestimated, and given different, more administrative tasks than male colleagues.

“I believe the fundamental problem is lack of belief that women have equal intellect at a baseline level. And everything follows from this . . . because women are just not viewed as intellectually competent, like fundamentally. And so maybe . . . it comes out more in workplaces (like academia), where intellectual capacity is, you know, generally more demanding, and more important than in some other workplaces.” (7-3)

Some participants talked about the bias existing in their field, but also how that is compounded by the bias from society. A few participants mentioned how the bias they experienced in the K-12 schooling years shaped their views and put them at a disadvantage before starting university.

“I felt like, even before I entered university, I knew I wanted to do science but even before I enter, I’m going to be put at a lower level to the boys because they had that opportunity in school, whereas we didn’t.” (13-4)

“If you’re a girl, you’re not good at math. So you can’t be an engineer.” (10-5)

This bias is perpetuated throughout university and reinforced throughout women’s careers. These experiences were common in each focus group, with reflections exemplified in the following quotes:

“I had an incident, when I was doing undergrad research with a mentor . . . [he] told me that woman shouldn’t be in STEM.” (7-7)

“He told me that the day that I was interviewing you, I had a call with your supervisor in university and . . . he told me that “she’s going to work as hard as a man, as good as a man.” And he said that “I’m happy . . . that you proved that and happy to have you here,” and that didn’t really make me feel good.” (5-5)

Other participants discussed “being a girl” through an intersectional lens and how being a person of colour or other minoritised group in STEM adds to the stigma:

“Sometimes . . . I felt like it’s a “being a girl” thing, not “being the Serbian”, “being Muslim” . . . something together that you cannot identify [what the problem is]” (5-5)

“Being an underrepresented woman, I feel it’s kind of like a double minority. So not only are you being a trailblazer on the woman’s side, being a trailblazer, or being a black person. So oftentimes in classrooms, my peers, or I would say, my white male peers are not used to someone looking like me doing calculations or running simulations. So oftentimes, I have to deal with this implicit bias, or microaggression.” (6-1)

“I don’t know whether some of the issues that I deal with stem from me being a woman, or stem from me being an underrepresented minority [in] engineering . . . like being the only female in my class work, I’ve [also] been the only student of colour in my class.” (6-2)

Many participants noted the expectation that they would assume more of the administrative and service roles, an assumption that is not made of their male colleagues. Others mentioned the mounting toll of the administrative tasks on their research:

“I feel like I’m the first one that like my advisor will go to [for secretarial roles] and I feel like that may not be the case if I was a man.” (12-10)

"I've seen many, many, many more examples of women being taken advantage of by ... dominant ... male lab leaders, ... like just working longer hours, or doing more menial tasks, for example ..." (3-3)

A few participants discussed the glass ceiling they were up against and the hidden 'boys club' to which they were rarely invited, which perpetuated many of the biases and expectations raised:

"I think one problem is kind of this glass wall, like this boys club, this hidden boys club. But you have the feeling you can't enter, but you can't point towards it ... there are always excuses, right? There's hierarchy and you're in this hierarchy. And you're always like, on the bottom, or kind of at the bottom." (7-6)

3.1.5. Isolation

Participants in all of the focus groups brought up the theme of feeling isolated and, at some point in their career, being acutely aware of being the only woman in the room. There were many participants that described leadership in STEM fields as male dominated, and not seeing many women around them. One later-stage researcher noted that while there are more female PhDs in her field, she is still not seeing that trend mirrored at higher levels.

"You know, I think I can think of one female department head. So we have 50/50 coming out of my field in PhDs, if not more women than men these days. But we still get fewer female applicants to our tenure track positions. We make fewer offers to those female applicants. And I mean, our department isn't anywhere near 50/50." (11-1)

This exclusion can extend to acceptance within a team on a day-to-day basis as well:

"You find yourself excluded ... I have had male colleagues who started the same time [as me], so we had quite a large cohort in my department of academic staff starting around the same point in time, and it took me over two years before I was even invited to someone's place for dinner, or almost two years to get a coffee invitation. My male colleague who started six months after me ... [he] is invited to the parties ... (5-1)

The 'boys club' was brought up again, and how having an ally can help women 'break in', as this quote from a late-career researcher shows:

"I went to ... big giant national meetings. And there was a dinner one night organized by, you know, the boys club, in the field I work in and one of the guys emailed me a little bit before, you know, 'hey, do you want to join us?' ... And, I went in knowing I'm being invited to the boys club ... And there were other people at the dinner that I work with, and some kind of closely, and nobody ever mentioned it, you know? It was very informal ... but then you see who's there and it's the who's who of the field. And it's me and one other woman ... it takes someone noticing and getting that invitation." (8-6)

Yet even making it to the 'boys club' did not necessarily mean inclusion, as this late-career participant recounts:

"Once there was a maths dinner. And again, I was the only woman and it was very obvious that people were turning away, not talking to me ..." (3-5)

3.1.6. Appearance

Another theme commonly raised in 10 of the 14 focus groups was women in STEM being treated differently because of their appearance and overt sexual objectification. The phrase 'you can't be pretty in science,' surfaced quite often; or 'if you are pretty, you're not taken as seriously'. The idea of a tightrope on which women in particular must walk was mentioned.

"There's this fine line between what you know, wanting to be different because you're a woman, and not wanting to have to lose any of your womanhood into STEM culture. But then there's also this 'I'm not different. I'm not here because I'm a woman. I'm here because I'm a scientist', and so, there's this really fine line to walk there." (9-5)

Some participants mentioned how the 'you can't be pretty' in science mentality influenced how women were judged by others, and the impacts this could have on women's authority and confidence in their own abilities:

"[For a lot of women] there's always this desire to be attractive and appealing, and sweet and desirable. And, and to do all those things, you can actually undermine your authority, and you can undermine your confidence. And you can have direct odds with what it takes to be successful in science, with what it takes . . . to be successful as a woman." (5-1)

"In grad school, we went to conferences and my lab was . . . mostly women, and we were, you know, fairly pretty women. And one time we sat there at the table with our professor, and his friend came . . . he said, 'Oh, that's why you hired them'." (13-1)

Some of the participants discussed overt sexual harassment in their careers occurring at all stages, and occurring in the office, the lab, and out in the field.

"I think we tend to block a lot (sexual harassment) and realise later, yeah, wait a minute. Yeah, that's not right. But at the time that it happens, we sort of just, you know, try to pretend or block it." (8-2)

"I know people who have been sexually assaulted in the field . . . especially if you're in a field of science that involves any sort of remote or field based or place based work. It is a huge issue." (11-5)

In one focus group, a few participants mentioned stories of hotel keys being slipped to graduate students from principal investigators (PIs—senior researchers) at conferences; one participant relayed how a similar experience negatively influenced her networking for years afterwards:

"It happened once when, when I was a postdoc, and somebody was talking to me about my poster and said it was really interesting. 'So some of us are meeting up afterwards. Do you want to come and join, we can talk about job opportunities, and whatever?' And when I got there, he was flaming drunk. And . . . not interested in science or jobs. It was just so frustrating to me that I basically avoided going to cocktail parties at science conferences for years after that . . . But I think that because when people are in the junior stages of their career, that's, you know, you're just some nameless posts, right? And disposable . . . I missed out on all these opportunities to network and be part of the old boys network, because I just didn't want to have that kind of interaction." (8-3)

3.1.7. Motherhood

The biological burden on female scientists was another frequently discussed topic. The majority of participants were worried about, or had worried about, the idea of having a family and being able to do that well while pursuing a career as a scientist. Many participants described being actively dissuaded from having children if they wanted a career in STEM, with science and children largely presented as an either/or proposition. This was especially noticeable for early career researchers:

"I was told by my PhD advisor 'If you want to be serious about science, you have to be a serious scientist, you cannot have children.' I was told later on by my postdoc advisor, who's a woman, the same thing. And I've seen women not be advanced if they know you have a child." (7-5)

"I am not looking to have kids or get married anytime soon. But there has to be a timeline, which is kind of scary. A PhD is like, five or six years. And then if I decide to stay in academia, [I need to do] one to two postdocs ... and then I'm ... 30 years old already or 32. Then I'm like, 'okay, maybe it's time to settle down?' And no, because I don't have a faculty position, I only have a temporary faculty position. And then it's a mess." (12-9)

One mid-career researcher amplified the trade-off women in science feel that they must make when it comes to their career or children with a story of a post-doc who was considering ending her pregnancy:

"... she's got a postdoc, she's doing research ... She's just found out she's pregnant, and it wasn't planned. And I got this horrible email saying, "What should I do? I want to have an abortion so I can have a career. But you know, I want to have a baby but just not yet. How can I manage to [do this]?" So she's six months into her postdoc. How can she manage to ... continue on with this 12 month postdoc, have a baby, tell her supervisor that she can't work with cytotoxic compounds, and this kind of thing ... it's just this horrible moral dilemma that women are put into that, so many careers are ended ... because of things like that. What do you do?" (5-1)

For women who do decide to have children, the trade-offs and barriers continue after they have given birth. One mid-career researcher talked about the pressure to come back to work, even though she had maternity leave, because "I just could not imagine that I wasn't going to get judged, and that I wasn't going to hurt myself [professionally]" (7-4). Another mentioned how hard women must work to adjust for having kids, but also how they have to hide their childcare responsibilities:

"I've also heard stories where people who've had children would leave their doors to their offices open when they had to go and pick up ... their children for Girl Scouts. And they didn't want their male colleagues to know that they left at 3:30 in the afternoon to go pick up their kid. And so they leave their door open and then come back in the evening." (9-5)

In comparison, another participant described the double-standard of being a 'dad' versus a 'mum' in science:

"There were two people in my department who had sick children who had to be pulled out of school and came [to work] with their parents ... Everybody all over said (but nobody said it to either of those two faculty members): he was a great dad; she couldn't plan." (9-7)

Yet having men bring their children to work can also help create a cultural shift: "It's not a big deal here because the men have had to do it here. And I think that that unfortunately makes a big difference when your majority group is the one who has had to start that practice of bringing their children to school, or with them to work or whatever, it opens the way for the rest." (9-5)

There were a few participants that specifically mentioned relationships where both partners are in academia, and how the burden of childcare, more often than not, falls on the women:

"I've seen a couple of PhD students who because of maternity leave or whatever, they will fall behind just a little bit. So when they go to look for jobs, the male partner is looking for the academic track and he's just that little bit ahead so they go ahead and target that position and she's like 'well, I'll take up whatever I can get, maybe a support position' because she's just not ready for that academic position or she's seen as auxiliary for whatever reason ... If there's a slight advantage for the male academic career then this is the one that gets prioritised and the female takes the shorter term support roles and they're seen as lesser." (3-4)

This occurs at different career stages and all contribute to women falling behind in their careers, irrespective of whether childcare is their sole responsibility or not:

“My husband and I are both [scientists]. And so we interviewed a lot of times at the same time, and sometimes at the same places. He was never asked the illegal question of do you have a family or do you have a wife? Almost, I would say I had 15 interviews one year, and of those 15, 14 of them, my family status was an issue . . . I had a woman chemist at an institution say specifically to me, ‘how will you do this job with three children?’ . . . My husband in all the years interviewing for many of the same positions, sometimes we competed directly head to head for the same positions, never had those questions . . . ” (9-5)

One participant noted that she did not feel much bias in STEM until she became a mother:

“I didn’t feel that there was much of a difference up until probably when I had a kid. And then there was this big chasm between how fathers are treated versus how mothers are treated. And, for me, at least, you know, I sort of felt that, you know, once I became a mother, there was this sort of attitude that maybe I wasn’t as dedicated to my work. Or if I had to leave early because of my kid that, you know, I would quit at any moment because I have a kid now, I might be a stay at home mother. And never has my husband ever experienced anything like that. And it’s not science at all, him being a father does not factor into his [science] career at all. And I feel like it’s this sort of big glaring red mark against me in my career.” (12-7)

3.2. Solutions

In each of the focus groups, participants discussed solutions to gender bias in STEM, and some common themes emerged. One of the main solutions mentioned in each focus group was fostering a supportive community of women in STEM and hearing other women’s stories. For many in the focus groups, this was the first time they were having a structured conversation around the barriers they faced as women in STEM; it helped them feel not so alone.

“I haven’t talked about these issues in like years. So just even getting in a room . . . it is nice to come here and just hash it out a little bit and become more aware. It’s always about being aware.” (8-5)

Others mentioned having strong mentoring networks that push you and support you along your career path, and having more women to look up to in leadership roles.

“It helps to have more women mentors around now . . . you can talk to people who are more able to directly relate to you and encourage you in the way that you need to be encouraged.” (6-3)

Another common theme was the importance of allies and advocates, especially male colleagues and those in leadership positions, as one participant notes: “For gender, a lot of these issues, I think, I think that effort needs to be put on men” (8-3). Participants particularly noted men being an effective bystander, being an advocate and inviting someone into the ‘boys club’, or simply having somebody to support you or promote your idea when you get talked over in a meeting. One senior researcher talked about the impact of a male colleague standing up for her to other male colleagues:

“He turned around and was very forthright about what he was hearing and how he knew it was affecting me as the only woman in the crowd. And how frustrating it was for me that . . . the language was just not inclusive . . . the first time it happened to me was the first time I felt like I was a part of my department . . . And it was the first time I felt like I was not this crazy person who was tired of hearing about it, you know, that feeling of maybe it’s just me, I’m making too much of this, this gender issue.” (9-5)

When discussing how to manage or prevent unwelcome or inappropriate behaviour, many participants seemed unaware of how they should make a complaint or what the policies actually were. For others, they did not feel that they would be protected or that the administration even cared: “I completely don’t expect anybody to give crap, when something happens to me that is sexist in the work place” (7-3). This speaks to a larger issue raised about the need for stronger leadership in academia. Earlier themes discussed the power imbalance, and participants felt that senior academics in supervisory roles should be trained to be part of the solution:

“One piece that’s really missing in academia is that we advance from a PhD student or postdoc to PI without ever going to management training. Because some of the things like the illegal questions in interviews are easy to train and in business, you get trained not to do it, right. We don’t do it in academia. I think that’s where a lot of the stereotypes about ‘Oh God, academic culture’, and all the backbiting politics come from is people just don’t know how to behave professionally. Right? And if we required something like crucial conversations, as you get tenure or as you start managing people or as you start making hiring decisions, I think that would help.” (9-3)

All focus groups typically acknowledged the scale and complexity of addressing gender bias in STEM fields and the multiple levels it needs to occur on. These discussions are best exemplified by the following quote:

“My experience of being a woman in this world from early on, has been that the glass ceiling was firmly in place when I was born and it’s still firmly in place. The only difference is that when I was born, I didn’t know where it was. And now my face is pressed against it. And there’s just a million ways, I think that you’ve touched on a lot of different things that are factors that we deal with, and they reinforce each other. And it’s such a tangle of factors, that we get exposed to it and affected by it on a daily basis, in a way that we don’t even know we’re being impacted upon. And so teasing out those factors and fixing them one by one is really the only way to do it. But it’s big work.” (5-1)

4. Discussion and Conclusions

The discussions within these focus groups consistently identified the perceived differences between the ways men are affected by the identified barriers in comparison to women. The results constantly highlighted how these barriers began from the time women were in secondary school (if not earlier) and continued throughout their career, irrespective of seniority. This is consistent with the findings of previous studies, which found that these biases could emerge from as early as kindergarten [10,11]. Comments from participants describe situations where they receive either subtle or blatant comments reinforcing stereotyping of who ‘does’ science, emphasising that ‘harder’ topics such as physics or mathematics were for males [9]. Many of the participants describe persisting in pursuing their interest in STEM topics, despite these comments, overcoming one of the first hurdles to a career in STEM. Continued perpetuation of these gender stereotypes throughout the course of a career can influence career choice, including the retention of women in STEM fields [45]. Career progression and retention could also be hindered by persistent stereotypical beliefs about the ability of women in STEM fields. Previous work found that undergraduate women encounter beliefs that their ability and talent is lacking, despite their outperformance of their male colleagues [46]. From the comments of participants, especially those from the mid- and late-career stages, these beliefs seemed to persist, with comments consistently showing women felt a pervasive pressure to prove their worth. These stereotypes and double standards that are applied to women in STEM were the most commonly described barriers by the focus group participants. The frequency and nature of comments pertaining to these stereotypes and double standards, echoed throughout the existing literature, highlight the pervasive nature of stereotypes not only

in academia or STEM disciplines but of those in society more broadly. Previous work has already shown how media [47], and cultural contexts and beliefs [48] all contribute to the development, acceptance and reinforcement of stereotypical societal norms of STEM being ‘male oriented’ [12]. For any progress to be made for women in STEM in academia, or in any other sector, equity for women in society is also requisite.

4.1. Barriers to Career Progression

Perceived barriers to career progression included deeply entrenched societal and institutional gender bias, but also more subtle microaggressions that, when compounded over a career, can put women at a significant disadvantage [19,22,23]. This is seen in the disproportionate number of women that make it to leadership positions in STEM fields in comparison to men, and in the implicit and explicit bias women in STEM face throughout their career. The discussions in this study about the double standard applied when women are negatively judged and evaluated on their communication and teaching is also reflected in the literature [15–17]. If women are not getting judged on the same equal playing field, and inherent bias is not taken into account in promotion decisions, then they are at an automatic disadvantage to advancement in their career.

The deeply embedded gendered and patriarchal systems that exist in STEM fields were commonly raised barriers. Many participants mentioned having to “act like a guy” or “have a thick skin” to fit in and get ahead; this attitude unfairly puts the onus on the women to change versus fixing an inherently sexist system. When women did complain or step outside of their expected stereotypes, they were often referred to as a “bitch” or were actively isolated in their departments or lab groups. Some participants mentioned that they do not feel comfortable talking about sexist issues and sexism in general in the workplace, especially in front of their male colleagues. Many participants did not feel protected in the current reporting structures, or even knew what systems were in place at their institutions. Others reported instances of not being believed or being told to “ignore it” or “avoid him” because we “already know he is a problem,” with the overwhelming message being that the department was not going to do anything about it or challenge the status quo. Participants discussed how deeply ingrained these messages were and how they were perpetuated by stories and observing how other women were negatively treated. In order to begin to address the barriers around equity for women and minoritised groups in STEM, clear policies and procedures need to be put in place, with consideration of whether any adopted policies or principles are reaching all minoritised groups equally [49]. Effective action against inequity also requires an enabling institutional environment, which can only be achieved through concerted efforts using multiple strategies targeted at individual, community and institutional levels [49]. Future studies may wish to move to more practically focused explorations of what strategies, policies and procedures are effective in enabling equity and how these may best be employed.

4.2. Personal Costs and Trade-Offs

Another overarching theme among the focus groups was the personal costs and trade-offs between career and family. The same message was communicated to participants throughout their career: it is extremely hard to be a mother and a successful scientist. Stories included cautionary tales from other women in leadership positions, watching as women around them struggle or even leave science or put their careers on hold once they have children, and observing how women were negatively treated once they became mothers. Everything from microaggressions and subtle comments to overt discrimination was experienced; these included bias from all genders. Various blogs and campaigns such as 500 Women Scientists’ “Sci-Mom Journey” have started to highlight the gender disparities in child rearing and the challenges faced by women in STEM, but institutional policies have been slow to respond [50]. Struggles begin for many women even before the child is born, including miscarriages and difficulties with getting pregnant; the pain and loss associated with these things are not often talked about and acknowledged by society, let alone amongst

professionals in STEM fields [51]. Once the child is born, participants reported challenges with trying to find spaces to breastfeed or pump at work, getting adequate (or any) parental leave, and the stress of keeping up research productivity—all consistent with challenges reported in the existing literature [24,52,53]. Participants also commonly reported feeling like they have to work harder than their male colleagues to gain the same recognition. This is consistent with studies showing that women faculty with children work 22+ hours more per week across all life domains (work and home) than their male colleagues with children [54]. The challenges of being a mother in STEM have been especially compounded by the coronavirus pandemic. Gender bias and stereotypes have been exacerbated by the fallout of the pandemic on women in STEM, with the heavier burden of caregiving falling more on women, causing drops in academic productivity [26,55]. Policies in academia must begin to address the unequal burden of childrearing that is placed on women in STEM fields in order to mitigate the loss of women in STEM at all levels. In concert, these norms which place child rearing and caregiving as the realm of women must be actively challenged in society.

4.3. Potential Solutions

The results of this study reinforce that the barriers to career progression for women in STEM are common, and that women perceive these barriers as impacting men differently, if at all. The focus groups also identified factors that have helped participants over the course of their careers. The role of mentors was consistently raised, with access to supportive mentors and role models considered valuable by participants. Participants also noted that a non-supportive mentor could be detrimental to careers. This is irrespective of mentor gender. Previous studies have shown that mentors who are members of minoritised groups may be more harsh on fellow group members [56], or put another way, women may be harder on other women [57]. Earlier authors have highlighted that knowledge of the most effective form of mentorship for women in academia is limited [58]. The results from this study indicate that effective mentors can be vital to retaining women in STEM in academia and enhancing their career progression, therefore enhancing our understanding of what works is worth attention. Similarly, many participants expressed that the ability to sit and talk about their experiences with other groups of women in similar contexts was valuable.

Within many of the focus groups, participants shared very personal, emotional stories. Many commented that this was the first time they were having a structured conversation about the experience of being a woman in STEM and, for some, sense of belonging to a community appeared cathartic. The importance of having allies was also consistently raised in focus group discussions. This ranged from having someone in a meeting to reinforce or reiterate their contributions and mitigate being talked over or ignored, through to calling out inappropriate language and comments. The use of allies can help women to create a sense of safety and belonging [59], including when an ally is counter-stereotypical [60], and the results presented in this study further attest. This extends to majority groups (like White men in STEM), whom many participants identified as valuable supporters. Allies should not only be representatives of other minoritised groups. We echo the call of earlier authors for future explorations of the role of allies in supporting women and minoritised groups in STEM to use an intersectional framework, recognising that individuals may have more than one minoritised identity [61].

Each of the categories arising from the qualitative analysis of these focus groups has been discussed or highlighted in the literature before, and is likely not specific to only women in STEM. This study brings a new perspective to this familiar content, through the use of focus groups with women of different nationalities, institutional contexts and career stages. Our results highlight that these barriers are global, persistent at all career stages and damaging. These barriers are consistently hindering the career progression of women and are seemingly resistant to change, despite some fairly simple solutions. Gender equity is not a ‘women’s problem’, it is a societal one, and the onus is on individuals within society

to reshape the gendered norms which currently limit progress to equity and inclusion for women everywhere, not just those in STEM.

Author Contributions: Both authors contributed equally to the conceptualization, method, data collection and formal analysis and writing of this manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: This study was conducted according to the National Statement on Ethical Conduct in Human Research 2007 guidelines (National Health and Medical Research Council Act 1992) and approved by the [blinded] University (2017/593) Human Research Ethics Committee.

Informed Consent Statement: Informed consent was obtained from all subjects involved in this study.

Data Availability Statement: The de-identified data presented in this study are available on request from the corresponding author. The data are not publicly available to protect the confidentiality of the participants and prevent their inadvertent identification through the comments made.

Acknowledgments: Thanks to Aarti Kapoor. and Karina Judd for early comments on this paper. The authors wish to acknowledge the time and contributions of the focus group participants, without whom this work would not have been possible.

Conflicts of Interest: The authors declare no conflict of interest.

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