University of Exeter

Finding the way

Understanding barriers to retention and success for underrepresented Early Career Researchers in Mathematics, Physics, Computer Science, and Engineering

About the School of Education, University of Exeter

The School of Education is recognised as one of the top Education research schools in the UK. The School's vision of education values learning in its broadest sense as an interdisciplinary, personal, social, professional and lifelong endeavour.

Staff within the School of Education are committed to excellent teaching and research within a scholarly, diverse, creative and safe environment. They seek to challenge existing thinking and orthodoxies in the field of education by stimulating debate and advancing both educational knowledge and practices via the interplay of theory, research, policy and practice.

Acknowledgements

The authors would like to thank the Translational Research Exchange @ Exeter, and the Wellcome Trust Institutional Strategic Support Award, for funding this work.

'Finding the Way' was produced by a team led by the School of Education's Dr Lucy Yeomans, with special thanks to the School of Education's Dr Lauren Stentiford, Innovation,Impact and Business' Emma Rundle and Marina Altoè, Professor Janice Kay CBE, and Catherine Davies.

We also want to thank the participants of the workshop "Understanding the barriers to success for Early Career Researchers from underrepresented groups" conducted on the 15th of March 2023.

This report was authored by the School of Education's Daniela Fernández and Dr Lucy Yeomans.

Contents

Foreword

The exploration of the journey of Early Career Researchers (ECRs) from underrepresented groups in Mathematics, Physics, Computer Sciences, and Engineering disciplines reveals a complex landscape of particular and sometimes additional barriers and disparities. This review, a testament to rigorous inquiry and meticulous analysis, delves into factors that shape the trajectories of these groups, shedding light on the challenges that are often hidden beneath the surface.

The authors of this systematic scoping review offer us a glimpse into stark reality: ECRs from underrepresented groups often do not start on a level playing field. While disparities are present at all stages of the academic journey, they are magnified at the ECR stage, exposing the complex interplay of socio-economic background, familial familiarity with academia, and the lure of alternative career paths with higher starting salaries.

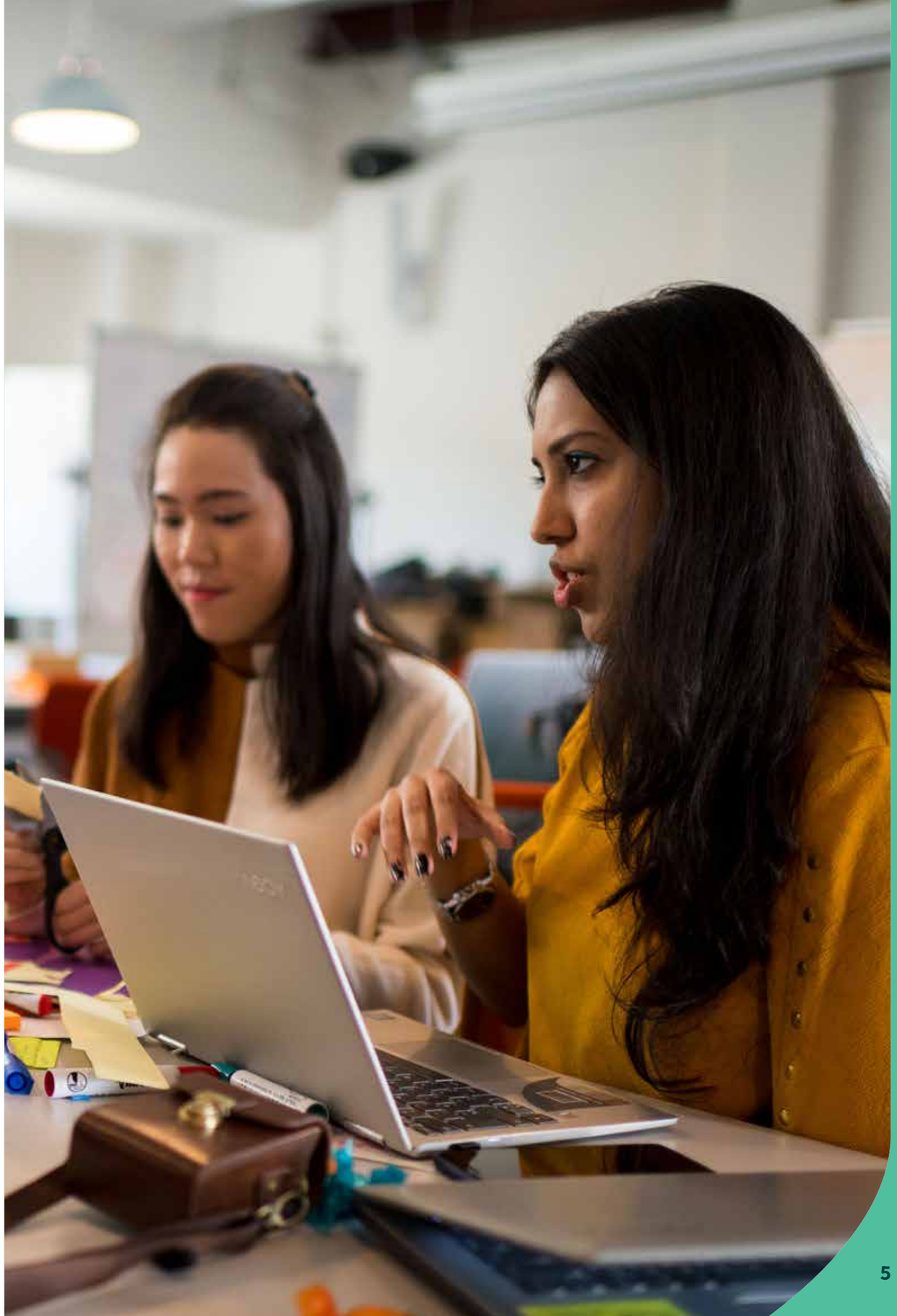
It is a journey that can be influenced by a narrative that overlooks and indeed ignores inequities of opportunity, failing to recognise barriers of gender, race, disability, and the intersectionality between them. There often is a sharp focus on the gender-centric approach that dominates research and interventions, inadvertently overshadowing the intersectional challenges faced by ECRs from different social classes and ethnicities. Negative impacts of gender and of colour, for example, must be addressed.

We know that well-intentioned endeavours can, however, have unintended consequences. Outcomes that appear tokenistic or quota based on the part of an institution, department or group do a disservice to everyone, often creating barriers to further inclusion, and diminishing achievements and the confidence of the participants involved. Greater inclusion requires a cultural transformation.

While institutions attempt to support parenthood and parental leave with flexibility, even with creative kinds of support, challenges faced particularly by women ECRs in balancing academic work with caring responsibilities, and effects of 'time out' on career structures, still need to be appropriately addressed. These challenges were magnified by the CV-19 pandemic and have not yet been addressed fully. These elements can be particularly acute for lab-based scientists and engineers and exacerbated by positions with fixed-term funding.

This is an important report that explores the challenges, triumphs, and aspirations that shape the paths of Early Career Researchers from underrepresented groups. As you read through the report, please consider, and recognise the barriers that exist and how you might work to address them. This review serves as an invitation - a call to action - for the academy to take the lead to further diversity, break down challenges, and pave a new way forward for those who have a vital part to play.

Professor Janice Kay CBE
Provost and Senior Deputy Vice Chancellor
University of Exeter



Executive Summary

The findings presented in this review aimed to identify the barriers for the retention and success of ECRs from underrepresented groups in Mathematics, Physics, Computer Sciences and Engineering disciplines. To this end, a systematic scoping review was conducted, and five databases were included to search for research related to underrepresented groups experiences in MPCEs disciplines. For details about papers' characteristics, see Appendices section.

Early Career Researchers do not start on a level playing field

- Although issues in terms of the underrepresentation of ECRs from the described groups are present throughout educational levels, they become even more acute at ECR level.
- Research located in the review showed that Early Career Researchers from working-class backgrounds or that were first generation students in their undergraduate degrees differed in their family knowledge of academia as a structure.
- For some Early Career Researchers from disadvantaged socioeconomic backgrounds, increased economic constraints made them question if an academic research career was a good decision in retrospect. This was highlighted by ECRs from Engineering, as a career in industry was seen as more lucrative than academia.

The dominant focus on gender in research and interventions obscures other inequalities or experiences

- Across the studies included, women's and intersectional barriers (in terms of gender and ethnically minoritised groups) were mentioned the most.
- However, interventions tended to focus on addressing barriers for gender, rather than take an intersectional approach, for example how the support required for women from different social classes and ethnicities may vary.
- Social class remains underexplored and was only considered in one paper.

Only focussing on increasing numbers might be counterproductive

- Due to the persistent low participation of underrepresented groups in these disciplines, most of the interventions were perceived as focussed on increasing the numbers of women or ethnically minoritised groups in these disciplines.

- However, these efforts led members of these underrepresented groups to feel a sense of tokenism for underrepresented groups. For example, women in physics perceived their success was undeserved and due to institutional quotas, rather than because of talent.

Motherhood/parenthood is conceptualised as a barrier, rather than the lack of support from academia

- Lack of institutional support led to difficulties for women balancing their identities around motherhood, academia and STEM.
- ECRs reported motherhood affected their publication record, which negatively affected their progression. This led ECRs to perceive motherhood as disruptive for their academic careers.
- The COVID - 19 pandemic was identified as a critical factor negatively affecting female ECRs' research activities, due to the unequal distribution of domestic work and disruptions to grants.

The competitive academic environment is especially problematic for those already in a precarious position.

- Women in physics and engineering perceived academia as a hierarchical work environment, where being 'productive enough' was an particular pressure.
- Female ECRs expressed that the work - centric lifestyle modelled by their mentors made them think that academia was not the best fit for them.
- Some ECRs reported that some PIs used their position to obtain authorship on ECRs' academic publications

Recommendations

Following the report findings, to support the retention and success of ECRs from underrepresented groups, universities could improve their support through the following recommendations, which were co-created in a workshop with relevant stakeholders discussing the scoping review results:

1. Create interventions to promote ECRs' retention and success that consider experiences as complex and intersectional.

Current intervention and practices to promote equality in Mathematics, Physics, Computer Science, and Engineering have historically been focussed on increasing numbers, rather than analysing how ECRs in academia experience their role. Interventions must consider common experiences that ECRs from underrepresented groups face and the particularities in the intersection of being part of multiple groups. Hence, additional to general programmes, tailored interventions need to be implemented. Furthermore, these interventions need to be reassessed periodically, as arriving to academic positions is just the first step to create diverse and inclusive spaces. Moreover, interventions and strategies for equality, inclusion and diversity need to consider that not all ECRs follow a traditional linear career pathway, especially when they belong to historically underrepresented groups. Furthermore, research and interventions must consider not just the commonalities across disciplines, but also the particularities of each discipline's culture.

2. Consistency and evidence-based strategies for mentoring programmes for ECRs

Evidence from the scoping review shows that mentorship is valued by ECRs from underrepresented groups in Mathematics, Physics, Computer Science, and Engineering. However, mentorship programmes need to be developed in a responsible way: considering ECRs' and mentors' needs (e.g., creating a workload where mentorship is equally as important as publication or teaching). Otherwise, mentorship will have detrimental effects on ECRs' and senior staff's motivation and sense of belonging. To this end, university culture needs to motivate and enable senior researchers to provide a supportive environment for ECRs. Moreover, university culture needs to provide the conditions for senior staff to conduct and participate in mentorship activities. Mentoring should also focus on different levels of ECRs as, on some occasions, line managers are also ECRs.

3. Challenge pressures about productivity and metrics

This report has identified how different barriers for ECRs from underrepresented groups are shaped by university culture, especially by productivity and metrics culture. Any intervention or programme that aims to improve ECRs experiences needs to consider institutional culture. Otherwise, changes will not be sustainable across time and, indeed, will communicate contradictory messages. Universities need to challenge productivity measures, as well as promoting collaboration to achieve realistic productivity goals. For instance, non-research activities - such as collaboration and both formal and informal mentorship - can be included in progression criteria. To deal with the competitive culture, strategies such as research group support, peer advocacy about employment and worker's rights, and a culture that welcomes sharing staff preferences (e.g., teaching activities) are recommended to de-centre the pressure on productivity and metrics, and recognise the value of non-research activities for academic and ECR culture.

4. Better support for ECRs on parental leave

Work-life balance for women has been discussed largely across disciplines. Report findings highlighted particular challenges that work-life balance entails for ECRs in Mathematics, Physics, Computer Science, and Engineering, and particularly for women. The idea that motherhood is a barrier or will be penalised needs to be challenged with concrete actions. Universities need to provide support for both women and men, for example, gender-neutral programmes to support childcare. Furthermore, to create collaborative research environments can help ensure women/men do not see parental leave as an interruption or disadvantage, but rather as a time where research teams continue to work on projects where they are involved and where they can integrate once parental leave is finished. Support and time should also be provided to enable those who have returned from parental leave to get up to speed on writing, project preparation, etc. so they are not expected to do so on top of their daily activities.

Introduction

Research is a key aspect of social development, contributing to the production of new knowledge and creating innovative solutions for individuals and communities' problems.

To create excellent research environments is critical to create inclusive and diverse academic organisations (Febria et al., 2022), with researchers from different backgrounds, who can provide different knowledge and perspectives to science. However, evidence has shown that research has a diversity problem (Tay, 2020). For instance, at compulsory education levels, women are underrepresented in certain areas, such as mathematics and engineering subjects (Fox & Gaughan, 2021; The Royal Society, 2014). At PhD levels, when women's participation increases in certain disciplines, these disciplines start to become associated with less prestige (Leslie et al., 2015). Moreover, black and minority ethnic students are less likely to progress to academic jobs after their graduation, compared to white students (The Royal Society, 2014). Diversity and inclusion issues appear beyond compulsory education and graduate levels and appear to be an extensive problem in academia. Indeed, inequalities faced by underrepresented groups in Higher Education also affect those starting their academic and research career: early career researchers (ECRs).

In this report, we aim to address the barriers that individuals from historically underrepresented groups face in their academic career after getting their PhD. We acknowledge that these barriers might be different across disciplines, and we focus on certain disciplines within the STEM group which have persistently low levels of participation of historically underrepresented groups: Mathematics, Physics, Computer Science, and Engineering. For instance, the proportion of female Mathematics professors is 11%, although they represent the 37% of total students enrolled in undergraduate (The Royal Statistical Society, 2022). These numbers are also concerning when we consider ethnicity: in Physics, 18.5% of students are from Black and Minority Ethnic groups, yet only 5.6% of lecturers/senior lecturers and 4.2% of professors are Black and Minority Ethnic groups (The Royal Society, 2014). These numbers as significantly lower than other STEM disciplines such as Biosciences, where the proportion of female first-degree students is 57.90%, maintaining similar numbers at doctoral levels (57.50%) and dropping to 44.0% in lecturer/senior lectures positions, and 16.40% in professors' positions (The Royal Society, 2014).

Hence, we aim to answer the following research question: What are the barriers that early career academics and researchers from underrepresented groups - in terms of gender, ethnicity and race, and social class - face to succeed in, Mathematics, Physics, Computer Science, and Engineering (MPCE) disciplines in Higher Education settings? This report is grounded in two specific aims: (a) to identify the barriers for the retention and success of ECR from underrepresented groups in MPCE disciplines; and (b) to identify the theoretical frameworks and methodologies used in previous research about the barriers that ECR from underrepresented group face to succeed in MPCE disciplines.

To address these aims we conducted a systematic scoping review (Arksey & O'Malley, 2005). A systematic scoping review aims to map the key concepts explored in a particular area of research (Mays et al., 2001). In this report, we review and disseminate previous research findings and identifying gaps in the literature (Arksey & O'Malley, 2005). For more information on the methods used, please see the Appendices.

Findings

The findings section is organised following the three key themes developed from the systematic scoping review conducted: (a) varying ECRs' trajectories, (b) challenges of institutional culture, and (c) discrimination experiences. Each theme includes different subthemes, providing a more detailed description of the findings, as well as illustrative quotes.

Varying Early Career Researchers' trajectories

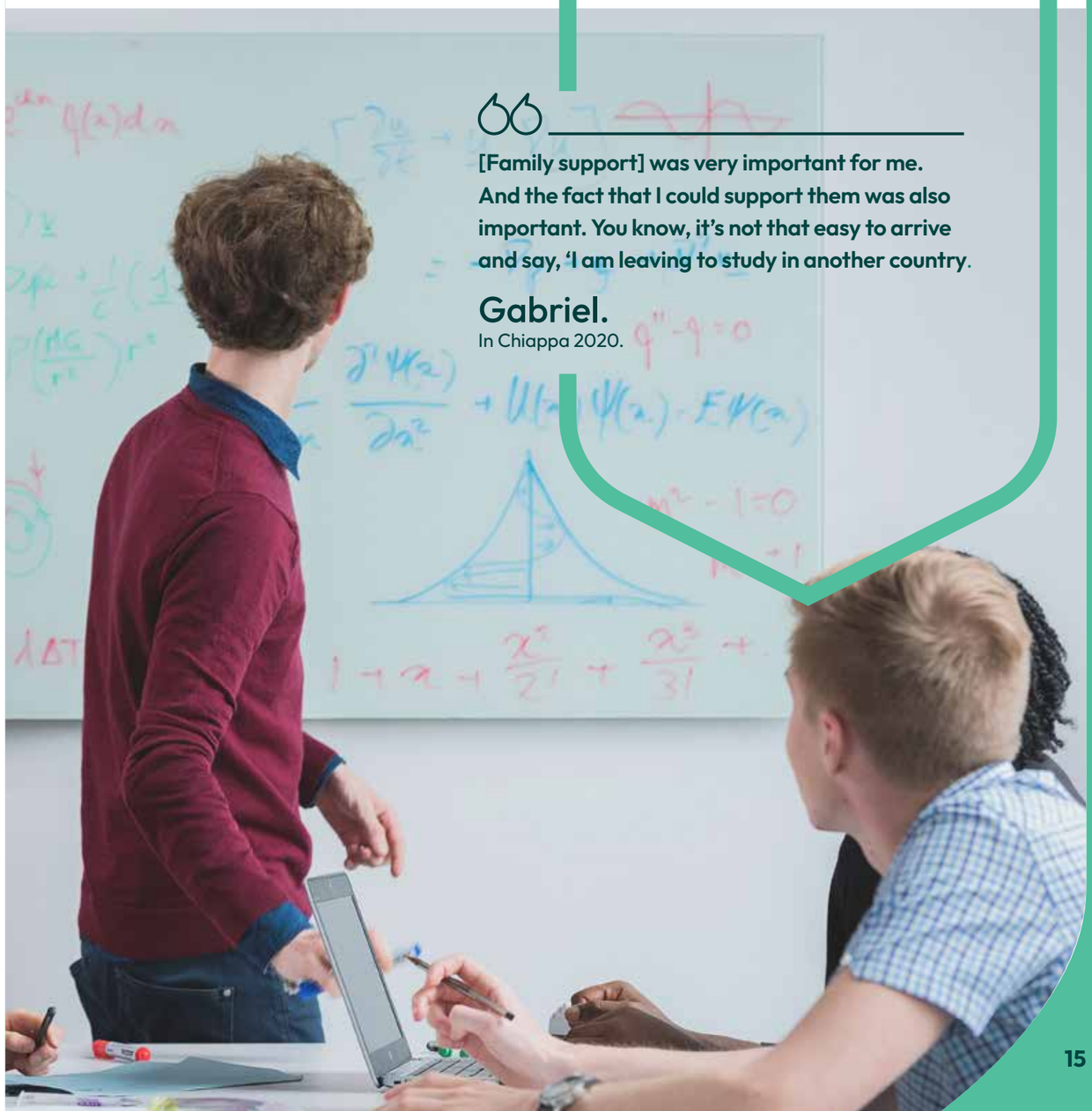
Inequalities in the trajectories of ECRs to become researchers

Although all the studies included in this review focussed on ECRs' experiences at academia, eight studies also recognised that the barriers and challenges that ECRs face don't start when they are appointed in these positions. These unequal trajectories could be seen as a potential explanation to the broadly discussed 'leaky STEM pipeline' (Eren, 2021; Eren, 2022b; Weisshaar, 2017). Three studies mentioned the importance of previous gender participation inequalities to explain the persistence of women's barriers to succeed, considering the unequal career patterns for women in Mathematics, Physics, Computer Science, and Engineering, where they have been historically a minority (Sonnert & Holton, 1996). For instance, Viefers and colleagues (2006) describe how the higher representation of men in ECRs positions within Mathematics, Physics, Computer Science, and Engineering is recognised from PhD levels, leading to an underrepresentation in post - PhD levels. Moreover, Start and McCauley's (2020) study described the lack of participation of women in these disciplines from undergraduate levels. Gender inequalities also were explained considering individuals' diverse academic trajectories, and a successful academic career was not a first straightforward option for some women, being one of the reasons the lack of representation of women in these disciplines in academia. This lack of representation and, hence, perceived fit and support, led women to not take some opportunities that will help them to transition to academia (Barnard et al., 2021).

The dissimilar ECRs' trajectories were associated with dissimilar knowledge about academia. Indeed, four studies also focussed on the lack of previous knowledge about academia as an important barrier to understand ECRs' experiences, especially in terms of their retention. These studies were focussed on ECRs from ethnically minoritised groups (N=3) and in terms of their social class (N=1). For instance, in the only study that explored social class experiences, Chiappa (2020) reported that for ECRs from low-income backgrounds, the decision of pursuing a PhD (a requirement to be an ECRs) was not easy, as they needed to financially support their families, as well as taking the risk of moving to a different country without a major support network.

Although in this review only one study focussed on social class experiences, the rest of the studies tangentially mentioned the role of previous socioeconomic status. Indeed, the three studies focussed on ECRs from minority groups (Chakraverty, 2022b; Patt et al., 2020; Yadav et al., 2020) highlighted the fact that ECRs from these groups are more likely to be first-generation students and, therefore, see themselves at a disadvantage when arriving to postdoc positions.

Hence, a critical barrier for ECRs in Mathematics, Physics, Computer Science, and Engineering (MPCE) disciplines are their difficulties in terms of their access to academia. In the following subtheme, we will explore how their underrepresentation in numbers might promote specific experiences when ECRs are in academic positions.



> **[Family support] was very important for me. And the fact that I could support them was also important. You know, it's not that easy to arrive and say, 'I am leaving to study in another country.**
>
> **Gabriel.**
> In Chiappa 2020.

Not being recognised as a scientist and an academic

Six articles described the lack of recognition and validation that ECRs experienced in their roles as a barrier for ECRs from underrepresented groups. These studies were focussed on the experiences of women (N=4), and women from ethnically minoritised groups (N=2). From these six studies, five used interviews as data generation methodology. In the interviews, women reported that their trajectories were shaped by their perception of lack of validation of them as STEM academics, which was most noticed when they participated in male-dominated and stereotyped disciplines. Particularly in disciplines where certain groups, such as women, have been historically underrepresented, such as Mathematics, Physics, Computer Science, and Engineering, the perception of being recognised by the academic community is important for their sense of identity of being an academic in sciences.

The only quantitative study in this category -which was the oldest one in this review – used surveys and proposed that female scientists might have higher levels of stress, compared to men, because women perceived having less power (Illovsky, 1991). Recent literature, mainly using interviews as method, also highlighted the role of power and feeling of being recognised as a scientist in academia. For instance, Amon (2017) found that women perceived not being recognised as authority figures or with legitimacy to communicate their opinions as scientists or academics. In Noel et al.'s (2022a) study, postdocs from minority groups referred to not being considered to share their opinions about recruiting lab members. This was also the case for a female academic in engineering working in a particular institution for several years, facing recognition only when she was successfully appointed (and recognised) as staff (Barnard et al., 2021). Hence, these studies demonstrated that ECRs from underrepresented groups had the unique challenge of negotiating their legitimacy, despite their education background and preparation for the role (Eren, 2022b; Strong et al., 2021).

The lack of recognition as a STEM academic was critical for women, as they perceived their position in academia as already isolated and with lack of a sense of community. One paper reported that the position of being the 'newcomer' as ECRs was also problematic when promoting feelings of recognition, as ECRs from underrepresented groups might feel welcomed but also suspicious of how they will be treated considering their status in academia (Buzzanell et al., 2015). Hence, ECRs expected not to be recognised due to how academia was perceived in terms of supporting (or not supporting) underrepresented groups. These processes might shape the entire lens of their experiences:

"She [participant] expresses a nagging feeling that she needs to remain alert for inequities. After talking about being a woman in academia and about expectations that she might incur differential treatment because she is a Black woman engineering professor, she remarks "So far, I haven't had anything that's been highly stressful or emotionally taxing since I've been here" (Buzzanell et al., 2015, p.445)

Lack of fit with STEM identity

One important aspect that was related to the perceived lack of recognition of ECRs was the perception that they were not people similar to them in academia. Indeed, ten papers reported that the experiences of lack of recognition for women, ethnically minoritised groups and individuals from a working-class background in Mathematics, Physics, Computer Science, and Engineering were related to the sense of not fitting with the prototype proposed for a STEM academic: white, male and with social connections to succeed (Seals et al., 2020; Sonnert & Holton, 1996). Although it is arguable that this stereotype about academics is present across disciplines and not just in STEM, there might be additional challenges related to scientist identities and the historical heavily masculinised culture of these disciplines. Hence, individuals that were not part of this prototype perceived that they didn't belong to the scientific and academic community; or that they needed to minimise aspects of their identity to fit in, such as being less feminine (Eren, 2021); or felt that they must mimic or adopt a set of behaviours to belong (Strong et al., 2021). From these studies, five focussed on gender experiences, two focussed on gender and ethnically minoritised groups experiences, and three on minority groups experiences. Across these studies, ECRs mentioned a clear and fixed idea of how a scientist and academic look. For instance, Eren (2022b) described how women in physics perceived that they didn't fit the idea of being a successful scientist, as only male scientists' contributions were credited and emphasised:

> **Science, according to the majority of the participants, requires commitment and hard work. They stated that despite their devotion and hard work, women are not given equal credit in science. For instance, as Carol (postdoc) said, 'we were taught in school that men made all of the greatest scientific discoveries. As a result, women's work must be outstanding in order to stand out and be noticed**
>
> Eren.
> 2022b,

Yadav and colleagues (2020) also describe how ECRs perceive senior academics (the ones that have succeeded in academia) as 'older White men' (Patt et al., 2022). This prototype was reinforced due to the actual lack of representation in academia: indeed, women were less likely to receive tenure positions, even when they worked at institutions with higher numbers of tenure positions available (Weisshaar, 2017).

ECRs must overcome experiences that signpost a sense that they don't fit with what is expected to be an academic. This lack of fitting the prototype of an academic in Mathematics, Physics, Computer Science, and Engineering negatively affected ECRs' sense of belonging to their disciplines, especially as they did not feel recognised as part of the academic and science community (Buzzanell et al., 2015; Coso et al., 2021). Moreover, the sense of lack of identity-fit can lead ECRs from ethnically minoritised groups to feel doubts about their abilities (Barnard et al., 2021; Viefers et al., 2006), and that they did not deserve to be in or did not belong in academia, as they did not see people similar to them. Two papers linked these processes to the notion of Impostor Phenomenon in Engineering (Chakraverty, 2022b), and Engineering and Mathematics (Chakraverty, 2020b). However, rather than seeing this phenomenon as an individual problem, these studies explained the feelings of being an impostor or not being qualified enough to be an academic as a product of the organisational practices and culture promoted by academia (Barnard et al., 2021; Chakraverty, 2020b).

Intersectional experiences

The 31 articles included in this review demonstrate that ECR experiences are complex, and the barriers and challenges that they face integrate different aspects of their academic and personal experiences. Eleven papers within the review explored ECRs' intersectional experiences, considering the intersection of gender and ethnically minoritised groups identities. Most of these papers (N=9) used qualitative methods to explore the specific challenges that women of ethnically minoritised groups face as ECRs in Mathematics, Physics, Computer Science, and Engineering (Anderson et al., 2015; Buzzanell et al., 2015; Long et al., 2018; Miles et al., 2020; McGee et al., 2021; Strong et al., 2021; Noel et al., 2022a; Noel et al., 2022b).

The focus on intersectionality was used to create awareness about the particular challenges that women from ethnically minoritised groups face, and as a call to consider these particularities when analysing academia inequalities. For instance, one paper by McGee and colleagues (2021) showed that women from ethnically minoritised groups perceived support from their colleagues, but not from the institution, as they were less likely to receive research funding support or tenure support. Indeed, evidence outside this scoping review shows that white women have seen more benefits from gender equality initiatives, and that women of colour are less likely to get funding (Jebsen et al., 2022). Furthermore, women of colour in US academia described that the interventions that universities have developed to tackle these inequalities and promote women ECRs retention and success follow an 'one size fit all' approach (McGee et al., 2021). In the same research, Asian women referred to how strategies were focussed on Black and Latina women, leaving the particularities of their experiences outside:

> **[in] high school I was kind of left wondering... I feel like I've been a minority my whole life because again I really didn't fit in here and also I didn't fit in in China either, 'cause they knew I was American so that was kind of discouraging in that sense. I think there's more open opportunities and then also on campus for undergrads, there's SHPE and NESBE, respectively, for Hispanic students and African American students and there isn't an equivalent for Asian students for the equivalent for an engineering society. I'm not sure if we need it, but it's just... there are disparities here and there. And there's a lot of scholarships and things associated with NSBE and SHPE that I would not be eligible for"**
>
> **Dr. Susan.**
> in McGuee et al., 2021.

At this point, it is important to acknowledge that ECRs' experience are not in a vacuum. ECRs' perceptions about academia are shaped by the context where they work. Therefore, an important aspect to understand ECRs' barriers is to understand how academia is organised and the challenges that its institutional culture entails, particularly for ECRs from underrepresented groups.

Challenges of institutional culture

Uncertainty and precarity in academia

A total of six articles in this review described academic culture, including how academia is organised, is a significant barrier for ECRs to both maintain and succeed. Half of these articles (N=3) focussed on gender experiences, two articles focussed on ethnically minoritised group experiences, and one article focussed on the intersection of gender and ethnically minoritised groups. The definition of academia as an uncertain context was communicated differently across papers, following two key aspects: (a) uncertainty about having a permanent job and (b) uncertainty about the expectations towards postdoctoral scholars' role.

Across these studies, ECRs saw their positions in academia as unstable (Anderson et al., 2015; Eren, 2021; Noel et al., 2022b), mainly due to the lack of permanent contract offered (Bozzon et al., 2017). The context of these studies was Western academia: Italy (N=1), Ireland (N=2) and United States (N=3). For postdoctoral scholars, uncertainty was also defined as not having a clear idea about the expectations of their role:

"For me it was like trying to understand the transition from being a graduate student to a postdoc, the levels of expectation, and the metric of performance. How am I doing? Is this good? I feel like sometimes the things that I do are in this black hole and there's no feedback that this was good or bad. I don't know what areas to improve. A clear indication of the expectations and how grad school is supposed to be different from a postdoc experience were missing" (Postdoc participant in Yadav et al., 2020).

For instance, even while receiving support from other academics, ECRs described feeling disorientated regarding how to act and conduct themselves in academia (Anderson et al., 2015). Indeed, expectations about the postdoctoral experience are not clearly defined, promoting a sense of being in a 'limbo' (Patt et al., 2022). Postdoctoral positions were also defined as 'academia purgatory': an in-between stage where individuals are not students nor faculty members, where postdocs might have some benefits of being an academia, but also a lack of clarity about their role (Yadav et al., 2020).

"Postdoc is—I call it academia purgatory. You're not a graduate student and you're not a faculty member, you're stuck in between, and you don't know what to do, which way to go or to find how you belong in the lab. You have your PhD, but you're not on the level of a faculty member, you have the benefits. You're treated as a student, but at the same time, you're not a student because you're not taking classes, you're not being a TA or anything of that nature, you're just doing public research. It feels like you're just there to just gain more experience. It is somewhat of an adjustment because you don't have a defined role. I feel like I don't have a defined role" (Postdoc participant in Yadav et al., 2020, pp. 173-4).

The issues raised regarding uncertainty and precarity in academia were highlighted by women. This lack of job stability was considered as a barrier in ECRs' retention in academia. For instance, Eren's (2022b) study described how female ECRs in physics needed to plan aspects of their personal life (e.g., motherhood) by taking into consideration the instability of the contracts for ECRs, most of them being short/fixed-term. Both the uncertainty and flexibility of postdoctoral positions were experienced as demanding: the flexibility of the positions might be seen as positive to achieve work-life balance, but it actually led to difficulties to differentiate the boundaries between work and personal life. For instance, in one study by Bozzon and colleagues (2017), postdoctoral scholars reported working during the weekends and evenings, which was something that participants found problematic. Furthermore, on top of their paid job, participants needed to split their time between preparation of publications to improve their cv, and job and funding applications (Bozzon et al., 2017).

Although the research productivity culture in academia and its negative impact on researchers' wellbeing has previously been highly criticised, this review shows women in in Mathematics, Physics, Computer Science, and Engineering disciplines were particularly affected by this culture. Indeed, compared to men, women in Computer Science receive fewer citations per publication and publish fewer articles (Weisshaar, 2017), which negatively affects their opportunities to obtain a tenure promotion. Using data from Google Scholar, Weisshaar's (2017) study showed that, on average, men received 4.475 citations per publication, against 3.234 of women. This is critical, as not obtaining a tenure promotion implies that ECRs are more likely to work in precarious conditions, with a lack of security regarding their jobs. Moreover, one study by Viefers and colleagues (2006) based in Sweden showed that women in physics and engineering perceived academia as a hierarchical work environment. This perception makes the concern of being 'productive enough' even more critical for women, due to their concerns about work-life balance. It seems that these disciplines are particularly focussed on the idea of 'high standards', associated with a scientific discourse of objectivity and success. Hence, women in these disciplines saw academia as stressful and demanding, although they reported that they wanted to continue in their positions, as they perceived the stress and pressure as an individual challenge, rather than an institutional one (Barnard et al., 2021):

"I want to be in academia. I like it. It's a fantastic job. We do what we want. Who else gets paid to do things they want to do? . . . I know we all say it's stressful, but I have to remind myself every now and again that if I don't do something nobody is going to die. I have no emergencies in my job. I have no kind of pressure to do something. At the end of the day all the pressure I put on myself it's for my own career progression. I'm not doing it for anyone else." (Debra, in Barnard et al., 2021).

Eight studies explored the uncertainty linked to academia and particular challenges for women. Life experiences such as motherhood entailed changes in ECRs trajectories, due to the lack of childcare support from institutions,

as well as the consequences of maternity leave in terms of their productivity (Eren, 2022a). Indeed, according to Eren (2022a), academia does not share clear and supportive practices for maternity and childcare. For instance, funding agencies often don't recognise absences due to maternity leave. Although one study concluded that leave extended the time to tenure for both women and men, women were particularly disadvantaged in the promotion to full professor when they had used maternity leave years before (Fox & Gaughan, 2021).

The lack of institutional support led to difficulties for women in terms of balancing their motherhood and academic and science identities. For instance, female ECRs from physics in Ireland described the need to work harder to accomplish all their responsibilities (at the workplace and at home), and these pressures promoted stress (Eren, 2022a). Moreover, the lack of support and challenges to balance work and motherhood led ECRs to perceive motherhood as a gap and interruption for their academic careers: for instance, ECRs declared that motherhood affected their publication record, an important strength to pursue better jobs in academia (Eren, 2022a). This problem was worse during the Covid-19 pandemic: research activities and work-life balance of female academics in Engineering (including tenure track, tenured and non-tenure track positions) were significantly more negatively impacted by the pandemic than for male academics (Caldarulo et al., 2022).

The perception of female participants across these studies is that, unlike men, women's life choices also tended to have an impact on their careers. For instance, Sonnert and Holton's (1996) research describes how single women in sciences at US institutions faced pressures to stop being single. However, the same study reports that married women also face challenges, in terms of balancing the work and partner's careers, or to balance motherhood with their careers. Hence, it seems that – regardless of a women's situation - challenges emerge due to expectations about work and life organisation, and lack of institutional support for work-life balance. Again, recent research suggests that these challenges have not changed in the last 20 years and can be found in other contexts, such as Ireland:

"I think a woman has to decide not to have a family. This is the first thing that pops up through your mind if you really want to pursue a very high level of position because you need to have dedicated time. It is always easier for men" (Carol, postdoc. In Eren, 2022a, p.143)

Two papers reported that this work-centric lifestyle led ECRs from ethnically minoritised groups to see work-life balance as difficult (Noel et al., 2022b), as they also considered the importance of their family as a core value of their identity (e.g., being a Latina) (Yadav et al., 2020).

University culture and support

A total of four articles reported university and specifically academic culture as a barrier for ECRs' success. The aspects related to academic culture highlighted by each paper varied and can be grouped in two areas: (a) lack of understanding about cultural differences (N=1), and (b) challenges to promoting a sense of belonging for all ECRs (N=4).

The lack of understanding about cultural differences was experienced by Native American ECRs in a traditionally White institution from USA within Engineering (Chakravarty, 2022a). In this study, ECRs expressed cultural differences with academia, but also a lack of effort from academia to understand these cultural differences, leading to them to 'assimilate' to academic values and, overall, Western science:

"There is a large pressure to assimilate to academic viewpoints that are Western science, a very calcified view of science that's not necessarily always consistent with an Indigenous world - view (...) Anna discussed her knowledge of historical work in genetics with Indigenous subjects that was ethically problematic and objectionable. There were classical research papers in genetics "done on these Indigenous populations that probably did not give informed consent" (Chakraverty, 2022a, p.6).

Indeed, research outside this review has shown that Mathematics, Physics, Computer Science, and Engineering are disciplines that are taught following a Western perspective, denying the contribution from Native American and other cultures in the development of science (Page et al., 2019). Hence, this lack of understanding towards ECRs' cultures is also a sign of a colonialist vision of science and academia, promoting the marginalization of groups outside these categories.

The lack of understanding about ECRs' background and culture created difficulties to establish environments where everyone can feel they belong. For instance, ECRs

> **For the last place I worked, I was on the gender committee. They were discussing what maternity leave was and they said it depends on what grants you are on. They probably give you the leave, but luckily it hadn't been an issue yet. They had no plan. If it did happen, you would just have to ask in advance like, Oh, thinking of getting pregnant, so, could you let me know if I have maternity leave, which is just so disastrous on like all grades and no one would ever do that.**
>
> Dee.
> In Eren, 2022a.

from Hispanic/Latino backgrounds in US Engineering and Mathematics' departments reported a sense of not feeling welcomed by their colleagues (Chakraverty, 2022b) - alluding to cultural differences with White people:

"Juan (postdoc) grew up in a culture where people supported each other as a community, doing simple things such as stopping by someone's desk to say hi. Yet, his workplace was culturally different; people did not spend much time socializing. He added, "It impacts how you work, especially if you are sad or not feeling necessarily welcome" (Chakraverty, 2022b, p.11).

The lack of sense of belonging was also mentioned by women in Engineering and Mathematics disciplines (Chakraverty, 2020b). Hence, participants from studies based in US reported that Mathematics, Physics, Computer Science, and Engineering academia is seen as an environment lacking diversity and, therefore, ECRs from ethnically minoritised groups feel unwelcomed and not belonging to this context:

"This lack of connectedness or an unwelcoming environment they felt could be attributed to their racial and ethnic identity. Postdocs in our study discussed that being a minority in a STEM field was a challenge as they often did not often get opportunities to see, interact with, or work with other URMs [underrepresented minorities]" (Yadav et al., 2020, p. 174).

Lack of support from experienced academics

One of the strategies that universities reported in this review have put together to face the barriers described has been to promote support from more experienced academics towards ECRs from underrepresented groups, mainly using mentoring programmes (Yadav et al., 2020). Indeed, theoretically, mentoring is perceived as a positive strategy to support ECRs (Barnard et al., 2021). However, a total of nine papers described the ineffective support that ECRs received from more experienced academics as a barrier, with seven papers focusing on mentoring experiences.

Overall, the studies of the relationship between ECRs and mentors was focussed on the experiences of women and ethnically minoritised groups. According to Blake-Bear and colleagues (2011), women and individuals from ethnically minoritised groups particularly recognised the importance of having a mentor that 'matched' with their identities. However, they were also less likely to experience this matching. This paradox was also identified in Chakraverty's (2022b) study on Hispanic/Latino ECRs in Engineering and Mathematics at US universities.

Despite the importance given to mentorship and the expectation from universities that junior faculty socialised with senior faculty (Long et al., 2018), studies described a lack of clarity in terms of who was a mentor and what was expected from them. For instance, for postdoctoral scholars, in some cases, the Principal Investigator of the project (PI) filled that role, although this was not formally communicated to neither mentor nor mentee (Barnard et al., 2021). Start and McCauley (2020) suggested that giving PIs this role formally is a positive step to promote ECRs' engagement with research culture.

Mentorship relationships emerged in formal and informal settings (Buzzanell et al., 2015). In the same study from Buzzanell and colleagues (2015), the participant (a female assistant professor from an ethnically minoritised group working in US academia) described how faculty requires for all new staff to choose two mentors. Yet, she also described mentorship relations outside this faculty requirement, with colleagues open to ask questions and provide insights about academia life. Furthermore, the role of supervisors is shown to be important for ECRs from underrepresented groups' motivation (Chakraverty, 2020b), even to apply for these positions to start with. For instance, Barnard and colleagues (2021) describe the case of a postdoctoral scholar who, motivated by their PhD supervisor and the support showed by the Dean, applied for an academic job. In fact, the nine studies reported in this section mentioned that mentors are seen as important figures to discuss academic trajectories and career goals (Noel et al., 2022a).

Hence, the role of other academics - especially the ones more experienced - is critical. These studies showed that women ECRs recognised that more could be done, describing the need of more role models (Viefers et al., 2006), and highlighting the importance of mentoring from their supervisors. Noel and colleagues (2022b) describe how postdoctoral researchers from Engineering and Computer Science reported a lack of support and ineffective mentoring relationship. Participants in this study mentioned how the relationship they developed with their supervisors did not contribute to their professional development and productivity, as it was mostly focussed

on supervisors' career rather than theirs. For instance, a female African American ECR in Physics working at a US university said:

"I don't think my current PI likes me…he is really prickly. I don't ask him for advice because his advice is always for his best interest. He has no experience on what it takes to run a collaboration…How [do] I feel about my PI? I can't take him seriously. I don't trust him, and he probably feels the same way about me" (Noel et al., 2022b, p. 445)

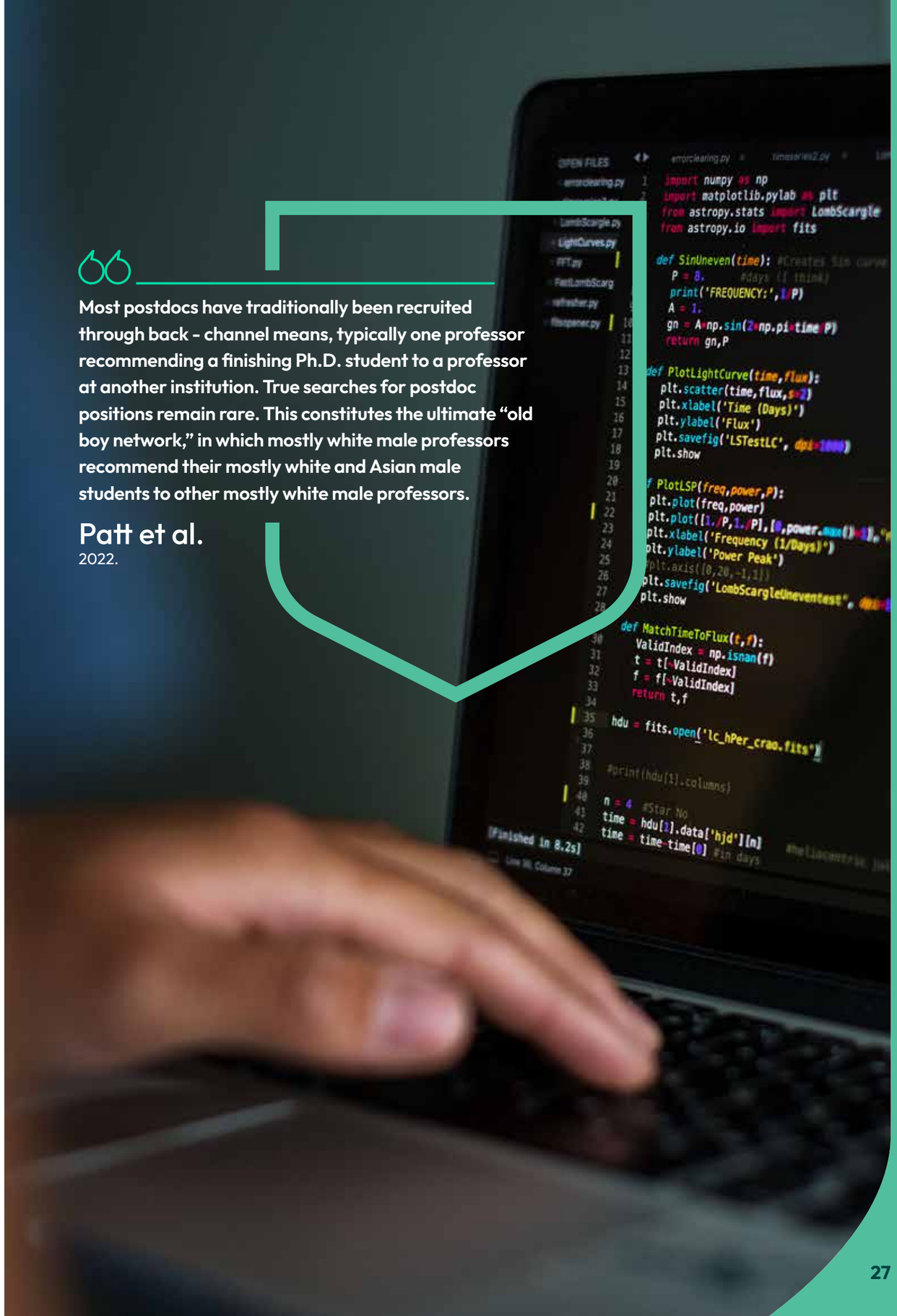
Lack of access to networking

An important barrier detected in this systematic scoping review was the lack of access to networking for ECRs. To succeed in academia, ECRs identified the importance of having contacts and the social capital to navigate academia. A total of five studies described that academic culture was grounded in connections and networking and, therefore, the lack of connections that ECRs have with other academics was identified as a barrier, which affected particularly ECRs' job opportunities. These studies mainly focussed on the experiences of women (N=3), ethnically minoritised group (N=1), and individuals from first generation background (N=1).

Although networking was identified as an important aspect of academia and a means to accomplish ECRs' career goals, the literature suggested members of underrepresented groups might find it particularly challenging to do networking (Patt et al., 2022). In a sample of mostly White female postdoctoral scholars from US universities, participants - who expressed they felt like impostors - found it difficult to introduce themselves and talk about their work with other colleagues. Indeed, networking was associated with anxiety and had an impact on their mental health (Chakraverty, 2020b). The predominance of gender barriers to develop networking was associated with the culture of Mathematics, Physics, Computer Science, and Engineering disciplines, as male-dominated careers, which made it harder to create networking and professional relations. For instance, women in Engineering reported a lack of 'social capital', described as a lack of relations with influence to improve their status (Amon, 2017). Underrepresented ECRs in Mathematics, Physics, Computer Science, and Engineering disciplines face a closed culture of the 'old boys' club' (Star & McCauley, 2020), which has a role in postdoctoral hiring, especially because postdoctoral positions are largely based on networking (Patt et al., 2022).

Finally, the importance of the networking culture in academia was described in terms of social class. Chiappa's (2020) study with male ECRs in Engineering working in Chile, reported the importance of contacts and networking to secure faculty positions, a resource that ECRs from working-class groups are less likely to have.

Therefore, following the studies' results, ECRs from ethnically minoritised groups entered to academia with unequal knowledge about academic life, social network, etc., and - at the same time - academia has created an organisation where those things matter. This tension might constrain ECRs' experiences in different way. However, the studies included in the review particularly focussed on discrimination experiences.



> **Most postdocs have traditionally been recruited through back - channel means, typically one professor recommending a finishing Ph.D. student to a professor at another institution. True searches for postdoc positions remain rare. This constitutes the ultimate "old boy network," in which mostly white male professors recommend their mostly white and Asian male students to other mostly white male professors.**
>
> Patt et al.
> 2022.

Discrimination experiences

Stereotypes about abilities to succeed in academia

A total of eight papers (six based in US academia, one in Ireland, and one did not report the country) explored the role of stereotypes and social expectations regarding gender and ethnically minoritised identities, especially in terms of their abilities - or lack of - to succeed in Mathematics, Physics, Computer Science, and Engineering. A total of three paper described gender stereotypes, four papers described ethnically minoritised groups stereotypes, and one paper described stereotypes regarding the intersection of both gender and ethnically minoritised groups.

Women recognised gender stereotypes as an important barrier for advancing in their careers, especially in leadership positions, as this participant in Amon (2017) study explained:

"She's either going to be an authoritative b - word, or she's going to be like this motherly figure"

According to Eren's study (2022b), these gender stereotypes and labels are particularly harmful as they move the focus from women's careers to socially gendered expectations. Furthermore, stereotypes associated to feminism were mentioned in terms of labels that women in physics wanted to avoid (Eren, 2022b), due to the negative image of feminists and feminism in their academic circles, which were mainly male-dominated.

In a different study, Eaton and colleagues (2020) tested the effect of implicit gender and ethnicity stereotypes in the assessment of a job application of postdoctoral scholars in the US. Their results showed that professors demonstrated gender and racial bias in the evaluation of the candidates. For instance, physics faculty evaluated male candidates as more competent and hireable than female candidates. Additionally, physics faculty evaluated Asian and White candidates for a post-doc position as more hireable and competent than Black and Latinx candidates. Furthermore, this study demonstrated an interaction of gender and ethnicity bias, as Black women and Latinx men and women were perceived as less hireable than Asian and White candidates from both genders, and Black men.

Therefore, stereotypes and social expectations put pressure on ECRs to 'prove' they have the abilities needed to be a scientist and an academic (Eren, 2021). For instance, Hispanic/Latino ECRs in the US perceived that they needed to work harder to overcome the stereotype of Latino people as people who like to party and don't take work seriously (Chakraverty, 2022b). This effect could also be seen for women of ethnically minoritised groups, as they described not being perceived as a person or an academic, rather as a stereotype of a women of colour:

"Especially for the Black woman in the post - Oprah era. There's this sense that I am someone's personal Oprah. I don't look like Oprah, but the assumption is, and of course it goes back to those general stereotypes that Black women are to be the nurturers of all people at all times and have some very good witticisms or whatever available for whomever at whatever time. There's that expectation that there's going to be some kind of Oprah moment or even the expectation of being motherly. No! That is definitely a burden as a person of color and as a Black woman in particular that people come with - an expectation based on their own racial understanding" (Yadav et al., 2020)

Stereotypes not only prescribed abilities and behaviours, but also appearance. Eren (2021) showed how women in physics in Ireland associated the stereotype of being a scientist in physics as being a 'white man':

"The narratives that emerged from the data showed that the physical appearance of a scientist is gendered and stereotyped in contrast to the personality traits of a scientist. Most of the participants described the physical appearance of a scientist as such: 'old white men in senior position', 'man in a lab coat fuzzy Albert Einstein hair', 'crazy old bald scientist', 'crazy white men', 'Einstein kind of the old dude'" (p.1146).

Women of colour in postdoctoral positions also reported not being seen as competent because of their physical appearance:

"Well it's assumed that because I'm a woman of small stature and an African American woman, that I am not competent in any regard." (Yadav et al., 2020)

Overall, stereotypes communicated the idea that Mathematics, Physics, Computer Science, and Engineering identities are not compatible with ethnically minoritised group characteristics (Chakraverty, 2020a; Miles et al., 2020). Because stereotypes are beliefs that don't change easily, gender and ethnically minoritised identities stereotypes constrain ECRs' sense of belonging to the scientific and academic community, and - with good reason – make them feel judged about their abilities (Eren, 2021).

Gender and racial discrimination in academia

A total of ten papers described discriminatory practices as barriers for ECRs' retention. Discrimination experiences were reported in women (N=3), ethnically minoritised groups (N=4), and women from ethnically minoritised groups (N=3). These studies focussed on different ways to conceptualise discrimination. For example, some studies focussed on racial microaggressions, defined as subtle race-based interactions (Sue et al., in Miles et al., 2020). In one study based in US academia, these micro-aggressions were reported at different levels: programme/institution/field (Miles et al., 2020):

"Celine also described an experience of a racial microaggression at an international academic conference with a White student. She stated, "[The student said], 'Oh, you should sing because you're Black.' ... It kind of made me feel like, um...my uniqueness was always a factor." Celine went on to describe how this feeling of being hyper - visible made her feel uncomfortable during the conference" (Miles et al., 2020, p. 1623).

As the quote above shows, discrimination was experienced in different academic contexts, such as conferences, and with colleagues and senior academics. For instance, women in physics based in Ireland described hearing sexist comments and experienced gender discrimination in conferences (Eren, 2021):

"Sometimes some researchers or my advisor would talk more naturally to the guys in my department, even though they are Ph.D. students. I have realized that they would not look at me and they would talk to the guys even though I have more expertise on the questions they are asking. (Lou, postdoc)" (In Eren, 2021).

Furthermore, discrimination experiences also affected ECRs' access to academic positions. As it was mentioned before, stereotypes play an important role. Eaton and colleagues (2020) demonstrated that faculty from a physics department in the US evaluated male candidates more positively than female candidates, even with the same CV. Similar results were found regarding ethnically minoritised ECRs, as physics faculty evaluated candidates from Asian and White groups as more competent and hireable, compared to Black candidates. Furthermore, this study showed support for the effect of the intersection of gender and ethnically minoritised identities biases when candidates in physics were evaluated: black and Latina female candidates were rated lower than all other candidates on hireability.

Additionally, to these open experiences of discrimination, a number of studies (N=6) also described a subtler form of discrimination in Mathematics, Physics, Computer Science, and Engineering disciplines, categorised as tokenism. Tokenism was described by women and women of colour, as an insidious consequence of the institutional attempts to reach more diversity in MPCE disciplines. According to Sonnert & Holton (1996) women in certain disciplines were seen as tokens, as other STEM disciplines (such as biology) had reached similar levels in gender participation (or even female surpassing male participation). Although this study is from almost 20 years ago, the feeling of being a token is still an issue for ECRs. For example, Eren (2022b) study reported that women in physics shared the idea of perceiving that their awards and success were not deserved, and explained because they were women and the institution needed to fulfil a quota, rather than because of their talent, similar to findings reported by Chakraverty (2020b):

"I even felt when I got my offer letter [for an internship] from [name of company] that I was just a quota, like a number, because I'm a Black. My interview, I'm still shocked how easy it was. Maybe they made it easy to make sure I got in. I thought it was because of the diversity quota" (Participant in Chakraverty, 2020b)

Hence, some from underrepresented groups in Mathematics, Physics, Computer Science, and Engineering perceived that academia was diverse, but not necessarily inclusive. Hispanic/Latino ECRs in the US perceived that their presence enhanced diversity in their department, but without feeling real support from their institutions (Chakraverty et al., 2022b). Moreover, the studies demonstrated that groups are complex, and strategies to increase participation of underrepresented groups need to consider ethnically minoritised identities' complexity:

When offered a diversity scholarship during PhD training, she felt guilty and wanted to offer it to someone else, not feeling like she belonged as a diverse candidate, because she "looked like the White girl in a class of diverse people. I don't know if people judge me for that." She did not consider herself "enough of a minority to deserve some of the opportunities

Chakraverty.
2022a.

As it was mentioned, these discrimination experiences were associated with a sense of 'lack of fit', not-belonging and disconfirmation of their STEM identities. Brockman and colleagues (2022) showed that perceived racial discrimination was negatively associated with perceptions of being recognised as scientist and, in turn, decreased the role of being a scientist in an individuals' identity:

"He said that too many women were coming in and for him, women were not fit to go on the field, because they were not as strong as men. He also said we were doing too much modelling, we should not rely so much on computers and we should still go more in the field. At first, I was shocked to hear that. I felt super bad. I thought it was a joke at first. I was waiting for the end of the joke, he was super serious. So, I heard afterward that people were shocked by what he said, but nobody called him out" (Postdoc participant, Eren, 2021)

Hence, the barriers and challenges that ECRs face in the disciplines described are multiple. Some of these barriers are specific to those from underrepresented backgrounds (e.g., work-like balance and motherhood), and others can be said to apply to all (e.g., productivity). However, the precarious positions of ECRs from underrepresented backgrounds makes them more susceptible to experience the negative consequences associated to these barriers.

Discussion

This report aimed to map the barriers for the retention and success of underrepresented groups - specifically in terms of gender, social class and ethnically minoritised groups - in Mathematics, Physics, Computer Science, and Engineering. Across 31 papers, we identified a range of target groups studied, theoretical frameworks used, and methods utilised. We also conducted a thematic analysis to systematise the barriers described in the papers, creating three core themes: (a) varying ECRs trajectories, (b) challenges of institutional culture, and (c) discrimination experiences. Despite having persisted through their academic careers to obtain paid research positions, the literature shows that Early Career Researchers from underrepresented backgrounds still face several challenges. In this section, we will discuss these findings, the limitations of the studies included and make recommendations for future directions of research.

Academic culture: competitiveness and precarious conditions for ECRs

University culture has tied academics' success to productivity and metrics (Ma & Ladisch, 2016). The review has shown that women are particularly affected by this definition of success, as they face the challenge of making 'motherhood' and 'academic productivity' compatible. Indeed, motherhood was seen as a barrier for retention, and was associated with a lack of productivity and, hence, impacting opportunities to have tenure track and more stable positions. The conflicts between motherhood and academic careers have been documented in STEM disciplines (Cech & Blair - Loy, 2019), and academia in general (Amer, 2013). However, in disciplines where women are in the minority, such as those covered in this review, expectations about women in motherhood are shaped by the lack of role models, i.e., 'being the only one' and a 'strong male' culture (Wolf-Wendel & Ward, 2015).

Indeed, the problems regarding academic culture exposed in this report, such as competitiveness, heavy workloads, precarity (Albayrak - Aydemir et al., 2023), and gender discrimination (Pruit et al., 2021) are not limited to ECRs or individuals from STEM disciplines. While many of these challenges can be linked to the experiences of ECRs more generally, it is the precarious position of those from underrepresented backgrounds which makes them more vulnerable to these challenges. To begin with, and following the systematic scoping review findings, ECRs from underrepresented groups are likely to be first generation students or academics with fewer social networks compared to ECRs from more privileged backgrounds (Chakraverty, 2022; Roberson, 2020). Moreover, due to job opportunities, many ECRs from underrepresented groups need to relocate in different cities and countries, leading to them losing their family and friends' support network, which tends to be more local (Christian et al., 2021).

The one study that focused on social class experiences made the argument that academic culture for individuals in these disciplines is seen as an unattractive career option - less lucrative than industry. Those from working-class backgrounds are often found to financially support their parents or other extended family and therefore income will be a significant factor in considering career pathways (Chiappa, 2020). However, this statement must be analysed carefully, as in industry, women and ethnically minoritised groups still face a payment gap (Wynarczyk et al., 2006). Therefore, more data are needed about this group.

Inconsistent support for Equality, Diversity & Inclusion

Despite the environment created and reproduced in academia, the papers included in this scoping review showed that universities have created strategies to 'level the field', especially in terms of gender inequalities regarding participation. However, it has also led to consequences that have directly affected ECRs. For instance, one of the most frequently cited strategies to increase diversity and inclusion mentioned across studies was mentoring. The evidence in our review showed that effective mentoring for ECRs was generally experienced within informal spaces, rather than as a structured and tailored strategy from universities. This is critical because the review showed that, for some ECRs, there was a lack of lack of representation of underrepresented groups in senior levels, which can lead to a lack of attainability from the senior mentor.

Another strategy to support ECRs from underrepresented groups discussed in this review was parental leave. The evidence in this review demonstrates the challenges faced by ECRs who go on parental leave - especially women - and we argue this is compounded by the 'pragmatic' strategies taken by universities to continue research projects in this competitive environment. For instance, how research projects are managed when researchers go on parental leave. Often, measures are put in place to ensure the project timeline is not affected, for example recruiting additional research assistants or reallocating leadership of outputs. While this seems to be a sensible approach, there are often negative effects for those who are away – for example the loss of leadership on outputs such as papers or patents will create a gap in their c.v., or their fixed-term contracts may end while on leave and the work given to someone else (Davies et al., 2022).

Hence, it is important to consider that, for women that want to be mothers, institutional support needs to be provided. The decision of having children should not be shaped by institutional constraints and precarity, but rather by women's own choices. Furthermore, these support policies should not only focus on women: gender neutral policies that provide equal parental leave to both women and men promote equal childcare responsibilities (Powell, 2021). There is some evidence about the positive impact of gender-neutral policies for gender equality (see Rocha, 2020), but more work needs to be done. We argue that motherhood/parenthood itself is not the barrier or a cause of penalties – the barrier

is the lack of support and clear policies to minimise the impact of the 'research gap' or to promote a good work-life balance in academia. Without this acknowledgement, the lack of representation of women in these disciplines and in senior academic positions will still be understood as an individual-choice problem, rather than a structural one (Ryan, 2022).

A call for a more specific and theoretically-robust approach to research on ECRs experiences in STEM.

Although research interest in Early Career Researchers (ECRs) has increased in recent years, this review has found a lack of consensus in the literature on what constitutes an ECR. This report framed ECRs as individuals starting their careers in paid positions at academia, to understand these positions outside the scope of being a student (e.g., PhDs), or from being an "apprentice" to a "colleague" (Laudel & Gläser, 2008).

However, literature from this review has shown a disperse approach to understanding what an ECR is, with important lacunas in terms of the operationalisation of this concept. For instance, can PhD students be considered as ECRs? At what point are ECRs not 'early' anymore, in a context where getting a tenured position is harder due to the precarious conditions of academia? Do ECR positions have a 'transitional' aspect (Laudel & Gläser, 2008; Yadav et al., 2020) and, hence, cannot be captured in fixed definitions? Although we recognise the changing context of academia, it becomes critical to develop a clearer definition of ECRs or, at least, a common ground from which ECRs, stakeholders and organisations can discuss ECRs' role in academia, as well as their challenges. To clarify these aspects is critical for academia as a whole, but also of particular importance in the disciplines covered in this report. The inclusion of ECRs from different backgrounds in Mathematics, Physics, Computer Science, and Engineering is imperative, as - otherwise and how the literature has shown - the notion of who fits in the ECR category will keep perpetuating the 'old white man' prototype in STEM.

Furthermore, 'sciences' or 'STEM' can also be considered as broad concepts. An important challenge faced while conducting this systematic scoping review was a lack of detail in the papers on the specific disciplinary cultures of Mathematics, Physics, Computer Science, and Engineering. Most of the research exploring ECRs' experiences in STEM disciplines did not identify the particularities that disciplinary cultures have nor the ways that these might differently shape ECRs from underrepresented groups' experiences. We acknowledge that there are similarities across academia and STEM disciplines, however, the literature that indeed considered discipline particularities highlighted that - for example - the differences in terms of gender participation across STEM disciplines needs to be considered (Caldarulo et al., 2022; Fox, M.F. & Gaughan, M.; 2021). Furthermore, disciplines across STEM are also associated with different levels of prestige (Leslie et al., 2015) which, incidentally, are associated with the level of participation of underrepresented groups: disciplines with lower levels of participation of underrepresented groups, such as the ones included in this report, are associated with higher prestige and expectations of brilliance (Leslie et al., 2015).

The review conducted also showed a lack of specification in some papers in terms of what theoretical frameworks were used to frame research questions and analyse the data. We argue that the lack of information regarding the theoretical frameworks utilised in the research is problematic for several reasons. First, not identifying the theoretical frameworks used - in other words, the 'lens' that researchers used to situate ECRs' experiences - can result in a lack of understanding in the ways that ECRs' experiences are contextually situated. Hence, without clear theoretical frameworks, how ECRs' experiences are interpreted might lead to a focus on analysis that do not consider the role of social and cultural circumstances to understand ECRs' experiences. This can result in research that, instead of promoting social change, paradoxically is contributing to the reproduction of inequalities for underrepresented groups in these disciplines.

Second, research about ECRs' experiences needs to integrate the complexities of this phenomenon, in terms of subjective experiences, underlying mechanisms leading to underrepresentation, contextual (social, economic, institutional) factors that promote or not underrepresentation. Consequently, a theoretical framework from which researchers explore this phenomenon provides validity and rigor to the research.

The dominant focus on gender in research and interventions obscures other inequalities or experiences

In the literature identified in this scoping review, the primary focus was on gender or its intersection with ethnically minoritised experiences, with very little research on other background characteristics. For instance, a notable aspect detected in this systematic scoping review was that research considering social class barriers is limited – with only one study from Chile. Hence, the lack of research on ECRs' social class experiences might be leaving out important insights in terms of how inclusion/exclusion of particular groups actually happens in these disciplines. Moreover, this lack of research does not align with the growing interest of social class experiences in undergraduate (e.g., Grineski et al., 2018; McPhee et al., 2013; Ro et al., 2021) and graduate education levels (e.g., Crumb et al., 2020).

To understand the nuances of underrepresented groups' experiences in Mathematics, Physics, Computer Science, and Engineering disciplines, research and interventions need to include an intersectional approach to social class inequalities (see Sparks et al., 2021). An intersectional approach will also provide a framework to compare and understand how different underrepresented groups (White, working-class women; Ethnically-minoritised men, etc.) experience research careers and the barriers to retention and success in Mathematics, Physics, Computer Science, and Engineering disciplines. Moreover, an intersectional approach will also provide theoretical and methodological tools to understand how the barriers for these groups may be different. Hence, integrating intersectionality in interventions will allow researchers and stakeholders to better understand the 'matrix of oppression' faced by STEM ECRs minoritised by their gender and social class, for example (Collins, 1991).

Research covered in this review provided evidence of the lack of integration of intersectional experiences in interventions to support ECRs in Mathematics, Physics, Computer Science, and Engineering disciplines. For instance, interventions and support programmes conducted by a university in the US were perceived as 'one size fit all' strategies (McGee et al., 2021), which did not consider particularities of (a) other underrepresented groups and (b) what entails to belong to different underrepresented groups (e.g., women of colour, biracial identities). Therefore, the increasing literature focusing on intersectional experiences of those from underrepresented groups can provide a more nuanced approach to understand the challenges and barriers that these groups face, as well as integrating these results in equality, diversity and inclusion interventions.

Conclusion

Using evidence from a systematic scoping review, this report has looked in detail at the evidence around the barriers that individuals from underrepresented groups in terms of gender, social class, and ethnicity face as Early Career Researchers in Mathematics, Physics, Computer Science, and Engineering disciplines. The barriers that ECRs from underrepresented groups face have historically persisted, and changes at university and department levels need to be conducted to ensure equality, diversity and inclusion in these disciplines. However, more research is needed, as we detected significant gaps regarding: social class experiences; a more nuanced approach to disciplines and their particular challenges; and wider use of theoretical frameworks to improve the validity of findings. This is important, because ECRs from underrepresented groups face these barriers in these disciplines on top of the issues we are already aware of in these disciplines, such as stereotype threat (see Achtzehn et al., 2023), negative stereotyping (see Legget - Robinson & Villa, 2021), or harassment (see O'Brien et al., 2016).

Following this review and a co-creation workshop with stakeholders, where results were presented and discussed, this report recommends: creating interventions to promote ECRs' retention and success that consider experiences as complex and intersectional; promoting consistency and evidence-based strategies for mentoring programmes for ECRs; challenging pressures about productivity and metrics; and providing better support for ECRs on – and returning from – parental leave.

Without considering the complexities of ECRs' experiences and the role of organisational and cultural practices grounded in academia and departments, strategies focussed on increasing numbers of participation and promote diversity will be detrimental to achieve inclusion for underrepresented scholars in these disciplines. Previous research has shown that diversity strategies need to analyse what norms about the organisational culture they convey - for instance, whether inclusion is understood as 'assimilation' with the predominant group or strategies aim to deny differences among groups (Kirby et al., 2020). Furthermore, the focus on increasing numbers of individuals from underrepresented groups in ECR positions, while appearing to be a practical and fast solution to improve diversity in these disciplines, has led to insidious consequences that affected the ones that would benefit from inclusion policies the most.

Finally, it is important to note that academia is not a 'culturally neutral' environment – people bring different experiences and knowledge, and some are more valued (and leverageable) than others. When this is more widely acknowledged we will be able to take appropriate steps to create a socially-just, innovative, and welcoming research culture.

Appendices

Papers included in the review

The results reported in this document are based on the following papers:

1) Amon, M. J. (2017). Looking through the Glass Ceiling: A Qualitative Study of STEM Women's Career Narratives. Frontiers in Psychology, 8, 236. https://doi.org/10.3389/fpsyg.2017.00236

2) Anderson, L. B., Long, Z., Buzzanell, P. M., Kokini, K., Batra, J. C., & Wilson, R. F. (2015). Compartmentalizing Feelings: Examining the Role of Workplace Emotions in the Mentoring Experiences of Underrepresented Women Faculty. The Electronic Journal of Communication, 25(3 & 4). https://www.cios.org/ejcpublic/025/3/025304.html

3) Barnard, S., Rose, A., Dainty, A., & Hassan, T. (2021). Understanding social constructions of becoming an academic through women's collective career narratives. Journal of Further and Higher Education, 45(10), 1342 - 1355. https://doi.org/10.1080/0309877X.2020.1865523

4) Blake - Beard, S., Bayne, M. L., Crosby, F. J., & Muller, C. B. (2011). Matching by Race and Gender in Mentoring Relationships: Keeping our Eyes on the Prize. Journal of Social Issues, 67(3), 622 - 643. https://doi.org/10.1111/j.1540 - 4560.2011.01717.x

5) Bozzon, R., Murgia, A., Poggio, B., & Rapetti, E. (2017). Work–life interferences in the early stages of academic careers: The case of precarious researchers in Italy. European Educational Research Journal, 16(2 - 3), 332 - 351. https://doi.org/10.1177/1474904901416166699364

6) Brockman, A. J., Naphan - Kingery, D. E., & Pitt, R. N. (2022). When talent goes unrecognized: racial discrimination, community recognition, and STEM postdocs' science identities. Studies in Graduate and Postdoctoral Education, 13(2), 221 - 241. https://doi.org/10.1108/sgpe - 12 - 2020 - 0079

7) Buzzanell, P. M., Long, Z., Anderson, L. B., Kokini, K., & Batra, J. C. (2015). Mentoring in Academe. Management Communication Quarterly, 29(3), 440 - 457. https://doi.org/10.1177/0893318915574311

8) Caldarulo, M., Olsen, J., Frandell, A., Islam, S., Johnson, T.P., Feeney, M.K. (2022) COVID - 19 and gender inequity in science: Consistent harm over time. PLoS ONE 17(7): e0271089. https://doi.org/10.1371/journal.pone.0271089

9) Chakraverty, D. (2020). The Impostor Phenomenon Among Black Doctoral and Postdoctoral Scholars in STEM. International Journal of Doctoral Studies, 15, 433 - 460. https://doi.org/10.28945/4613

10) Chakraverty, D. (2020b). The Impostor Phenomenon Among Postdoctoral Trainees in STEM: A US - Based Mixed - Methods Study. International Journal of Doctoral Studies, 15, 329 - 352. https://doi.org/10.28945/4589

11) Chakraverty, D. (2022a). A Cultural Impostor? Native American Experiences of Impostor Phenomenon in STEM. CBE Life Sci Educ, 21(1), ar15. https://doi.org/10.1187/cbe.21 - 08 - 0204

12) Chakraverty, D. (2022b). Impostor Phenomenon Among Hispanic/Latino Early Career Researchers in STEM Fields. Journal of Latinos and Education, 1 - 19. https://doi.org/10.1080/15348431.2022.2125394

13) Chiappa, R. (2020). Seeking faculty jobs: exploring the relationship between academic's social class of origin and hiring networks in chilean universities. Calidad en Educacion. (52), 205 - 238. https://doi.org/10.31619/caledu.n52.760

14) Eaton, A. A., Saunders, J. F., Jacobson, R. K., & West, K. (2019). How Gender and Race Stereotypes Impact the Advancement of Scholars in STEM: Professors' Biased Evaluations of Physics and Biology Post - Doctoral Candidates. Sex Roles, 82(3 - 4), 127 - 141. https://doi.org/10.1007/s11199 - 019 - 01052 - w

15) Eren, E. (2021). Exploring Science Identity Development of Women in Physics and Physical Sciences in Higher Education: A Case Study from Ireland. Science and Education, 30(5), 1131 - 1158. https://doi.org/10.1007/s11191 - 021 - 00220 - 3

16) Eren, E. (2022a). Never the right time: maternity planning alongside a science career in academia. Journal of Gender Studies, 31(1), 136 - 147. https://doi.org/10.1080/09589236.2020.1858765

17) Eren, E. (2022b). Talking science and feminism. Journal of Gender Studies, 31(8), 911 - 927. https://doi.org/10.1080/09589236.2022.2091527

18) Fox, M.F. & Gaughan, M. (2021). Gender, Family and Caregiving Leave, and Advancement in Academic Science: Effects across the Life Course. Sustainability, 13, 6820. https://doi.org/10.3390/ su13126820

19) Illovsky, M. E. (1991). A Comparison of the Physical and Mental Health of Doctoral Level Women Scientists. Journal of College Student Psychotherapy, 5(3), 99 - 110. https://doi.org/10.1300/J035v05n03_08

20) Long, Z., Buzzanell, P. M., Kokini, K., Wilson, R. F., Batra, J. C., & Anderson, L. B. (2018). Mentoring women and minority faculty in engineering: A multidimensional mentoring network approach. Journal of Women and Minorities in Science and Engineering, 24(2), 121 - 145. https://doi.org/10.1615/JWomenMinorScienEng.2017019277

21) McGee, E. O., Main, J. B., Miles, M. L., & Cox, M. F. (2021). An Intersectional Approach to Investigating Persistence among Women of Color Tenure - Track Engineering Faculty. Journal of Women and Minorities in Science and Engineering, 27(1), 57 - 84. https://doi.org/10.1615/JWomenMinorScienEng.2020035632

22) Miles, M. L., Brockman, A. J., & Naphan-Kingery, D. E. (2020). Invalidated identities: The disconfirming effects of racial microaggressions on Black doctoral students in STEM. Journal of Research in Science Teaching, 57(10), 1608 - 1631. https://doi.org/10.1002/tea.21646

23) Noel, T. K., Miles, M. L., & Rida, P. (2022a). Using social exchange theory to examine minoritised STEM postdocs' experiences with faculty mentoring relationships. Studies in Graduate and Postdoctoral Education, 13(1), 90 - 108. https://doi.org/10.1108/sgpe - 12 - 2020 - 0080

24) Noel, T.K., Miles, M.L., & Rida, P. (2022b) Stressed - Out of STEM: Examining Mentoring Experiences of Women, People of Color, and International Postdocs, Educational Studies, 58(4), 435 - 457, DOI: 10.1080/00131946.2022.2051030

25) Patt, C., Eppig, A., & Richards, M. A. (2021). Postdocs as Key to Faculty Diversity: A Structured and Collaborative Approach for Research Universities. Frontiers in Psychology, 12, 759263. https://doi.org/10.3389/fpsyg.2021.759263

26) Sonnert, G., & Holton, G. (1996). Career Patterns of Women and Men in the Sciences. American Scientist, 84(1), 63 - 71. https://www.jstor.org/stable/29775599

27) Start, D., & McCauley, S. (2020). Gender underlies the formation of STEM research groups. Ecology and Evolution, 10(9), 3834 - 3843. https://doi.org/10.1002/ece3.6188

28) Strong, A. C., Smith - Orr, C., Bodnar, C., Lee, W., McCave, E., & Faber, C. (2021). Early Career Faculty Transitions: Negotiating Legitimacy and Seeking Support in Engineering Education. Studies in Engineering Education, 1(1), 97–118. http://doi.org/10.21061/see.52

29) Viefers, S. F., Christie, M. F., & Ferdos, F. (2006). Gender equity in higher education: why and how? A case study of gender issues in a science faculty. International Journal of Phytoremediation, 31(1), 15 - 22. https://doi.org/10.1080/03043790500429948

30) Weisshaar, K. (2017). Publish and Perish? An Assessment of Gender Gaps in Promotion to Tenure in Academia. Social Forces, 96(2), 529 - 560. https://doi.org/10.1093/sf/sox052

31) Yadav, A., Seals, C. D., Sullivan, C. M. S., Lachney, M., Clark, Q., Dixon, K. G., & Smith, M. J. T. (2020). The Forgotten Scholar: Underrepresented Minority Postdoc Experiences in STEM Fields. Educational Studies, 56(2), 160 - 185. https://doi.org/10.1080/00131946.2019.1702552

Methods

The initial search was conducted on the 13th of December 2023 and included five databases: APA PsyNet (including APA PsycInfo, APA PsycArticles Full Text, and APA PsycExtra), EBSCO (including E - Journals, British Education Index, Education Research Complete, ERIC), International Bibliography of Social Sciences (IBSS), Scopus, and Web of Science. In this search, we aimed to include the key concepts of our review (e.g. engineer* "gender", "early career*"), while maintaining an exploratory approach. To this end, we did not include in our search words such as "barriers".

Syntax (Search in title and abstract)

((engineer* OR math* OR physic* OR "comput* science*") AND (wom?n OR gender* OR female* OR "non - binary" OR "non binary" OR transgender* OR queer* OR "LGBT*" OR underrepresent* OR marginali?ed OR marginali?ation OR disadvantage* OR ethnic* OR race* OR racial* OR "people of colo?r" OR minorit* OR socioeconomic* OR "SES" OR "first generation student*" OR "first - generation student*" OR "low* income" OR "low* - income" OR "subjective social status" OR "economic status" OR "working class*" OR "working - class*" OR "social class*" OR poor* OR "first in family") AND ("early career*" OR "early - career*" OR "ECA*" OR "ECR*" OR postdoc* OR "post doc*" OR "post - doc*" OR "post PhD" OR "post - PhD" OR lecturer* OR "assistant professor*" OR "academic assistant*" OR "adjunct professor*" OR "research fellow*" OR "research associate*" OR "associated researcher*" OR "research assistant*") NOT (adolescen* OR child* OR school* OR "stem cell*" OR physician* OR medic* OR "physical education" OR soil* OR protein* OR {cancer} OR fluid* OR steel* OR "DNA" OR nurse* OR {nursing} OR veterina* OR {solar} OR teach* OR aluminium* OR {blood} OR animal* OR "breeding" OR plasma* OR "x - ray*" OR "EGM" OR "acid*" OR thermal* OR arrhythmia* OR ablation* OR water* OR "physical activit*"))

After conducting this research, we exported the results to Endnote (v.20) and, after deleting duplicates, we exported the references to an Excel spreadsheet. We then screened the titles and abstracts of each reference and organised them in three categories: include, exclude or to be reviewed. We included references:

(a) focused on Mathematics, Physics, Computer Science, and Engineering disciplines;

(b) focused on ECA/R - this is, postdoctoral and individuals appointed in research and academic positions recently;

(c) focused on the experiences of disadvantaged groups within these disciplines, in terms of their gender, ethnicity/race and social class;

(d) published following a peer - review process; and

(e) written in English.

When the study included more than one discipline under the "STEM" umbrella, or more than one group, studies reported specific results for the disciplines and groups described in (a), (b) and (c). To be included, the abstract needed to mention at least (a) one of the disciplines and (b) one of the groups specified. We did not include date or country restriction.

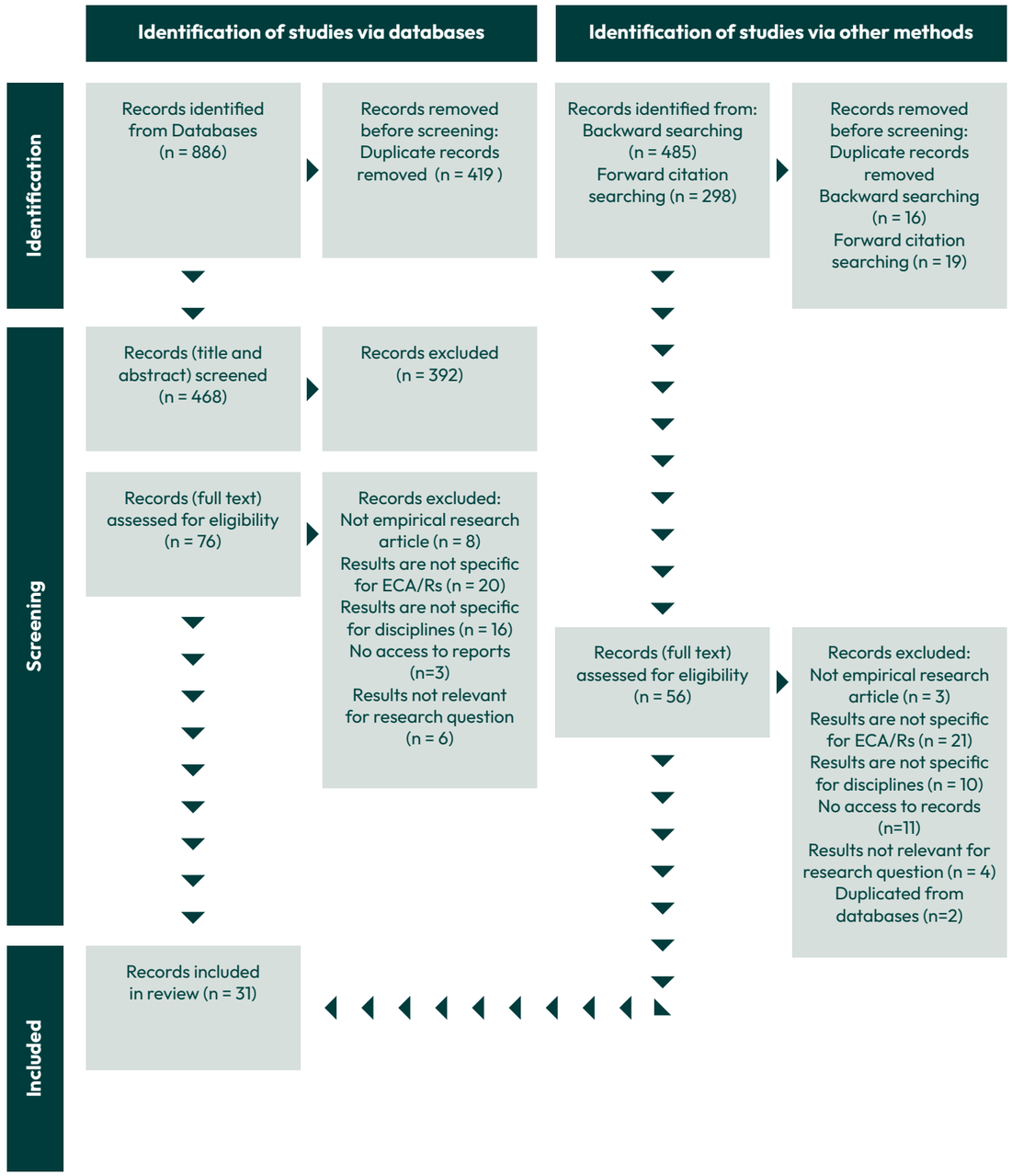
We then read the full texts of the references labelled under the included and to be reviewed categories, and created the final list of references. In a second stage, we conducted a backward and forward reference searching with the final list of references. The backward list included the reference list of each paper, and the forward list was created using Google Scholar. We followed the same procedure and criteria to select the references from these second search stage.

As the criteria returned a list of papers (N=14) that did not include all the disciplines described in the systematic scoping review aim, we looked at again the papers under the category "to be reviewed" and modified the initial criteria, now including research that did not report specific results by discipline or academic positions. The disciplines and academic positions part of our criteria were still mentioned in the methods or participants section. The new total number of papers was 31.

After reading the papers, we extracted key information from each paper: (a) title, (b) year, (c) authors, (d) journal, (e) country, (f) theoretical framework, (g) method(s), (h) discipline(s), and (i) group (gender, social class, ethnically minoritised groups). For practical purposes, we grouped studies covering race and ethnicity as ethnically minoritised groups. However, we acknowledge the complexities of the different concepts used to talk about ethnicity and race.

The included studies were analysed through a thematic analysis (Braun & Clarke, 2006) with the purpose of identifying patterns across the papers. As the researchers had experience researching the key topics of this scoping review, we first coded the papers following a largely deductive approach. Then, we reviewed these first codes and labelled them looking at similarities and patterns. Subsequently, we grouped the codes in subthemes, and the subthemes in themes (For details, see Appendix). We organised the data in three main themes that aimed to answer our research questions, identifying the barriers that ECRs from underrepresented groups face in MPCE disciplines: (a) varying ECRs trajectories, (b) challenges of institutional culture, and (c) discrimination experiences.

Prisma Diagram



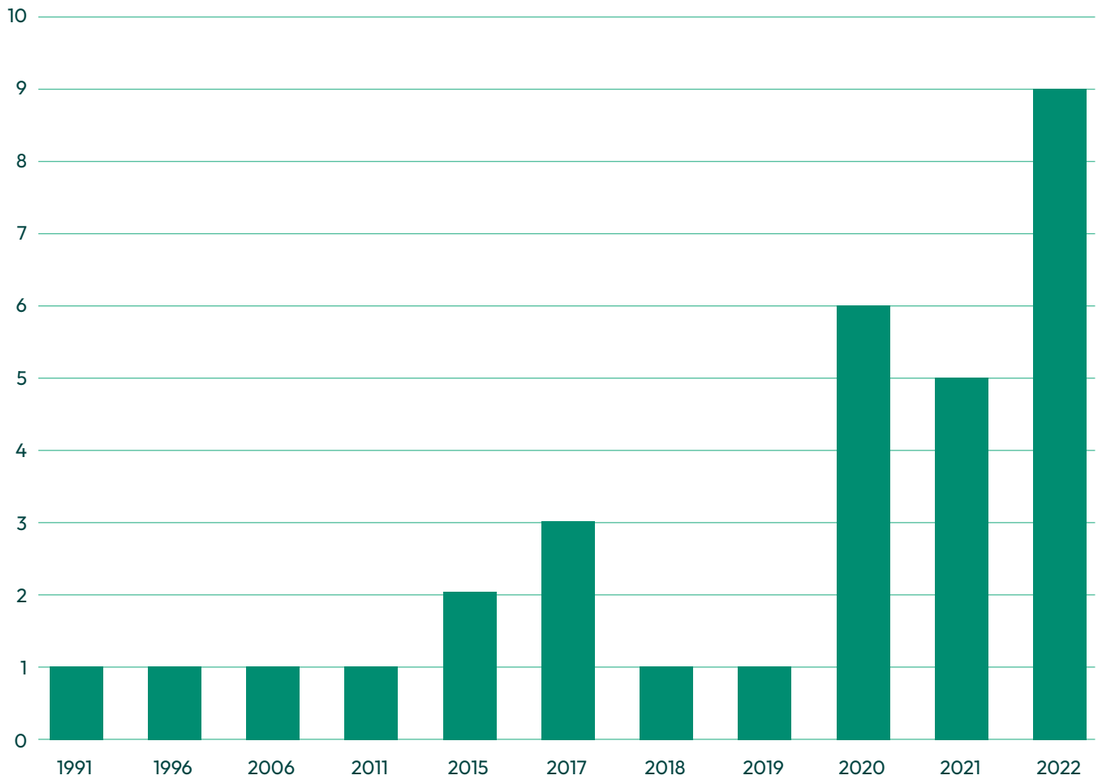
Results - Descriptive

The publication date of the articles was consistent from 1991 to 2011, with a slight increase in 2015 and 2017. However, most of the articles included in the review were published between 2020 and 2022 (N= 20).

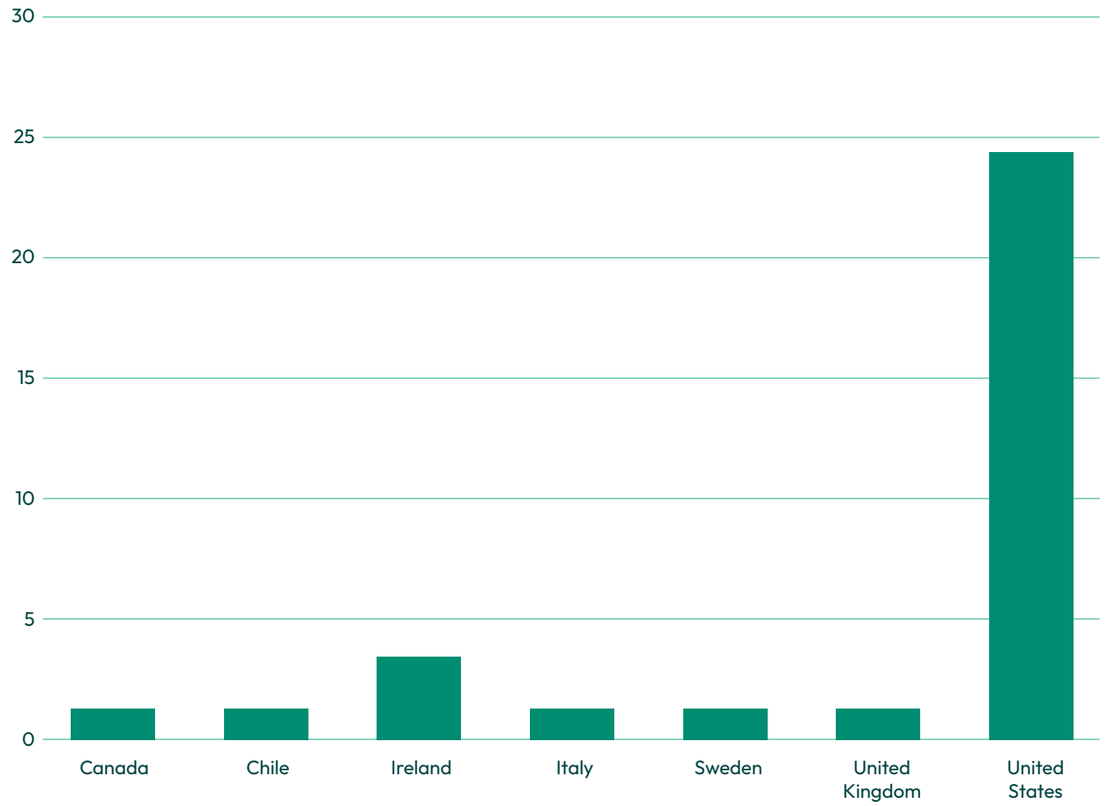
These results show that the interest in ECRs from underrepresented groups experiences within Mathematics, Physics, Computer Science, and Engineering is recent.

The majority of papers included in this review included participants from United States (N = 24), followed by Ireland (N=3). Chile, Italy, Sweden and the United Kingdom were represented with one paper each. One paper included a sample from both Canada and United States (both countries were included separated in the graph).

Publications by year

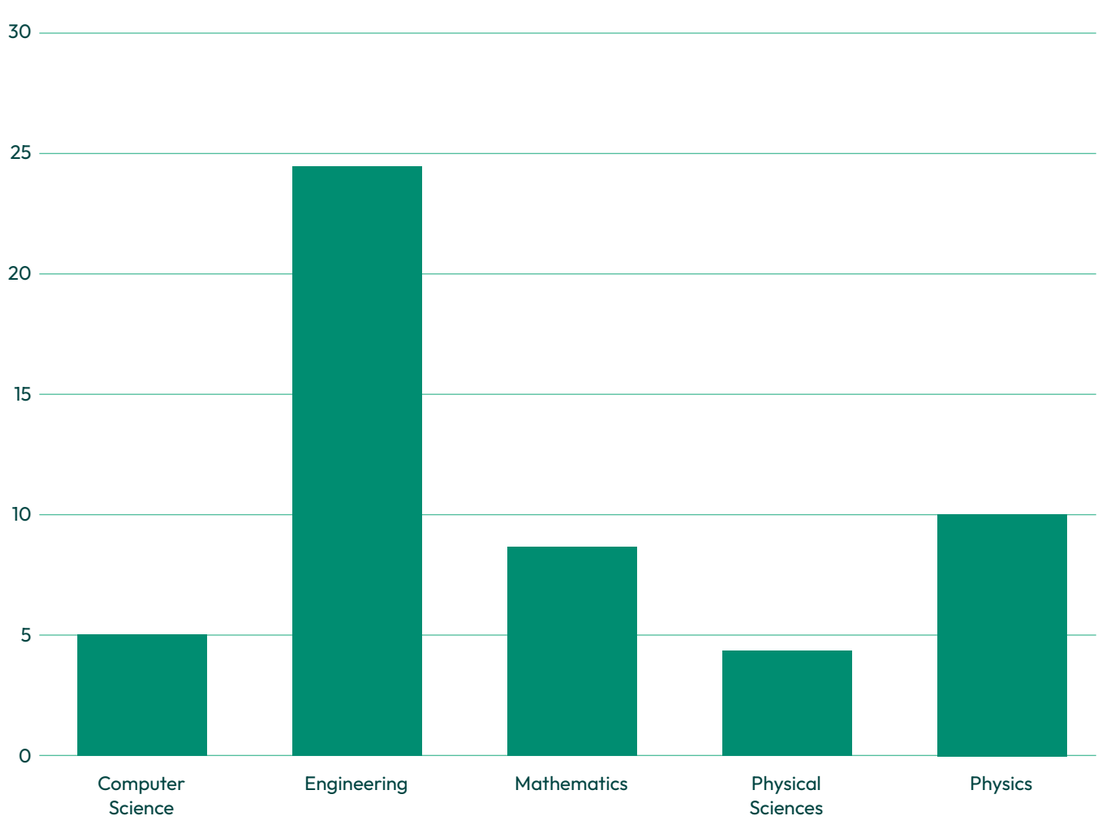


Publications by country



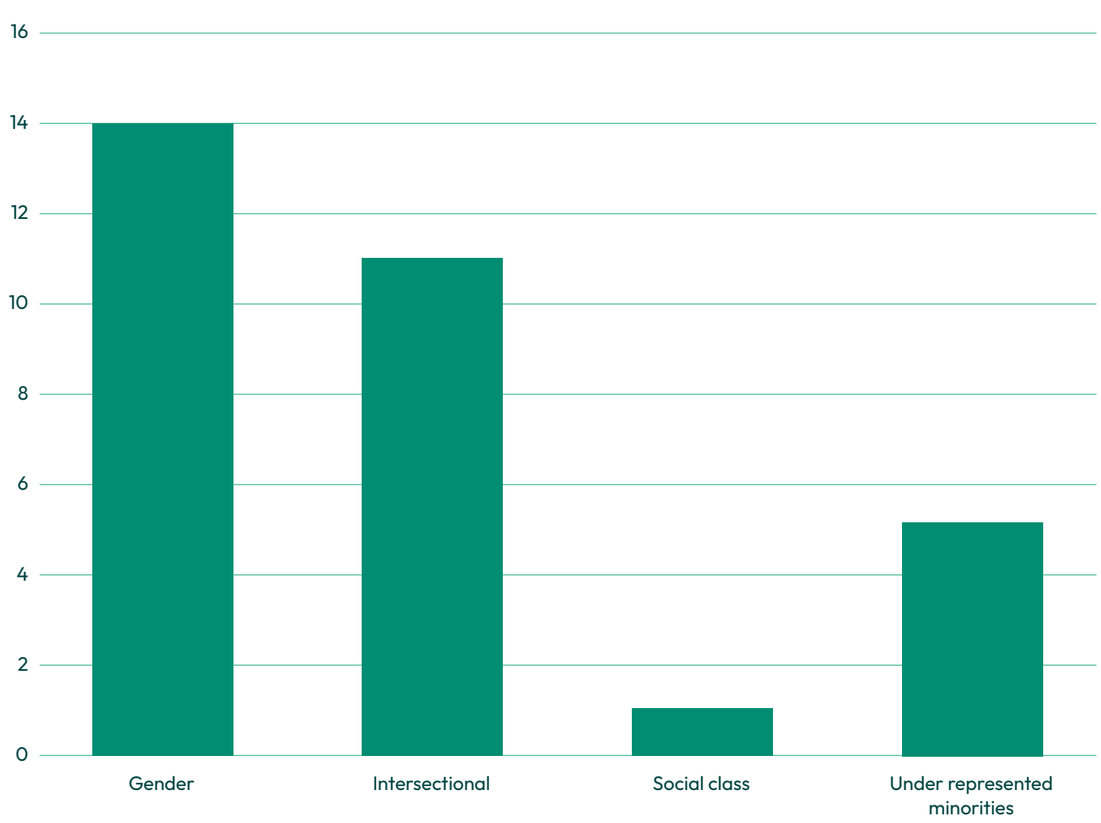
Almost half of the papers (N = 16) focussed on more than one discipline. Across studies, the disciplines covered were Engineering (N = 24), Physics (N = 10), Mathematics (N = 8), Computer Science (N= 5), and Physical Sciences (N = 4).

Publications by discipline



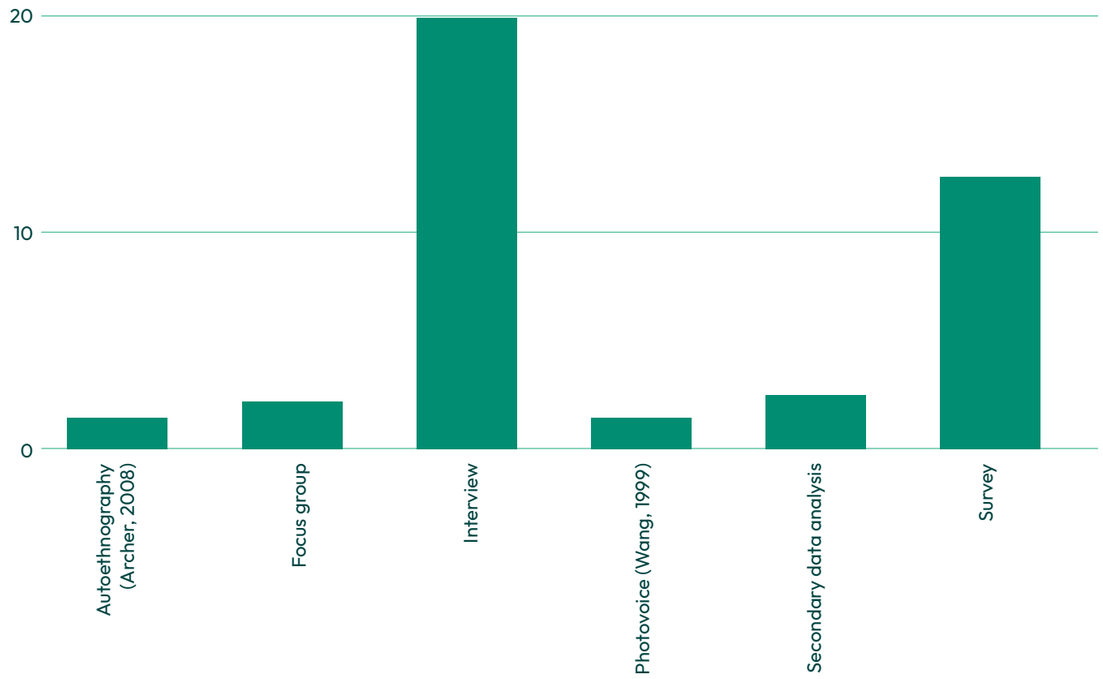
Studies mostly focussed on gender experiences (N=14), particularly women, yet also considering the interaction of gender with minoritised groups (N = 10). From these papers, one declared the inclusion of “social capital” as a group category. In this paper, “social capital” was defined as the membership to an academic group (American Society for Engineering Education). A total of 6 papers focussed only on minoritised groups, with one including the complexities of biracial identities. Finally, the systematic scoping review showed only 1 paper exploring social class as underrepresented group in academia. This paper explored social class experiences within male recently - appointed lecturers. However, it did not explore the intersection of gender experiences and social class.

Publications by group



Studies followed a diverse range of methodologies, with a predominance of qualitative methods (N=24). A total of 8 papers declared using multiple methods. Studies reported - in their majority - results from individual interviews (N = 20), followed by results from surveys (N = 13). One paper reported the use of questionnaires in controlled/experimental designs. Other qualitative methods mentioned were: autoethnography (N=1), focus groups (N=2) and photovoice (N=1). Similarly, 2 papers reported secondary data analysis.

Publications by methodologies

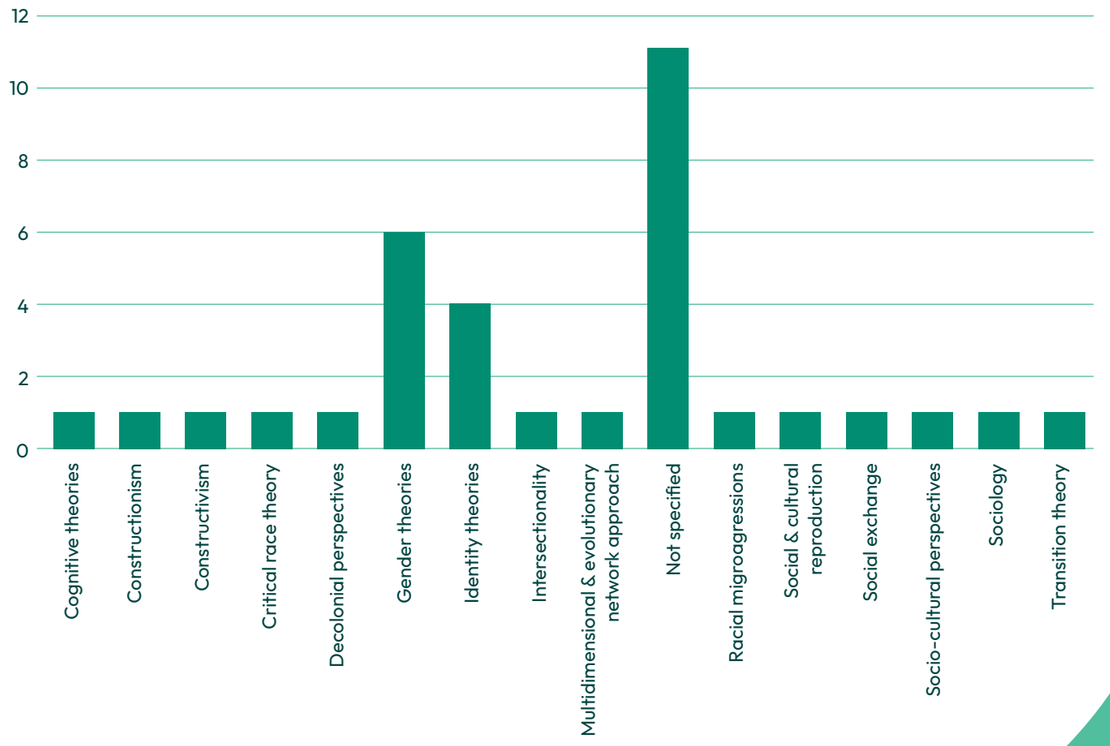


Papers were published in a wide range of journals, most of them (N = 15) centred in Education.

Studies defined ECR differently: most of the papers defined ECR as postdoctoral scholars (N = 13), yet some research included PhD students within this category (n = 8). A number of papers (N = 8) focussed on recently appointed lectures or junior faculty.

The theoretical background used for the studies was diverse. Most of the articles did not declare the theoretical framework used in the research (N=11). An important number of articles (N=6) used gender theories as theoretical frameworks, such as feminist and post - structural feminist theories (Ashcraft, 2014; Armenti, 2004; Butler, 1988; Rupp & Taylor, 1999), or the glass ceiling hypothesis (no author specified). A total of three articles also mentioned identity theories, such as the stereotype content model theory (Fiske et al., 2002), identity - based othering approach (Chakraverty, 2020a), and identity theory (Buke, 1991). It is important to highlight that in some cases the authors identify the theoretical framework used (e.g. social constructionism) without referring to any authors.

Publications by theoretical frameworks



Title	Author	Year	Journal	Country	Theoretical framework	Methods	Discipline	Group
Looking through the glass ceiling: A qualitative study of STEM women's career narratives	Amon, M.J.	2017	Frontiers in Psychology	United States	Feminist methodology approach (Weiler, 1988)	Photovoice (Wang, 1999)	Engineering	Gender
Compartmentalizing feelings: Examining the role of workplace emotions in the mentoring experiences of underrepresented women faculty members.	Anderson, L. B., Long, Z., Buzzanell, P. M., Kokini, K., Batra, J. C., &Wilson, R. F	2015	Electronic Journal of Communication	United States	Not specified	narrative semi-structured interviews	Engineering	Gender; Underrepresented minority groups
Understanding social constructions of becoming an academic through women's collective career narratives	Barnard, S., Rose, A., Dainty, A. & Hassan, T.	2021	Journal of Further and Higher Education	United Kingdom	Interpretivist epistemology (n/a); social constructionism (n/a)	Interviews following a career narrative approach using life-story (Sang, Al-Dajani, and Özbilgin 2013); creative research methods approach (Kara, 2015).	Engineering	Gender
Matching by Race and Gender in Mentoring Relationships: Keeping our Eyes on the Prize	Blake-Bear, Bayne & Crosby	2011	Journal of Social Issues	United States	Not specified	Survey	Engineering	Gender; race
Work-life interferences in the early stages of academic careers: The case of precarious researchers in Italy	Bozzon, R., Murgia, A., Poggio, B. & Rapetti, E.	2017	European Educational Research Journal	Italy	Not specified	Individual interviews	Engineering (mention)	Gender
When talent goes unrecognized: racial discrimination, community recognition, and STEM postdocs' science identities	Brockman, A.J., Naphan-Kingery, D.E., & Pitt, R.N.	2022	Studies in Graduate and Postdoctoral Education	United States	Reflected appraisal process (Stets & Burke, 2014); Identity theory (Buke, 1991)	Survey	Engineering; Physical Sciences	Racially minorisited
Mentoring in academe: a feminist poststructural lens on stories of women engineering faculty of color	Buzzanell, P.M., Long, Z., Anderson, L.B., Kokini, K. and Batra, J.C.	2015	Management Communication Quarterly	United States	Feminist post-structural analyses of narratives (Ashcraft, 2014)	Narrative semi-structured interviews (Atkinson, 2007)	Engineering	Gender; people of colour
COVID-19 and gender inequity in science: Consistent harm over time	Caldarulo, M., Olsen, J., Frandell, A., Islam, S., Johnson, T.P., Feeney, M.K.	2022	PLoS One	United States	Not specified	Survey	Engineering	Gender

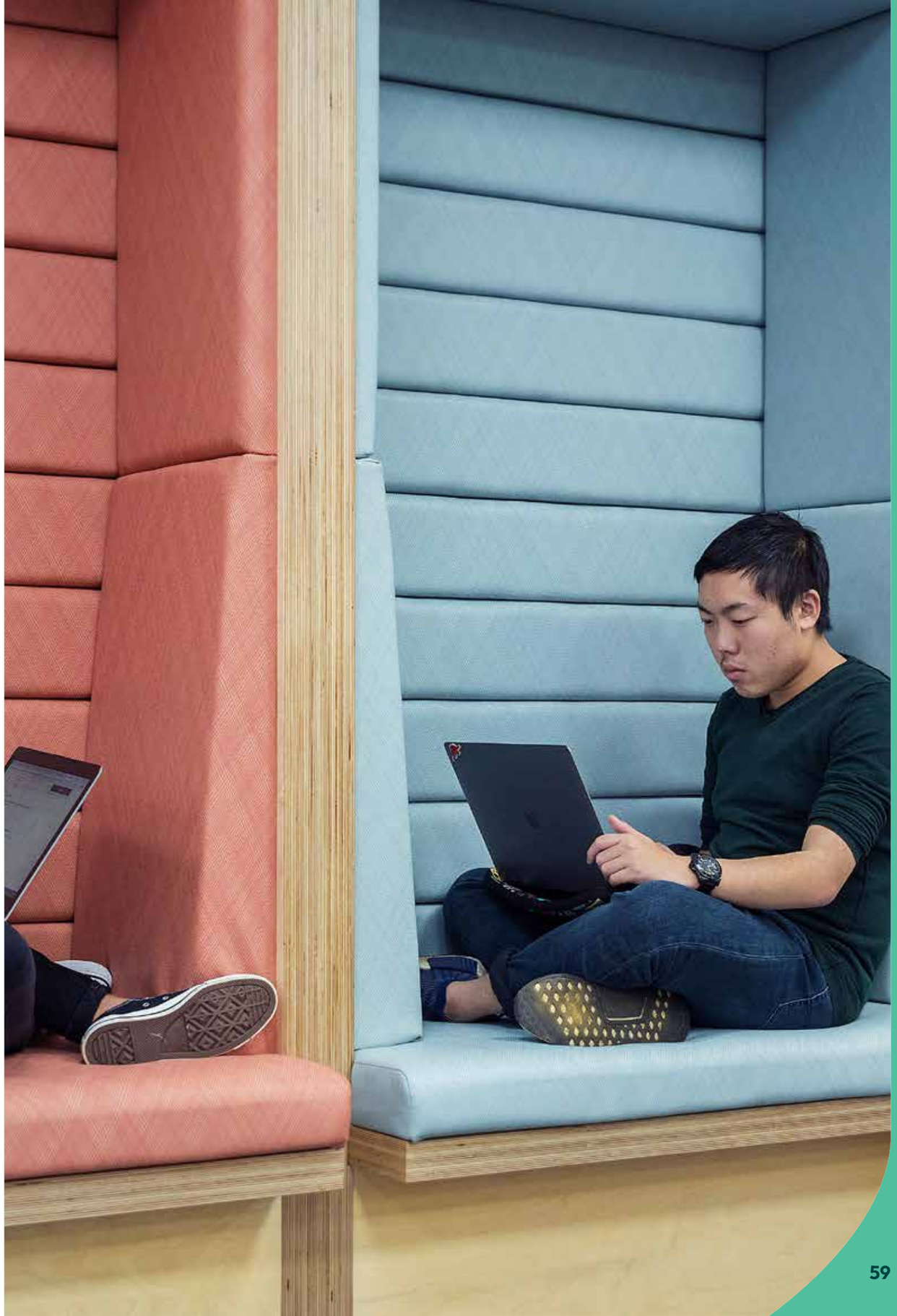
Title	Author	Year	Journal	Country	Theoretical framework	Methods	Discipline	Group
A Cultural Impostor? Native American Experiences of Impostor Phenomenon in STEM	Chakraverty, D.	2022a	CBE - Life Sciences Education	United States	Colonization in STEM (Barron et al., 2021)	Short survey; interviews	Bioengineering; Chemical engineering	Ethnicity
Impostor Phenomenon Among Hispanic/Latino Early Career Researchers in STEM Fields	Chakraverty, D.	2022b	Journal of Latinos and Education	United States	Socio-cultural perspective; identity-based "othering" (Chakraverty, 2020)	Short survey; semi-structured interview	Technology and Engineering; Mathematics	Ethnicity
The impostor phenomenon among black doctoral and postdoctoral scholars in STEM	Chakraverty, D.	2020a	International Journal of Doctoral Studies	United States	Not specified	Semi-structured interviews; survey	Engineering; Mathematics	Race
The impostor phenomenon among postdoctoral trainees in stem: A us-based mixed-methods study	Chakraverty, D.	2020b	International Journal of Doctoral Studies	United States	Not specified	Semi-structured interviews; survey	Engineering; Mathematics	Gender
Seeking faculty jobs: exploring the relationship between academic's social class of origin and hiring networks in chilean universities.	Chiappa, R.	2020	Calidad en Educacion	Chile	Social and cultural reproduction (Bourdieu, 1983, 1987, 1988; Bourdieu & Passeron, 1977); Human capital (Becker, 1967; Mincer, 1984; Schultz, 1970); Network theory (Burt, 2000; Granovetter, 1973; Lin, 2001).	Semi-structured interviews	Industrial Engineering	Social class
How Gender and Race Stereotypes Impact the Advancement of Scholars in STEM: Professors' Biased Evaluations of Physics and Biology Post-Doctoral Candidates	Eaton, A.A., Saunders, J.F., Jacobson, R.K. & West, K.	2019	Sex Roles	United States	Stereotype content model (Fiske et al., 2002)	Survey (experimental design)	Physics	Gender; ethnicity
Never the right time: maternity planning alongside a science career in academia	Eren, E.	2022	Journal of Gender Studies	Ireland	Critical feminist theoretical framework (Armenti, 2004)	In-depth intensive interviews	Physics; Physical Sciences.	Gender

Title	Author	Year	Journal	Country	Theoretical framework	Methods	Discipline	Group
Exploring Science Identity Development of Women in Physics and Physical Sciences in Higher Education	Eren, E.	2021	Science & Education	Ireland	Feminist poststructuralist (Keller, 1987; Sowell, 2004); Intersectionality (n/a); theory of performativity (Butler, 1988)	In-depth intensive interviews	Physics; Physical Sciences.	Gender
Talking science and feminism	Eren, E.	2022	Journal of Gender Studies	Ireland	Feminist approach (Rupp & Taylor, 1999)	In-depth individual interviews	Physics; Physical Sciences	Gender
Gender, Family and Caregiving Leave, and Advancement in Academic Science: Effects across the Life Course	Fox, M.F. & Gaughan, M.	2021	Sustainability	United States	Sociology (Blair-Loy, 2003, 2004; Weber, 1946)	Survey	Engineering, Mathematics	Gender
A Comparison of the Physical and Mental Health of Doctoral Level Women Scientists	Illovsky, M.E.	1991	Journal of College Student Psychotherapy	United States	Not specified	Survey	Physics; Mathematics	Gender
Mentoring Women and Minority Faculty in Engineering: A Multidimensional Mentoring Network Approach	Long, Z., Buzzanell, P.M., Kokini, K., Wilson, R.F., Batra, J.C. & Anderson, L.B.	2018	Journal of Women and Minorities in Science and Engineering	United States	Multidimensional and evolutionary network approach (Contractor et al., 2011)	In-depth semi-structured interviews	Engineering	Gender, Underrepresented minorities
An intersectional approach to investigating persistence among women of color tenure-track engineering faculty	McGee, E., Main, J.B., Miles, M.L. and Cox, M.F.	2021	Journal of Women and Minorities in Science and Engineering	United States	Persistence theory (Bean & Metz, 1975; Metz, 2004); Intersectionality (Crenshaw, 1989).	Semi-structured interviews; Focus group	Engineering	Gender; people of colour
Invalidated identities: The disconfirming effects of racial microaggressions on Black doctoral students in STEM.	Miles, M.L., Brockman, A.J. and Naphan-Kingery, D.E.	2020	Journal of Research in Science Teaching	United States	Racial microaggressions (Pierce, Carew, Pierce- Gonzalez, & Wills, 1977); Identity nonverification (Stets & Burke, 2014)	Semi-structured interviews; Focus group	Engineering	Gender; race

Title	Author	Year	Journal	Country	Theoretical framework	Methods	Discipline	Group
Stressed-Out of STEM: Examining Mentoring Experiences of Women, People of Color, and International Postdocs	Noel, T.K., Miles, M.L. & Rida, P.	2022a	Educational Studies	United States	Not specified	Interviews	Physics; Computer Sciences; Engineering	Gender; “people of colour”
Using social exchange theory to examine minoritised STEM postdocs’ experiences with faculty mentoring relationships	Noel, T.K., Miles, M.L., & Rida, P.	2022b	Studies in Graduate and Postdoctoral Education	United States	Social exchange (Molm’s, 2006)	Open-ended interviews	Engineering; Computer Science; Physics (Biophyiscs, Physics and Astronomy)	Gender; ethnicity
Postdocs as Key to Faculty Diversity: A Structured and Collaborative Approach for Research Universities	Patt, C., Eppig, A. & Richards, M.	2022	Frontiers in Psychology	United States	Not specified	Data e interventions analysis	Mathematics; Physics; Computer Science; Engineering	Underrepresented minorities (ethnicity)
Career patterns of women and men in the sciences	Sonnert, G. & Holton, G.	1996	American Scientist	United States	Glass ceiling and threshold hypotheses	Survey; open ended interviews	Mathematics; Engineering	Gender
Gender underlies the formation of STEM research groups	Star, D. & McCauley, S.	2020	Ecology and Evolution	Canada; United States	Not specified	Survey	Physics; Mathematics	Gender
Early Career Faculty Transitions: Negotiating Legitimacy and Seeking Support in Engineering Education	Strong, A.C., Smith-Orr, C., Bodnar, C., Lee, W., McCave, E. & Faber, C.	2021	Studies in Engineering Education	United States	Transition theory (Schlossberg, 1981)	Autoethnography (Archer, 2008; Geist-Martin et al., 2010)	Engineering	Gender; ethnicity; social capital
Gender equity in higher education: why and how? A case study of gender issues in a science faculty	Viefers, S., Christie, M., & Ferdos, F.	2006	European Journal of Engineering Education	Sweden	Constructivism (n/a)	Semi-structured interviews (Belenky et al., 1997); survey (data not reported).	Physics	Gender
Publish and Perish? An Assessment of Gender Gaps in Promotion to Tenure in Academia	Weisshaar, K.	2017	Social Forces	United States	Not specified	Data set analysis	Computer Science	Gender
The Forgotten Scholar: Underrepresented Minority Postdoc Experiences in STEM Fields	Yadav, A., Seals, C., Soto Sullivan, C., Lachney, M., Clark, Q., Dixon, K. & Smith, M.	2020	Educational Studies	United States	Critical race theory (Bell, 1980); Social cognitive career theory (Lent, Brown, & Hackett, 1994); Intersectional identities (Jones & McEwen, 2000)	Intensive interviewing method	Engineering; Computer Science	Underrepresented minorities

Thematic coding - framework

Codes	Subthemes	Themes
Economic inequalities	Inequalities in the previous trajectories of ECRs	**Varying ECRs trajectories**
Knowledge about academia		
Previous experiences		
Validation as academic	Not being recognised as an academic and scientist	
Mental health		
Lack of representation	Identity lack of fit with prototype	
Feeling unqualified		
Lack of fit		
Second language		
Deny intersectional identities	Intersectional identities	
Lack of tailored interventions		
Lack of understanding about ECRs identities	University culture and support	**Challenges of institutional culture**
Hierarchies		
Belonging		
Academic publishing		
University support		
Environmental pressure		
Disorientation	Uncertainty and precarity in academia	
Uncertainty		
Beliefs about motherhood		
Family and childcare		
Work life balance		
Mentoring problems	Lack of support from experienced academics	
Social connections		
Relationship with PI		
Lack of role models		
Others academics support		
Multiple identities support		
Networking	Lack to access to networking	
Social connections		
Social capital		
Tokenism	Gender and racial discrimination in academia	**Discrimination experiences**
Gender discrimination in academia		
Microaggressions		
Positive discrimination		
Racial discrimination		
Subtle discrimination		
See mistreatment		
Gender stereotypes	Stereotypes about abilities to succeed in academia	
Stereotypes about feminism		
Racial stereotypes		



Report references

Amer, M. (2013). Combining Academic Career and Motherhood: Experiences and Challenges of Women in Academia. International Research Journal of Social Sciences, 2(4). http://www.isca.me/IJSS/Archive/v2/i4/3.ISCA - IRJSS - 2013 - 050.pdf

Amon, M. J. (2017). Looking through the Glass Ceiling: A Qualitative Study of STEM Women's Career Narratives. Frontiers in Psychology, 8, 236. https://doi.org/10.3389/fpsyg.2017.00236

Anderson, L. B., Long, Z., Buzzanell, P. M., Kokini, K., Batra, J. C., & Wilson, R. F. (2015). Compartmentalizing Feelings: Examining the Role of Workplace Emotions in the Mentoring Experiences of Underrepresented Women Faculty. The Electronic Journal of Communication, 25(3 & 4). https://www.cios.org/ejcpublic/025/3/025304.html

APPG on Diversity and Inclusion in STEM. (2021). Inquiry into Equity in the STEM Workforce. Final report. Retrieved from https://biochemistry.blob.core.windows.net/public/2021/11/appgdiinstem - equitystemworkforcereport - webversion.pdf

Barnard, S., Rose, A., Dainty, A., & Hassan, T. (2021). Understanding social constructions of becoming an academic through women's collective career narratives. Journal of Further and Higher Education, 45(10), 1342 - 1355. https://doi.org/10.1080/0309877X.2020.1865523

Blake - Beard, S., Bayne, M. L., Crosby, F. J., & Muller, C. B. (2011). Matching by Race and Gender in Mentoring Relationships: Keeping our Eyes on the Prize. Journal of Social Issues, 67(3), 622 - 643. https://doi.org/10.1111/j.1540 - 4560.2011.01717.x

Bozzon, R., Murgia, A., Poggio, B., & Rapetti, E. (2017). Work–life interferences in the early stages of academic careers: The case of precarious researchers in Italy. European Educational Research Journal, 16(2 - 3), 332 - 351. https://doi.org/10.1177/1474904901416166699364

Braun, V. & Clarke, V. (2006) Using thematic analysis in psychology, Qualitative Research in Psychology, 3:2, 77 - 101, DOI: 10.1191/1478088706qp063oa

Brockman, A. J., Naphan - Kingery, D. E., & Pitt, R. N. (2022). When talent goes unrecognized: racial discrimination, community recognition, and STEM postdocs' science identities. Studies in Graduate and Postdoctoral Education, 13(2), 221 - 241. https://doi.org/10.1108/sgpe - 12 - 2020 - 0079

Buzzanell, P. M., Long, Z., Anderson, L. B., Kokini, K., & Batra, J. C. (2015). Mentoring in Academe. Management Communication Quarterly, 29(3), 440 - 457. https://doi.org/10.1177/0893318915574311

Caldarulo M, Olsen J, Frandell A, Islam S, Johnson TP, Feeney MK, et al. (2022) COVID - 19 and gender inequity in science: Consistent harm over time. PLoS ONE 17(7): e0271089. https://doi. org/10.1371/journal.pone.0271089

Casad, BJ, Franks, JE, Garasky, CE, Kittleman, MM, Roesler, AC, Hall, DY, Petzel, ZW. Gender inequality in academia: Problems and solutions for women faculty in STEM. Journal of Neuroscience Research, 99: 13– 23. https://doi.org/10.1002/jnr.24631

Cech, E. A., & Blair - Loy, M. (2019). The changing career trajectories of new parents in STEM. Proceedings of the National Academy of Sciences of the United States of America, 116(10), 4182–4187. https://doi.org/10.1073/pnas.1810862116

Chakraverty, D. (2020a). The Impostor Phenomenon Among Black Doctoral and Postdoctoral Scholars in STEM. International Journal of Doctoral Studies, 15, 433 - 460. https://doi.org/10.28945/4613

Chakraverty, D. (2020b). The Impostor Phenomenon Among Postdoctoral Trainees in STEM: A US - Based Mixed - Methods Study. International Journal of Doctoral Studies, 15, 329 - 352. https://doi.org/10.28945/4589

Chakraverty, D. (2022a). A Cultural Impostor? Native American Experiences of Impostor Phenomenon in STEM. CBE Life Sci Educ, 21(1), ar15. https://doi.org/10.1187/cbe.21 - 08 - 0204

Chakraverty, D. (2022b). Impostor Phenomenon Among Hispanic/Latino Early Career Researchers in STEM Fields. Journal of Latinos and Education, 1 - 19. https://doi.org/10.1080/15348431.2022.2125394

Chiappa, R. (2020). Seeking faculty jobs: exploring the relationship between academic's social class of origin and hiring networks in chilean universities. Calidad en Educacion. (52), 205 - 238. https://doi.org/10.31619/caledu.n52.760

Collins, P.H. (1991). Black Feminist Thought: Knowledge, Consciousness, and the Politics of Empowerment. (London: Routledge).

Davies, Joanna M., Brighton, Lisa J., Reedy, Florence, and Bajwah, Sabrina. 2022. Maternity Provision, Contract Status, and Likelihood of Returning to Work: Evidence from Research Intensive Universities in the UK. Gender, Work & Organization, 29(5), 1495–1510. https://doi.org/10.1111/gwao.12843.

Eaton, A. A., Saunders, J. F., Jacobson, R. K., & West, K. (2019). How Gender and Race Stereotypes Impact the Advancement of Scholars in STEM: Professors' Biased Evaluations of Physics and Biology Post - Doctoral Candidates. Sex Roles, 82(3 - 4), 127 - 141. https://doi.org/10.1007/s11199 - 019 - 01052 - w

Eren, E. (2021). Exploring Science Identity Development of Women in Physics and Physical Sciences in Higher Education: A Case Study from Ireland. Science and Education, 30(5), 1131 - 1158. https://doi.org/10.1007/s11191 - 021 - 00220 - 3

Eren, E. (2022a). Never the right time: maternity planning alongside a science career in academia. Journal of Gender Studies, 31(1), 136 - 147. https://doi.org/10.1080/09589236.2020.1858765

Eren, E. (2022b). Talking science and feminism. Journal of Gender Studies, 31(8), 911 - 927. https://doi.org/10.1080/09589236.2022.2091527

Fox, M.F. & Gaughan, M. (2021). Gender, Family and Caregiving Leave, and Advancement in Academic Science: Effects across the Life Course. Sustainability, 13, 6820. https://doi.org/10.3390/ su13126820

Homes England (2020). Annual Equality, Diversity and Inclusion Report 2020/21. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/964585/Homes_England_Annual_Equality__Diversity_and_Inclusion_Report_2020_21.pdf

Illovsky, M. E. (1991). A Comparison of the Physical and Mental Health of Doctoral Level Women Scientists. Journal of College Student Psychotherapy, 5(3), 99 - 110. https://doi.org/10.1300/J035v05n03_08

Jebsen, J.M., Nicoll Baines, K., Oliver, R.A. & Jayasinghe, I. Dismantling barriers faced by women in STEM. Nature Chemistry. 14, 1203–1206 (2022). https://doi.org/10.1038/s41557-022-01072-2

Long, Z., Buzzanell, P. M., Kokini, K., Wilson, R. F., Batra, J. C., & Anderson, L. B. (2018). Mentoring women and minority faculty in engineering: A multidimensional mentoring network approach. Journal of Women and Minorities in Science and Engineering, 24(2), 121 - 145. https://doi.org/10.1615/JWomenMinorScienEng.2017019277

Ma, L. and Ladisch, M. (2016), Scholarly communication and practices in the world of metrics: An exploratory study. Proceedings of the Association for Information Science and Technology, 53: 1-4. https://doi.org/10.1002/pra2.2016.14505301132

McGee, E. O., Main, J. B., Miles, M. L., & Cox, M. F. (2021). An Intersectional Approach to Investigating Persistence among Women of Color Tenure - Track Engineering Faculty. Journal of Women and Minorities in Science and Engineering, 27(1), 57 - 84. https://doi.org/10.1615/JWomenMinorScienEng.2020035632

Miles, M. L., Brockman, A. J., & Naphan Kingery, D. E. (2020). Invalidated identities: The disconfirming effects of racial microaggressions on Black doctoral students in STEM. Journal of Research in Science Teaching, 57(10), 1608 - 1631. https://doi.org/10.1002/tea.21646

Noel, T. K., Miles, M. L., & Rida, P. (2022a). Using social exchange theory to examine minoritised STEM postdocs' experiences with faculty mentoring relationships. Studies in Graduate and Postdoctoral Education, 13(1), 90 - 108. https://doi.org/10.1108/sgpe - 12 - 2020 - 0080

Noel, T.K., Miles, M.L., & Rida, P. (2022b) Stressed - Out of STEM: Examining Mentoring Experiences of Women, People of Color, and International Postdocs, Educational Studies, 58(4), 435 - 457, DOI: 10.1080/00131946.2022.2051030

Page M.J., McKenzie J.E., Bossuyt, P.M., Boutron I., Hoffmann, T.C., Mulrow, C.D. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 372(71). doi: 10.1136/bmj.n71.

Page - Reeves, J., Marin, A., Moffett, M., DeerInWater, K., & Medin, D. (2019). Wayfinding as a concept for understanding success among native Americans in STEM: "Learning how to map through life". Cultural Studies of Science Education,14(1), 177–197. https://doi.org/10.1007/s11422 - 017 - 9849 - 6.

Patt, C., Eppig, A., & Richards, M. A. (2021). Postdocs as Key to Faculty Diversity: A Structured and Collaborative Approach for Research Universities. Frontiers in Psychology, 12, 759263. https://doi.org/10.3389/fpsyg.2021.759263

Powell, K. (2021). The parenting penalties faced by scientist mothers. Nature, 595. Retrieved from https://www.nature.com/articles/d41586 - 021 - 01993 – x

Rocha, M. (2021) Promoting gender equality through regulation: the case of parental leave, The Theory and Practice of Legislation, 9(1), 35-57, DOI: 10.1080/20508840.2020.1830565

Ryan, M.K. (2022). To advance equality for women, use the evidence. Nature, 604. Retrieved from https://www.nature.com/articles/d41586 - 022 - 01045 - y

Sonnert, G., & Holton, G. (1996). Career Patterns of Women and Men in the Sciences. American Scientist, 84(1), 63 - 71. https://www.jstor.org/stable/29775599

Start, D., & McCauley, S. (2020). Gender underlies the formation of STEM research groups. Ecology and Evolution, 10(9), 3834 - 3843. https://doi.org/10.1002/ece3.6188

Strong, A. C., Smith - Orr, C., Bodnar, C., Lee, W., McCave, E., & Faber, C. (2021). Early Career Faculty Transitions: Negotiating Legitimacy and Seeking Support in Engineering Education. Studies in Engineering Education, 1(1), 97–118. http://doi.org/10.21061/see.52

The Royal Society (2014). A picture of the UK scientific workforce. Diversity data analysis for the Royal Society. Summary report. Retrieved from https://royalsociety.org/topics - policy/diversity - in - science/uk - scientific - workforce - report/

Viefers, S. F., Christie, M. F., & Ferdos, F. (2006). Gender equity in higher education: why and how? A case study of gender issues in a science faculty. European Journal of Engineering Education, 31(1), 15 - 22. https://doi.org/10.1080/03043790500429948

Weisshaar, K. (2017). Publish and Perish? An Assessment of Gender Gaps in Promotion to Tenure in Academia. Social Forces, 96(2), 529 - 560. https://doi.org/10.1093/sf/sox052

Wolf - Wendel, L. & Ward, K. (2015). Academic Mothers: Exploring Disciplinary Perspectives. Innovative Higher Education, 40, 19–35https://doi.org/10.1007/s10755 - 014 - 9293 - 4

Yadav, A., Seals, C. D., Sullivan, C. M. S., Lachney, M., Clark, Q., Dixon, K. G., & Smith, M. J. T. (2020). The Forgotten Scholar: Underrepresented Minority Postdoc Experiences in STEM Fields. Educational Studies, 56(2), 160 - 185. https://doi.org/10.1080/00131946.2019.1702552

University *of* Exeter

2023CLES012