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A study of factors affecting women's lived experiences in STEM

Elena Prieto-Rodriguez [1]✉, Kristina Sincock[1], Regina Berretta[1], Juanita Todd[1], Sarah Johnson[1], Karen Blackmore[1], Erica Wanless [1], Anna Giacomini[1] & Lauren Gibson[1]

The number of women employed in STEM in Australia is increasing, however, they continue to remain underrepresented in most industries. A significant corpus of literature on female underrepresentation has emerged in the past 20 years, however, many of those studies focus on educational access and retention and not many look at the lived experiences of women after they have left higher education. In this article, we take a different stance and explore the heterogeneous experiences of female STEM professionals in regional Australia. Through the qualitative analysis of 25 interviews, we learn what women have endured, accepted, and valued on their individual STEM journeys. While these journeys are often quite different, our interviewees independently reported having experienced similar societal prejudices and possessing similar personality traits. Our data reveals that resilience and determination proved vital for these women, as did a strong early interest in STEM. Our interviews also unearth issues in which women's opinions are fiercely divided, such as whether positive discrimination has been a barrier or an enabler for their careers. Based on what we have learnt from their accounts, we argue that these women have 'survived' their work environments despite structural barriers, only due to their determination, resilience and fervent interest.

[1] University of Newcastle, Newcastle, Australia. ✉email: Elena.Prieto@newcastle.edu.au

Introduction

The task of attracting women to, and then retaining them in STEM, is well documented. Many attempts have been made to "fix" what has been perhaps problematically labelled as a "leaky pipeline"—that is, the large number of women who do not remain in STEM university programs or STEM careers (Blickenstaff, 2005, p. 722; Glass et al., 2013; Goulden et al., 2011; Liben and Coyle, 2014). Other conceptualisations of this problem, encapsulating the loss of women across multiple pathways into and out of STEM, have been suggested as an alternative to the singular 'leaky pipeline' metaphor (Miller and Wai, 2015). Regardless of the different views on the problem, there is a broad body of literature relating to women's participation in STEM, however, much of this literature centres on issues of access and retention at a school or tertiary level, as most research "has focused on educational issues and academic women" as opposed to women in the STEM workforce (Fassinger and Asay, 2006, p. 431).

A recent report commissioned by the National Centre for Student Equity in Higher Education drawing on data from Longitudinal Surveys of Australian Youth offers new insights into STEM pathways for young people as they progress from school, through tertiary education and into the workforce (McMillan et al., 2021). Among these insights, one resonated highly with the experiences of the authors of this paper: "When it comes to transition into a STEM occupation, fewer than one in three STEM university commencers go into a STEM occupation, and for women in STEM the transition rate is even lower, at one in four" (McMillan et al., 2021, p. 1). What happens to women who are successful in their tertiary education endeavours, and yet leave their desired profession?

The existing literature helps us to understand the barriers women face entering the workforce, however, little research sheds light on which factors influence retention once their careers begin. One qualitative study of women ($N = 30$) working in Natural Resource industries (energy, mining, forestry) in Canada identified a number of barriers to recruitment, retention, and advancement in their careers including; work commitment and competency inequitably being questioned after returning from parental leave, a lack of information and awareness of opportunities available in the sector (partly due to a lack of informal networks), and, an 'old boys' club' workplace culture where women experience isolation, mockery, and sexual harassment (Baruah and Biskupski-Mujanovic, 2021). Women working in other male-dominated industries such as the legal profession, report similar barriers to employment, with specific barriers such as implicit gender bias (e.g., associating judges with men) impacting hiring practices, and an expectation that women complete additional administrative work that does not benefit their career progression, also noted (LaPira et al., 2020; Levinson and Young, 2010; Sterling and Reichman, 2012). Across these studies and industries, both individual and structural factors are identified as interacting and interfering with women's ability to succeed in these male-dominated workforces. As the STEM workforce is considered an essential part of the future of all countries, and there appears to be a global shortage of STEM graduates required to meet industry needs, it seems imperative to find ways to retain women in this STEM careers (Corrigan and Aikens, 2020; Lazio and Ford, 2019).

The aim of this paper is to explore the lived experiences of a group of women in regional Australia in order to unearth what enabled their journeys in STEM. We focus on the exploration of positive influences (referred to from this point as *enablers*), something that, to our knowledge, few others have done (Bilimoria et al., 2014). We also try to uncover the barriers to retention in their chosen careers, so that our region, and perhaps our society, might be better equipped to increase the number of women who find secure long-term employment in STEM fields.

The paper is structured to provide an overview of literature informing the research, followed by a thorough description of how the study was conducted and the main findings observed. The following section begins with a review of literature on the barriers to STEM engagement before considering STEM engagement enablers. Following this, the methodology used to address our research question, including the study sample, recruitment procedure, interview guide, and transcription and qualitative analysis process is presented. The "Analysis" section provides a detailed description of each of the barrier and enabler themes relating to women's STEM career paths. Lastly, the "Discussion" section summarises the key findings from the study, contextualises the findings within previous relevant literature, identifies limitations of the study, and provides a conclusion including directions for future work in this area.

Literature review

Barriers to STEM engagement. A characteristic of literature concerning barriers is that it commonly (and, we will suggest, sometimes problematically) separates the individual and the structural barriers to engagement (Blickenstaff, 2005; van den Hurk et al., 2019). This separation suggests that individual motivations are not influenced by societal pressures, a suggestion we find untenable. A focus on individual barriers can lead to the belief that it is solely women's responsibility to adapt themselves in order that they are 'STEM ready'. Here the implication is that girls and women "are in some way inadequately prepared to learn from or fully participate or succeed in STEM" (Liben and Coyle, 2014, p. 92). This not only ignores the "differential perspectives" (Heybach and Pickup, 2017, p. 615) women might bring to a traditionally masculine, fixed construction of STEM, but also marks them as lacking in some fundamental 'STEM' characteristic. Also, explaining lack of engagement with STEM as being a result of innate female characteristics, suggests that women inhabit an "essentialized experience of being a woman that a pink version of STEM resolves" (Heybach and Pickup, 2017, p. 615).

Individual academic performance has historically been an area of interest when analysing the failure of STEM to engage women as often as men. Claims of biological differences have now largely been dismissed, except for the persistent belief by some, that males have superior mathematical and spatial abilities, while women perform better in verbal activities (Blickenstaff, 2005; Ceci and Williams, 2010; Ceci et al., 2009). Even if a difference in academic ability can be found, it is so small as to not adequately explain gender differences in STEM participation (van den Hurk et al., 2019). It is observed that children who identify as girls who do have a high level of STEM ability, also often have high verbal ability in comparison to boys, providing them more career choice, and reducing the chance they will follow a STEM path (Wang et al., 2013). Girls' possessing less preference for STEM than boys might be considered an individual influencing factor, but this would rely on the (perhaps unlikely) assumption that choices are freely made and not "constrained by biology and society" (Ceci and Williams, 2010, p. 278).

Other literature considers structural barriers to engagement. In the school environment, social background, specifically high school students' beliefs about the way that gender and race influence their compatibility with STEM pursuits, has been found to impact STEM engagement "at a developmental time when many adolescents make critical decisions about future academic and career pathways" (Grossman and Porche, 2014, p. 722). While some claim that "cultural and discriminatory causal

pathways may be less important today than in the past" (Ceci et al., 2009, p. 251), other evidence suggests that these barriers still exist. Interviews with 28 STEM PhD students revealed that, despite early support from teachers and family, once women reached graduate school they experience an informal culture which positions them as outsiders, they experience a lack of role models, and they find that academic careers conflict with having children (De Welde and Laursen, 2011). The barriers women tackle on their paths in STEM have been characterised as a 'glass obstacle course', a term which encapsulates factors such as the 'Old Boys' Club', a lack of women role models, outright sexism, and finding a work/life balance. These obstacles are "unseen, yet unbreachable", and lead women to "question their ability to succeed and thrive in their discipline" (De Welde and Laursen, 2011, pp. 571–577). This trend of structural barriers has been observed as continuing once women enter the workplace. Motherhood has been identified as increasing the chance that women's presence in the STEM workplace might have been considered tokenistic rather than significant and influential (Glass et al., 2013; Heilbronner, 2013). Ceci, Williams and Barnett acknowledge that women are "expected to devote more time than men to family matters" (2009, p. 247). However, family factors cannot account for the much larger loss of women from STEM careers than from other professional fields, and enablers such as advanced training, high job satisfaction and a supportive environment have been identified as missing for women in STEM contexts (Glass et al., 2013).

Isolation is also considered a barrier; the "lack of a critical mass of women in STEM fields, especially at higher levels of authority" makes women "vulnerable to the ideologies of gender-conservative men" (Glass et al., 2013, p. 727), and loneliness at work discourages women from sticking with STEM careers (Heilbronner, 2013). Other barriers such as employers' perceptions of gendered ability mean that women are less likely to be promoted as quickly or paid as much as their male colleagues (Glass et al., 2013). Field segregation, salary discrepancies when compared to men, and "persistent difficulties in achieving the same levels of support and recognition for their work as men", were cited as ongoing barriers (Fassinger and Asay, 2006, p. 432). For example, an Australian study of women in the mining industry found that "lack of flexible work arrangements, gender-biased work practices and processes, a work environment that is not conducive to family, and requirements for travel and work in remote locations" were disincentives to stay in the industry (Nowak et al., 2014, p. 73).

Enablers to STEM engagement. Correcting the inequity created by structural barriers cannot be achieved by simply removing existing barriers; "to achieve inclusion, it is not sufficient to curb exclusion mechanisms but to enhance positive measures of inclusion" (Faulkner and Lie, 2007, p. 157). It is clear that explicit efforts are required to enable women to enter and be retained in STEM careers—and these efforts must include the transformation of "gender-socialisation practices" which will then allow women the "freedom and support to actualise into their best selves" (Fassinger and Asay, 2006, pp. 450–451). Individual solutions are "wholly inadequate" (Fassinger and Asay, 2006, p. 450) in addressing these entrenched structural barriers, and instead institutions and broader society must accept that change is required.

Participation in Living-Learning Programs, in which students live with their peers in intentional communities, has been shown to lead to improved expectation of overall professional outcome and career success (Carrino and Gerace, 2016), and expectations that participants might achieve career success in combination with a "balanced personal life" (Szelényi et al., 2013, p. 865). Other characteristics of learning environments such as smaller class size, student access to faculty offices, a cooperative rather than competitive peer culture and efforts of faculty to encourage and promote students' success might mitigate the negative impact of some barriers on minorities such as women of colour (Perna et al., 2010). Grossman and Porche consider it critical that "majority students and boys" learn about inclusion, and that this might lead to an appreciation of diversity (2014, p. 721). This speaks to the need for structural rather than individual change.

Beyond the educational context, Faulkner and Lie (2007) emphasise that women are heterogeneous and that factors which might enable their engagement with STEM are therefore varied. However, they conclude that the support of "local experts" (p. 165), i.e., those who operate in the same context as the women being encouraged into the field, is important. One study noted that women are more likely to be resilient and feel that they belong despite being in a gender minority, when they "have professional experiences indicating that they are valued and accepted in the engineering profession" (Richman et al., 2011, p. 494). Another study explored the ways in which career counselling might support women in finding strategies to thrive (Fassinger and Asay, 2006).

At the individual level, Heilbronner (2013) observes that interest is a highly influential factor in whether women enter STEM fields; that "more women are entering STEM than ever before" (p. 52); and that talented women "do not appear to shirk from competition or most of the traditional influences that in the past have driven them out of STEM fields" (p. 52). It is important to remember that individual interest is likely influenced by environmental factors, and that women should not have to rely on being competitive, in order to survive in STEM fields. In fact, the persistent minority of women in comparison to men in STEM fields shows that these individual factors are not adequate in fixing the shortage of women in STEM.

With consideration of the existing literature, as well as a specific interest in increasing female STEM participation in our locality, we conducted interviews to investigate the lived experiences of female STEM professionals. The questions in our interview aimed to track the STEM education and career path of our interviewees, and to highlight childhood aspirations and interest, as well as record specific examples of barriers and enablers. Interviews were driven by the following research question:

What do the experiences of our interviewees tell us about the nature and impact of barriers and enablers for 25 female STEM professionals in Australia?

Methodology

Our participants are 25 women working in STEM fields, and currently employed in either an academic or industry setting. Through purposeful recruitment of females working in STEM, we employed a snowball sampling strategy, reaching out via email within our STEM communities, and recruiting by word of mouth without a "sampling frame" but with the intention to achieve a level of interconnectedness (Check and Schutt, 2012, p. 105; Creswell, 2013). Potential participants were members of a network of women working in STEM in the Hunter region of New South Wales, Australia ($N = 32$ members at the time). The network offers women mentoring, workshop, and networking opportunities with the aim of retaining women in the STEM workforce. Participants' age range and level of experience is broad. Most of the interviewees were Australian, but several were born overseas and came to Australia to study or work. These

Table 1 Categorisation of factors influencing women's STEM career paths (number of references contributing to each sub-category across participants).

Barriers					
Gendered workplace	Old boys' club (77)	Lack of confidence to complain (54)	Isolation (62)	Difficulty gaining promotion (38)	Harassment (36)
Sexism and gender stereotypes	Perceptions of gendered ability (60)	Few role models (45)	Childhood experiences (39)	Uninformed about STEM (70)	
Expectations about women's responsibilities	Motherhood (76)	Work–family balance (56)			
Enablers					
Aptitude	Determined and resilient nature (74)	Broad skill base (41)	Belief in equal ability (43)	Natural STEM aptitude (43)	
Role models and mentors	Teachers (29)	Mentor (51)	Female role model (49)	Supportive family environment (32)	
Supportive workplace	Increased gender equity (36)	Positive discrimination (19)			
Internal motivations	Interest as young girl (32)	Lifelong interest (70)	Desire to do purposeful work (28)		

demographic data, however, were not collected explicitly when the interviews took place.

The interviews were carried out by the first two authors at a location that was convenient to participants (either via telephone or in their workplace) between August 2017 and June 2018. Interviews were structured in three main sections which explored their (1) childhood aspirations; (2) perceptions of equal opportunity in STEM, and; (3) experiences of barriers and enablers. The interview questions were informed by relevant previous literature and identification of themes we were interested in exploring among a local sample of women in STEM. Interviews ranged from 15 to 75 min in duration, with more than half exceeding thirty minutes. Before interviews commenced, women had the opportunity to read the questions and were given information regarding the anonymity of their answers. This paper focuses on the third part of the interview, although it does also consider the way childhood aspirations and perceptions about opportunity can influence paths towards STEM.

Once interviews were completed, the recordings were transcribed and de-identified. Methodologically, we acknowledge that when it comes to transcribing interviews there is "no transcription notation system capable of providing to the researcher a completely accurate and comprehensive narrative of the original performance" (Kowal and O'Connell, 2014, pp. 65–66). In an attempt to, at least partially, address this, transcripts were sent to interviewees to be checked for accuracy in the transcription itself, and to allow participants to remove or add to their answers if they so desired. Several participants made slight changes to their transcripts, with some elaborating on points they had previously made.

The transcribed interviews were analysed using QSR-International (2014) NVivo 12 software. Codes, and then broader themes, were developed by the first two authors both deductively and inductively, allowing for evidenced based analysis without ruling out the emergence of new ideas or understandings of the data. The fifth author scanned all the codes and checked for inconsistencies. Some codes were derived from themes present in existing literature, but that also appeared in our data. Other codes emerged as the transcripts were analysed and had not been considered by us previously in the context of this research. After a first read of the interviews it was clear that codes fell into the two broad themes of Enablers and Barriers. Although we were primarily interested in uncovering what has enabled women's careers, it was clear that many barriers persisted, and therefore could not be ignored. Interestingly, the code *Positive discrimination* did not fit neatly into either the Enablers or Barriers theme. This confirmed that importantly, as Bazeley and Richards observe, by "keeping questions open, we allow ourselves to be informed by the data, redirected, surprised" (2000, p. 10). Our method of data collection and analysis was designed to draw out the diversity of individual experiences of women and provide scope for spontaneous details to emerge (Maxwell and Chmiel, 2014).

Codes that were raised by a small number of women are not discussed in detail below. While we were wary of neglecting less common experiences, we decided that some of our codes, while providing insights that might be explored further in another article, did not reflect the concerns of a significant proportion of our participants. Table 1 shows the broad categories into which the responses we analysed fell, as well as the sub-categories within each of these broader categories. In order to protect the identity of our participants, all names used in this paper are pseudonyms.

Analysis

Barriers to STEM careers

The gendered workplace. The most common barrier to STEM careers that our participants referred to fell under the broad theme of a *Gendered Workplace*. There were five subcategories within this theme.

1. *Old Boys' Club* was the barrier most commonly mentioned by our participants. A picture emerged of a work environment created by men, which women must simply tolerate or adjust to, as they worked "within a system developed by men for men [that] hasn't changed" (Freda). Several women commented on men not necessarily wanting "the girls around this blokey environment" (Sally) and reflected on an "old boys' club mentality" (Lorraine). Sometimes the nature of the gendered environment was subtle, but this did not take away from the negative impact it had on women:

> I didn't feel like they purposely discriminated against me, but I know that sometimes they would do things

> without thinking about it. There were a couple of small incidents that made me feel a little bit uncomfortable because they brought my gender into it or they made a comment about something that was maybe a tiny bit sexual. It sort of—they didn't realise it made me uncomfortable and I didn't make it an issue because it was small enough that I could maybe let it slide (Jane).

2. Women *lacked confidence and were wary of complaining* in this environment, often leaving them without a voice to challenge discrimination. One woman shared:

> We think that nothing is going to happen if we report because we've seen stories of people who reported and nothing happened so we think it's a waste of time and because it's not only the time, you also put a lot of effort in there and it makes you angry, and if nothing happens it makes you even more angry (Alice).

This woman's assumption that her complaints would go unheeded was not isolated. Many participants felt that they had to tread a fine line in terms of not "coming across as the whinger" (Agnes) and often decided "to brush it off, […] ignore it, and move on" (Nia). Women avoided reacting in what might be perceived as 'emotional' ways. As one participant notes, "if you reply in a very bad way, or with a very excessive reaction it doesn't work at all" (Paula).

3. *Isolation in the workplace* left women feeling acutely aware of their minority status. Many of their workplaces "had never had a female engineer before" (Debbie). One woman even reported not taking a well-paid position at an engineering company because she "didn't think they were diverse enough and I didn't want to work in that environment where it was just me" (Jane). Some women were understandably not prepared to act as the forerunners and break ground in an often-challenging environment when they "always stood out" (Sally).
4. *Difficulty gaining promotion into higher level positions*, was frequently observed as women progressed towards a "senior role" (Lorraine). It is at the higher levels of management where "the unconscious bias really starts to come in" (Catherine). This glass ceiling effect was largely read by our participants as a result of the breaks they had taken to have families, and the often part-time roles they took on once they returned to work as "there is a history of the women who work part time to not be eligible for management roles" (Hannah). This can lead to women not applying for managerial positions. As one participant suggested: "I haven't been interested in applying for things like team leader positions because I felt like there was an expectation that you would work full time" (Nia).
5. *Sexual harassment or verbal abuse* are also reported:

> Sexual harassment? Totally. Inappropriate conduct within the workplace? Totally, completely. If you want to take that the next step forward that is active blocking of career because when someone makes suggestive remarks about my vagina in a […] meeting when I'm the only female […] I got asked whether I shave my vagina or not in [this] meeting, in front of a full room full of male colleagues (Freda).

> The comment above clearly depicts an example which would be considered by the Australian Human Rights Commission (Sex Discrimination Act, 1984) as sexual harassment, and illustrates the very challenging work environment which some women encounter. Unfortunately, it was not the only time we heard such comments in our interviews, with another participant saying that she was asked to work on the shop floor and "there were bets going around as to who I would sleep with first" (Debbie). Another participant reported to her manager that she had been followed home by a colleague, found that "nothing happened to him", and was told that if she felt uncomfortable, she could move office, while his behaviour was ignored (Alice).

Sexism and gender stereotypes within society. Our interview data suggests that levels of sexism within broader society hamper women's ability or willingness to enter STEM careers and stick with them, with five main sub-categories deterring these women from STEM careers.

1. *Perceptions of gendered ability* were reported by our interviewees, with a long-established sense within society of "social norms that are, sort of, not allowing people to think that a woman's as good as a guy" (Lorraine). They observed that women can underestimate their own capabilities and assume some jobs are not appropriate, believing that "that's not a girl thing" (Sally). At other times it was men, often older ones, who doubted women's abilities: one interviewee reported that an older family friend "just felt that particularly as a woman it would be too challenging [to be and engineer]" (Catherine); while another women was told "that's a lot of responsibility you've taken on there'" (Cherie). Societal influences pressure women, creating doubts about whether a role in STEM is appropriate for them.
2. Encountering *few role models* led women to comment: "you can't be what you can't see" (Sally). This is described at the university level: "when I was an undergrad […] we had no female lecturers, not one, not a single one" (Jane), and continues into the workplace: "there isn't too many women in leadership but a lot of that is to do with that there just isn't many women in the company at all" (Susanna). Women describe an environment where they often feel they are breaking new ground, which can be a challenging position. This extends to many of them reporting that "the majority of [their] family members were not university educated" (Sophie). In these cases, our interviewees were breaking new ground in their own families in terms of gaining an education as well as challenging gender expectations.
3. *Childhood conditioning or experiences* were considered influential with one participant describing the Australian culture in which she grew up, as one in which "the man is still seen as the one that has more time to focus on his career and the woman is still seen as someone that has also other career responsibilities in terms of family and looking after the kids and the house" (Paula). Another woman described "conditioning" as the way 'appropriate' female careers were suggested to her (Sophie). For other women this conditioning was less overt, but just as insidious. A young engineer believed that if girls were exposed to materials and toys that are commonly only given to boys it might "help us to develop some of the cognitive abilities

that men might have from a young age, so that when we do realise that we want to take up this career we don't have to catch up" (Sophie). These women felt that the way they were treated as children has placed them at a disadvantage which they must overcome before they consider themselves at a par, and able to compete in the job market, with men in STEM.

4. Being *uninformed about STEM* was a commonly stated barrier for interviewees when they considered their childhoods. One woman described how during her school years she "didn't actually know anything about scientists or engineers and [she] didn't have any opportunities to talk to any" (Sophie). When it came to career opportunities in STEM, one woman reported not "quite understand[ing] what they were" or having been exposed to them (Catherine). While being uninformed about STEM was clearly a significant barrier for these women, we acknowledge that this is also often a barrier for boys, and that young people of both genders "have very little awareness of the diversity of careers that science can lead to" (Archer et al., 2014, p. 38).
5. *Positive discrimination* might be considered an enabler for women pursuing careers in STEM, but several of our participants felt that perceptions of positive discrimination actually damaged the level of respect they received in the workplace. One woman saw positive discrimination as having a "stigma" and making it look like "women were getting extra advantages" (Sally). She claimed:

> Some of the initiatives even made me start to question, when a woman was promoted, whether she got the promotion because she was female (to make targets, quotas, optics, politics) or she was competent. And that is awful for a senior female to start thinking that (Sally).

We observed a cynicism about positive discrimination which sometimes undermined women's confidence in their own abilities as they wondered whether "if I achieved something it wasn't because I'd earned it, it was because I was a woman" (Samantha). There was a feeling that sometimes positive discrimination was tokenistic and that it was only useful "when it's done meaningfully as opposed to filling quotas" (Camilla).

Expectations about women's responsibilities. Responses categorised under this theme sometimes overlap with those categorised in the two broad themes above, but we have separated them because they specifically describe the way that having children, or caring for others, affects the way women are able to operate in their workplace.

1. *Motherhood affects professional status* was the second most commonly mentioned barrier for our interviewees. Many women described experiencing a smooth career path until they fell pregnant. In fact, they perceived the biggest discrimination was "against having children rather than being a woman" (Marina). Taking a break from their careers for maternity leave was perceived as detrimental, a move that "will just kill you" (Samantha). Some of our participants observed that female colleagues were even reluctant to openly discuss plans to have a family because "it might limit the training they might get" (Susanna). The narrative around maternity leave was associated with careers that "take another hit" (Hannah) and "lose momentum" (Samantha), and whose "track record" (Samantha) will be affected. One participant who didn't have children recognised that she "wouldn't have got to what [she has] achieved, in the timeframe [she] did, if [she] had stopped and had children" (Sally).
2. *Work–family balance* was a challenge because the STEM workplace is often somewhere where, "you need to work full-time and it needs to be long hours" (Marina). This was prohibitive for women who were looking for flexible work arrangements so that they could meet a range of out of work responsibilities—as this woman claimed: "my priority is not just my work" (Marina). Another interviewee described how even with a supportive employer she was faced with "an impossible equation" because there are simply not enough hours in the day (Cherie). One woman observes that women are still the "central pillar of the organisation of the family routine", a situation which "interferes […] with career progression" (Paula).
Several women considered the dynamic with their partner as negatively influencing their ability to pursue their career, observing that: "the degree of difficulty of getting to a very senior rank, unless you have an extremely supportive husband, you just can't do it" (Sally), and that often "women don't have either flexibility, mobility, support in the home environment—all things that can facilitate careers in general" (Kate). The implication is that it remains unusual for a male partner to break with traditional gender roles and take on responsibilities in the home which might enable women to pursue full-time careers.

Enablers to STEM careers

Aptitude. The most common ways that women reported being able to access and maintain STEM careers fell under the broad theme of *Aptitude*. Within this theme, we found four specific categories.

1. Possessing a *competitive, determined or resilient nature* was the most common factor described by women as enabling their success in STEM:

> it is so hard to, to survive in this kind of environment for a woman, so that requires the development of some skills…the resilience, with the…cognitive reappraisal, you know like you need to do a lot of work and build some internal strength to endure the kind of, kind of subtle messages of discounting that you often encounter because of your gender (Agnes).

Women spoke of being "driven from within" (Freda), having confidence and being competitive. Women described themselves as being "an adventurer" (Paula), "a risk-taker" (Catherine), and told us that they had made their own pathways and found success through "sheer perseverance" (Sophie).

2. A *broad skill base* was observed by interviewees to be a benefit that women can bring to STEM. They observed that "we think a little differently" (Alison) but this "actually bring[s] a lot of skills that [are] missing in STEM" (Samantha). One woman described the combination of skills required in STEM and the way that women can meet these requirements:

> What industry really wants is people who can do those things but who can lead people, who can think critically, solve problems and all that kind of stuff. So when you take that technical skill and you add this

> other layer, of perhaps people who wouldn't have been attracted to the profession in the past, what you get is this golden combination that opens doors (Catherine).

Our interviewees believed in women's capability to do all the things that men can do, but to also bring a variety of other skills: women, we heard, "grow up multitasking" (Paula); they are great at "motivating people" (Debbie), and are "really good communicators" (Debbie). Our interviewees show an awareness of the qualities which have traditionally been considered feminine, but they also rate themselves highly at the types of skills that have historically been associated with men.

3. A *belief in equal ability to men* was expressed by a large proportion of our participants: "there's no difference between men's and women's brains" (Lorraine). Some interviewees believed that because of prejudices around women in STEM, they have to work harder, and be more capable than men who have equal positions, because "to get anywhere you have to be twice as good" (Hannah).
4. *Natural aptitude* at STEM was identified in women who described themselves as "the person who always fixed things" (Freda), or for whom STEM skills "seem to come pretty naturally" (Caterina). These women have an affinity with design or problem solving which is a natural fit with STEM careers, they "just have a knack for it" (Marina). This was often paired with "an excellent UAI" (University Admission Index was a rank given to New South Wales students and used as criterion for university entry) (Sophie) or being "a top student" (Debbie). The majority of our participants identify as "high achievers" (Toula). This, coupled with their oft-reported "competitive" (Kate) natures and desire for "challenge" (Sally), seems to have driven their STEM success.

Encouragement from role models or mentors. Role models and mentors are described by interviewees as being hugely influential on women's study and career choices. These role models fall into four subcategories.

1. *Teachers* were identified by many of our interviewees as being instrumental in providing encouragement and support that led them into STEM degree programs. These teachers were described as "fantastic" (Kate), "really engaged and interesting" (Jane), "passionate and helpful" (Sophie), "unorthodox" (Agnes), "quite amazing" (Marina), and "very supportive" (Mia). Interestingly, only one participant identified a careers advisor as being influential on their path towards STEM.
2. A *mentor*, male or female, had been instrumental in helping many of our interviewees to succeed. Mentors who had been on their "side in the tough times" (Paula) to "challenge that self-doubt" (Agnes), gave women confidence, and encouraged them to go for promotions or explore new opportunities.
3. *Female role models* were also influential. The first positive female influence was sometimes a school visit from a STEM industry representative or university student. One participant noted of one such visit: their "experiences in the degree being so positive really did draw me to that engineering degree" (Jane). Once established in a workplace, a collegial network of female colleagues is "invaluable" (Freda) as it "normalises that experience of self-doubt, [and] imposter syndrome" (Agnes). Women value the "feeling that you're not alone" (Agnes) and the "sense of belonging" (Diane) that female support can bring.
4. A *supportive family environment* was also reported as enabling women's trajectories towards and within STEM careers. Participants shared with us the way they "were given every help at home to make the most of our studies" (Kate); that they were told by parents that "we could do anything" (Jane); or were provided tutoring to help achieve high academic results. As adults, participants also experienced support from their family, specifically one whose husband: "works part-time and takes care of the kids"; and another whose husband "shares with me the [family] responsibility". The narrative remains one in which women whose careers progress even after having children, are those whose "relationship with their partner […] enables that" (Hannah). This is a relatively unexplored field in the literature, and a potential area for further research.

Supportive workplace. Some of our interviewees also encountered support within their workplace.

1. *Increased gender equity* was reported by several of our participants: "women today have a lot more control over their own life and they can get […] the same opportunities as men" (Francesca). Some of our participants' comments reflect the very recent *in*equity which they see as gradually changing: "when I was at one of the mines they actually finally installed a female toilet underground for us"; another reports being told by a male colleague that she had shown him that, "you don't have to be butch to be an engineer". One participant suggested that:

> It's about building trust with your colleagues as well, find the people, find the blokes in the workplace that support you, I hear a lot of women say that they are not supported for whatever reason and a lot of it is systemic, and also individual clashes and things like that, so I just made a point of finding the people that do support you, and the way you get support, doesn't matter male, female is trust, building the relationship and doing a good job (Toula).

This indicates, once again, the responsibility women take in trying to make the workplace more equitable, and the ways they rely on their own resilience to overcome systemic barriers.

2. *Positive discrimination* was reported by some of our interviewees who emphasised that employers must "put forward some legislation or policies over a certain amount of time that bring people on equal footing" (Camilla). They noted that if equity already existed our government and universities "wouldn't be having all these programs for young girls" (Sally). Most of the comments our participants made in relation to positive discrimination simply acknowledged that it was happening in the companies that they worked for.

Internal motivations. Three subcategories emerged as internal motivators for STEM careers.

1. STEM *aspiration as a young girl* was present for some participants who shared with us that their STEM interest meant they could see themselves "as a scientist or engineer in high school" (Jane). Some described being drawn to science in primary school and being "very inquisitive" (Agnes) or "curious" (Francesca). Sometimes this early interest was piqued because the girls grew up knowing

someone in STEM, while others were motivated purely by their own curiosity.

2. *Interest* in STEM-related fields throughout their lifetime was also a common theme. One participant described herself as being drawn to a "logical, fact-finding, science-related field", and reported that "I like to know how things work" (Sally). One woman shared that she likes "the logic of [STEM] and being able to have a formula and get the answer" (Toula). Another interviewee told us "I always fixed things. I was always mechanically minded", another described how she "used to pull everything apart", and yet another that she loved "designing things and trying to fit everything together in a little puzzle". Interest in STEM was also prompted by Lego, and by strong female characters in *Star Trek*.
3. *Desire to do purposeful work* was reported by just under half of our interviewees as they believed a STEM career might be purposeful and help society or the environment. These participants believed that women were motivated by working towards a "compassionate, real reason, a real outcome, something that's beneficial" (Sally) or activities that have a "social impact" (Debbie) and can "actually making a difference" (Debbie).

Discussion

This article reports on the analysis of interview data within a project aimed to explore the lived experiences of female STEM professionals. Our analysis focuses on the most influential enablers that have equipped these women on their STEM career pathways, as well as uncovering some of the major barriers they have encountered from an early age to their present positions. We found that interest in STEM and having a competitive, determined or resilient nature were identified by our participants as major contributors to enabling their STEM paths. The major challenges they reported were the way motherhood affects professional status, the gendered nature of STEM work environments, and a pervasive lack of information about STEM careers in their youth. It is important to acknowledge that these interviews were held with women who have 'made it' in STEM. Many others, we might assume, start on STEM paths, but are adversely affected by some of the challenges described above. Others, potentially, may not have an interest in STEM, or while they might have shown an early interest, are put off by societal influences which still deem STEM as a predominantly male.

Our analysis of the factors most likely to have impacted our participants' careers in STEM suggests a persistent tension between the influence of enablers and barriers. As we discussed in our "Introduction" section, we find it untenable to claim that individual motivations are not affected by structural influences within society, in discouraging women from pursuing STEM careers. However, we have observed that of the top eight most commonly mentioned influential factors (see Fig. 1), the ones that acted as *enablers* (represented in orange in Fig. 1) for these women were all *individual* factors, driven by the personal characteristics that our interviewees claim to possess often from an early age. The *barriers* (represented in blue) most commonly mentioned by our participants were ones that existed in the environments in which they grew up and worked; these *structural* barriers exist within our society, and are embedded in persistent beliefs about traditional gender roles. Viewing our data from this perspective provides a picture of women's enduring individual resilience within a challenging social environment.

We repeatedly heard women tell us that it was their confidence, drive or perseverance that enabled them to continue along a

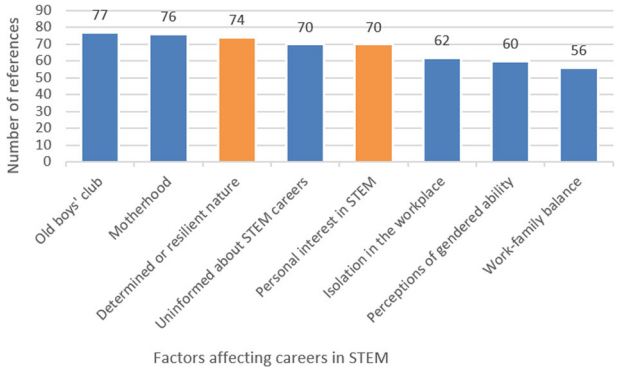

Fig. 1 Top 8 factors affecting participants' careers in STEM. Barriers are represented by the blue bars and enablers are represented by the orange bars. The number of references made to each of the barriers and enablers is noted above each bar.

STEM path: 23 of the 25 participants related stories where these elements of their personality propelled them forward on a STEM trajectory. The literature suggests this might not be exclusive to our participants. The connection between personality and career success (with success defined by factors such as higher salaries, being promoted and career satisfaction), is well established, with studies finding that the ability to "identify opportunities and act on them, show initiative, and persevere until [bringing about] meaningful change" has a significant positive impact on success (Seibert et al., 1999, p. 417). This type of proactive personality, often accompanied with recollections of academic achievement, could be identified in the attitudes expressed by many of our interviewees. This reinforces the notion that in order to forge long-term STEM careers, it is a pre-requisite for women to believe fervently in themselves and have confidence in their abilities (Ackerman et al., 2013). These findings are in line with previous research and suggest programs should focus on building these constructs across different education levels (i.e. high school and university) to promote retention of women in STEM careers (Botella et al., 2019; Heilbronner, 2013).

Consistent with previous research, interest in STEM was a major influence on decisions to pursue a STEM career among participants, and often led to success *despite* the hurdles that women have had to overcome. For example, in a previous study by Heilbronner (2013) ($N = 351$), 'Interest' was rated as the most influential factor on occupational selection among STEM professionals, compared to other factors such as financial reward, flexible hours, and prestige. While the different interests of men and women have been described as "one of the most important psychological mechanisms that underlie gendered career choices and gender disparities in the STEM fields" (Su and Rounds, 2015, p. 1), and improving interest may rely on changing girls' perceptions of STEM (Blickenstaff, 2005), we find it problematic to suggest that girls have a defective view of science, or that science is not a natural fit for them. Instead, we argue it would be preferable to focus on how understandings of STEM should involve "reclaiming scientific enquiry as a non-hegemonic endeavour" (Heybach and Pickup, 2017, p. 624) or, in the words of pioneering feminist physicist Evelyn Fox Keller, to promote efforts towards creating a society in which science is considered "a human instead of a masculine project" (1985, p. 178). If this is possible, then it follows that more girls and women would show interest in, and choose to follow, STEM pursuits.

Dismantling the gendered or bullying environment so commonly reported by our interviewees would lead to STEM workplaces becoming 'human' rather than 'masculine' dominated domains. The experiences of participants in our study are

consistent with those of women working in STEM institutions in the U.S.; where women perceived a more negative workplace climate compared to men, including: discrimination, sexism, and poor work/life balance, collegiality and department perceptions of their productivity (Riffle et al., 2013). Subsequently, men were more satisfied with their STEM jobs and had higher intentions to stay compared to women (Riffle et al., 2013). Part of dismantling these negative workplace environments might include making changes to the way that women's careers are often detrimentally affected when they become mothers, as working full-time becomes extremely challenging. We know that workplace climate issues seem to affect women for longer in STEM careers than in other fields, and our data might help to promote an understanding of the "peculiar unmeasured features of STEM jobs that are difficult to combine with family life" and the way these features become more prominent as women climb (or fail to climb as quickly as men) the workplace hierarchy (Glass et al., 2013, p. 744).

Our interviewees perceived that STEM careers might be especially challenging for women because the expectation is that one works very long hours, that it is preferred by (frequently male) management that employees work full-time, and that some employers are sceptical about women's commitment to work once they have children. Ceci, Williams and Barnett, suggest that "family–career trade-offs constitute a major factor in the dearth of women in fields such as engineering, physics, computer science" (2009, p. 232). While this might appear on the surface to be an individual preference, we suggest that such trade-offs might not always be made simply because women independently *prefer* motherhood over a career (although some may do so). Instead, our data suggests that often women feel obliged to reduce their hours following childbirth because of societal expectations about motherhood, because workplace environments are not always conducive to infant feeding and bonding with the mother, and do not offer flexible rosters, or because it is simply impossible to manage all the home-keeping expectations placed on them, as well as a full-time STEM position.

We also argue that societal expectations are a reason why girls often remain uninformed about STEM careers at school. Our sample consisted of women who overcame this hurdle, but they still repeatedly mentioned how little they knew about engineering and other STEM careers at a young age. It is possible that boys experience a similar dearth of information regarding STEM careers, and on the surface, this might appear to be an easy problem to solve—schools must simply do a better job at marketing STEM tertiary courses and potential careers. However, this is complicated by the fact that girls might remain uninformed about STEM careers because of the way societal perception of gendered ability or responsibilities means they are either encouraged away from, or self-de-select from, such marketing. According to Parson and Ozaki (2018), "viewing an institution as gendered shifts the focus from the individual to the structure when exploring gender discrimination" (p. 173). We suggest that institutions such as schools and universities must do more to challenge society's gendered conception of STEM. Specific actions to challenge these gendered conceptions and better retain women in STEM (particularly beyond undergraduate study) were identified by a group of international researchers and policy makers ($N = 44$) during a round-table conversation. Actions included: campaigns and events to promote a shift in culture and gender stereotypes, psychological support for women to improve self-esteem, support groups, and the creation of 'bridges' from undergraduate to postgraduate study or professional employment, and conversely from professional employment to postgraduate study (García Peñalvo et al., 2019). One real-world example of an initiative aiming to 'bridge' this gap is 'HunterWiSE', creating new and ongoing avenues for collaboration and mentoring opportunities among women working STEM in the Hunter region of Australia (HunterWiSE, 2022).

One last point of discussion in this section is the polarised views around positive discrimination, with our interviewees almost evenly split in their perceptions. While it was sometimes mentioned as an enabler, some participants saw positive discrimination as a hindrance to women being taken seriously in STEM careers. The conflicting perception of positive discrimination as both a barrier and enabler to women's STEM careers is reflected in previous research. While research demonstrates that positive discrimination (in the form of affirmative action or equal employment policies) can improve women's representation in employment generally and leadership positions (Harrison et al., 2006); research also indicates that positive discrimination can lead to a stigma associated with "assumptions of incompetence", and that the beneficiaries of the affirmative action often perceive that others assume this of them (Heilman and Alcott, 2001, p. 574). Attempts to make structural changes, while well-intentioned, can have negative effects, and forcing change without a true cultural shift, might cause more harm than good. Harrison et al. (2006) suggest there are key steps to ensuring affirmative action policies are perceived as fair (subsequently leading to supportive attitudes towards such policies), including using transparent selection procedures and communicating the justification of affirmative action to employees, emphasising "the need to redress past discrimination and the practical value of the diverse workforce that results from successful AAPS [affirmative action policies]".

Limitations

The findings of this study must be considered within the following limitations. Firstly, the data were collected up to four years ago and therefore it is possible that the current experiences of STEM professionals may differ to those reported in this paper. Further, due to sampling from a network of women currently employed in STEM professions, it is possible we are missing the perspectives of women who were unable to attain or maintain employment in their chosen STEM profession. Therefore, further research among such women may offer important insights regarding the barriers to overcome in order to retain women in STEM careers.

Conclusion

Undoubtedly, not all women in STEM, even all women in STEM in the locality where our research took place, have the same experiences leading to career choices. The heterogeneous nature of our sample contributes to the richness of our data and indicates that there is no 'one size fits all' solution to engaging and retaining women in STEM, even for women in a relatively small regional area. Although our interviewees' determination and resilience are admirable, it is a poor indictment of STEM fields that such personality traits appear to be a pre-requisite for success. Indeed, it would be problematic to assume that we can simply leave the problem of low female engagement in STEM in the hands of those determined and resilient women who might go some way towards correcting this gender imbalance. It would be also terribly problematic, we believe, to try to change women who do not possess this nature in order to make them fit within flawed structures which prevent them from succeeding. Our data indicates that many women are well equipped and are enthusiastic to follow STEM careers. When we consider the barriers to STEM that this article discusses, it is logical to assume that many more women would take an interest in STEM if they were not hindered by sexism and gender stereotypes within society and the

workplace. It might appear on the surface that *individual* characteristics drive women towards STEM careers. However, the data from our interviewees suggests that if it was not for existing *structural* barriers these *individual* enablers would not be such essential traits in women's success. We argue that careful structural changes need to occur around societal constructions of the relationship between gender and STEM, and only then STEM might prove to be a more inviting and rewarding field for women. The women who participated in the interviews are all members of the HunterWiSE network, and collaborate and support each other to make systemic changes in equity policies in our local industries. They believe, and we do too, that change is possible.

Data availability

Due to study data containing easily identifiable information, the data for this study are not publicly available so that participant confidentiality is protected.

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Ethical approval

The project was approved by the Human Research Ethics Committee of the University of Newcastle, Approval No. H-2017-0216.

Informed consent

Written consent via a signed consent form was obtained from all participants before beginning the study.

Competing interests
The authors declare no competing interests.

Additional information
Correspondence and requests for materials should be addressed to Elena Prieto-Rodriguez.

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