Increasing the persistence of female students in the science career pathway

A cross-institutional Australian study on the gendered experience of undergraduate science students

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MONASH University

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Copyright notice

Abstract

Reducing the gender imbalance in the science, technology, engineering, and mathematics (STEM) workforce requires recruiting and retaining more women in undergraduate STEM degrees. While international research into gender issues faced by university STEM students is prominent, Australian research in this space is limited. The aim of this thesis was to investigate gender differences in the university experience of Australian undergraduate science students. This cross-institutional study investigated factors that are known to impact student persistence in the science fields, specifically studying the levels of belonging, science identity, and perceived experiences of discrimination for these students. A mixed-methods sequential explanatory approach was used. Quantitative data was collected at four main time points using an online questionnaire from 1,019 students across ten Australian universities. Qualitative data was collected through subsequent video interviews with a sub-sample of students (n=10). Findings from this research highlighted the importance of feelings of belonging and high levels of science identity for female students' persistence intentions in the science fields. A similar effect was found for male students in the more "gender-balanced" science disciplines of biology and chemistry. Additionally, results demonstrated that discriminatory experiences were self-reported by a small proportion of female science students throughout their university degrees. These findings also report discrimination experienced by male and non-binary identifying science students. The causes of this discrimination differed for these students. Female students typically reported negative experiences associated with group work, while male students perceived gender diversity initiatives in STEM as discriminatory against men. Findings from this thesis highlight potential 'at-risk' groups within Australian science undergraduate cohorts, and some issues that science educators may need to be aware of occurring in their classroom. Specifically, a focus on more equitable group work in science classrooms and educating students on the gender issues that remain in the STEM fields may help create a more gender equitable university science classroom and work towards closing the gender gap that persists in the Australian STEM workforce.

Publications during enrolment

Fisher, C.R., Thompson, C.D., & Brookes, R.H. (2020). Gender differences in the Australian undergraduate STEM student experience: A systematic review, *Higher Education Research & Development*, **39**(6), 1155-1168. doi:10.1080/07294360.2020.1721441

Fisher, C.R., Thompson, C.D., & Brookes, R.H. (2020). "95% of the time things have been okay": The experience of undergraduate students in science disciplines with higher female representation, *International Journal of Science Education*, **42**(6), 1430-1446. doi:10.1080/09500693.2020.1765045

Fisher, C.R., Thompson, C.D., & Brookes, R.H. Levels of science identity, belonging and experiences of discrimination for commencing science students at an Australian university. *Under review.*

Fisher, C.R., Brookes, R.H., & Thompson, C.D. (2021). "I don't study physics anymore": a cross-institutional Australian study on factors impacting the persistence of undergraduate science students, *Research in Science Education.* doi:10.1007/s11165-021-09995-5

Thesis including published works declaration

I hereby declare that this thesis contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institution and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

This thesis includes four original papers published in peer reviewed journals. The core theme of the thesis is investigating the gendered experience of Australian undergraduate science students. The ideas, development and writing up of all papers in the thesis were the principal responsibility of myself, the student, working within the School of Chemistry under the co-supervision of Associate Professor Christopher Thompson and Dr Rowan Brookes.

The inclusion of co-authors reflects the fact that the work came from active collaboration between researchers and acknowledges input into team-based research.

In cases of Chapters 3 - 6 my contribution to the work involved the following:

Chapter	Publication Title	Status	Student contribution	Co-author name(s) and contribution	Co-author(s), Monash student?
3	Gender differences in the Australian undergraduate STEM student experience: A systematic review	Published	80%, Data collection, analysis, primary author.	Rowan Brookes and Christopher Thompson, input into manuscript (20%)	No
4	Levels of science identity, belonging and experiences of discrimination for commencing science students at an Australian University	Submitted	As above	As above	No
5	'95% of the time things have been okay': The experience of undergraduate students in science disciplines with higher female representation	Published	As above	As above	No
6	'I don't study physics anymore': A national study on the persistence of Australian undergraduate science students	Accepted	As above	As above	No

I have not renumbered sections of submitted or published papers in order to generate a consistent presentation within the thesis.

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Date: 9/4/2021

I hereby certify that the above declaration correctly reflects the nature and extent of the student's and co-authors' contributions to this work. In instances where I am not the responsible author I have consulted with the responsible author to agree on the respective contributions of the authors.

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Date: 9/4/2021

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Chapter 1

Introduction

1.1 The "leaky pipeline" in STEM

In Australia, a gender imbalance in the science, technology, engineering, and mathematics (STEM) fields persists, with only 29% of the STEM workforce being women (Office of the Chief Scientist, 2020). While there has been an increase in the number of female STEM graduates in recent years, this is not translating into a gender equal workforce. Attaining gender equality in the STEM fields is of importance as it would result not only in societal benefits, but also economic benefits for Australia (Department of Prime Minister and Cabinet, 2017). While the focus on the gender imbalance in STEM is a global issue (Valantine & Collins, 2015), Australian research in this topic is limited (Fisher, Thompson, & Brookes, 2020a), and further investigation into the gender issues women face in these fields is warranted.

The diminishing rates of women as they progress through the STEM educational and career pathway is often referred to as the "leaky pipeline" in STEM (Blickenstaff, 2005). While the "pipeline" analogy is becoming less relevant due to the increasing number of pathways into a STEM career (Lykkegaard & Ulriksen, 2019), it does highlight the critical time points in the science career pathway when women may leave the STEM fields. These key stages are typically broken up into; primary, secondary and tertiary education, as well as the post-graduate/workforce level. To understand why there is this gender imbalance in STEM, researchers and policy makers focus on what specific barriers women face at each step in this pipeline.

Additionally, each key stage has its own unique set of factors that impact women's persistence in their STEM careers (Figure 1.1; Australian Academy of Science, 2019).

In Australian research, early stages in secondary education have been a popular area of interest when studying gender inequality in STEM, as this is when individuals start to form gendered opinions about science and can electively opt out of STEM subjects for the first time (Lyons & Quinn, 2010; Watt et al., 2012). Yet, the subtle stereotypes of the science fields, such as the idea that boys are better at STEM subjects than girls, can begin as early as the primary school level (Master, Cheryan, Moscatelli, & Meltzoff, 2017). Post-graduate or workforce level stages in the STEM career pipeline are also frequently studied because the gender imbalance in these fields is greatest at this level (Case & Richley, 2013). Consequently, the undergraduate level can often be overlooked by researchers when studying gender inequality issues in STEM in the Australian research. Yet, studying the undergraduate STEM population is necessary as identifying the reasons behind the gender imbalance at the undergraduate level is known to shed light on reasons behind the lack of female representation later in this career pathway (Miller & Wai, 2015).

Women's recruitment into and retention in STEM university degrees is lower than men's. Additionally, there are disparities within the STEM fields. For example, 17% of Australian university enrolments into engineering degrees are women, while almost 60% of students enrolled in biology at university are women (Table 1; Department of Education and Training [DET], 2018). These discrepancies between the STEM disciplines is a current focus of the literature (Cheryan, Ziegler, Montoya, & Jiang, 2017), and has resulted in science fields being classed as "gender-balanced" or "gender-unbalanced". "Gender-balanced" STEM disciplines are ones with a relatively higher percentage of women at the university level, while "gender-unbalanced" fields have lower female participation rates. "Gender-balanced" does not refer to an equal 50:50 gender ratio within these fields. For example, biology is typically classed as a "gender-balanced" science field, but is actually more female-dominated (57% female enrolments at university; DET, 2018). Instead, this gender dichotomisation of the science fields is relative to female

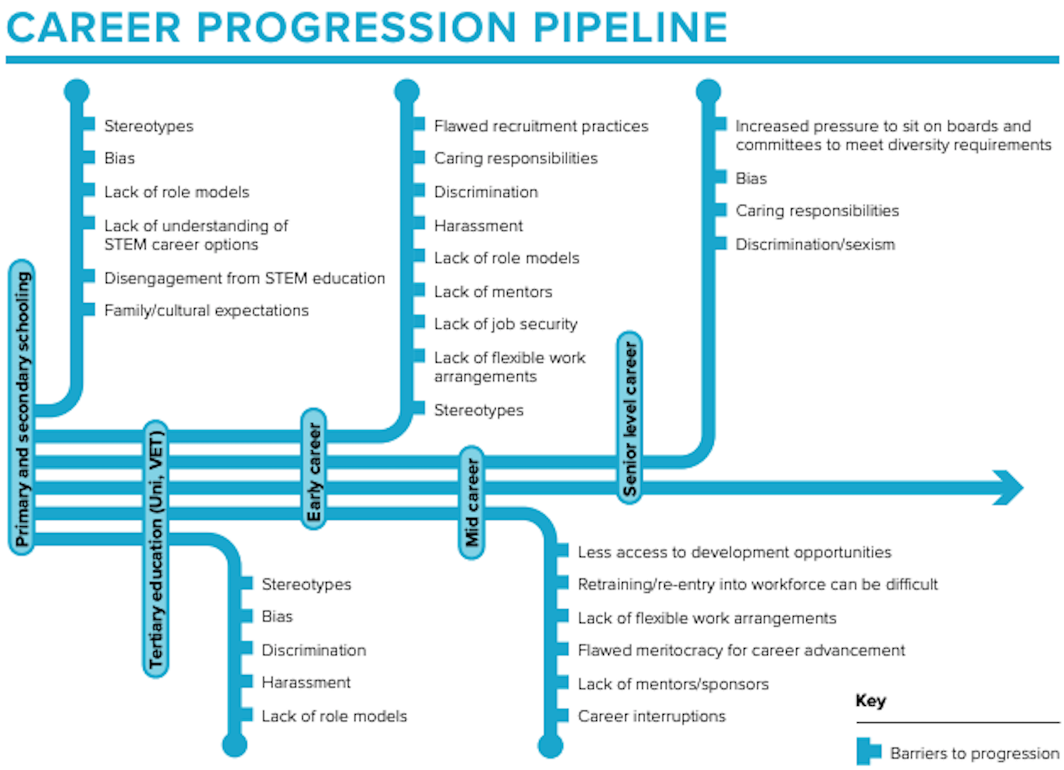

Figure 1.1: Barriers women face at each stage of the STEM career "pipeline"

Reprinted from the *Women in STEM decadal plan*, Australian Academy of Science, 2019.

participation numbers within these fields. Additionally, though a science field is "gender-balanced" at a university level, due to the "leaky pipeline" effect in STEM, this does not mean it cannot be classed as "gender-unbalanced" later on.

STEM Discipline	**Women**	**Men**
Engineering	17%	83%
Computing	19%	81%
Physics/astronomy	25%	75%
Mathematics	32%	68%
Chemistry	42%	58%
Biology	57%	43%

Table 1.1: Australian University STEM enrolments (DET, 2018).

1.2 Gender differences in the STEM university experience

Women have been found to be more likely to switch from a STEM to a non-STEM major, regardless of whether or not they are academically performing well (Astorne-Figari & Speer, 2018; Bettinger, 2010). This raises the question of what exactly is causing this attrition of capable women from these science degrees. By studying how male and female students differ in their experiences during a STEM university degree, researchers are starting to determine the critical factors causing this loss of women at a key stage in the STEM career "pipeline" (Cheryan et al., 2017; Eddy & Brownell, 2016). These gender differences in the STEM university experience, or gendered experience, will help identify what factors intervention programs should target to retain more women in STEM and improve the female STEM student experience.

In preliminary research into the gender imbalance in STEM, it was believed that women elected to leave or not pursue STEM fields due to cognitive differences between the sexes (Kimura, 1999). This argument has since been disproved (Spelke, 2005). Consequently, research is now focused on other societal, cultural, and psychological factors that are deterring women from careers in STEM, which are now the basis of many theoretical frameworks investigating student persistence and motivations in the STEM fields (e.g., Eccles, 1994; Lent, Brown, & Hackett, 1994). Additionally, importance is being placed on the *affective* domains impacting STEM student learning (National Research Council, 2012; Trujillo & Tanner, 2014). The affective domain relates to how emotions impact student learning, and is one of the three main domains of student learning (i.e., cognitive, metacognitive and affective domains; Vermunt, 1996).

Factors that contribute to the affective domain of learning are students' emotions, attitude and motivations, which lead to their greater interest and engagement. As van der Hoeven Kraft, Srogi, Husman, Semken, and Fuhrman (2011) discussed in their research on engaging students in the geosciences, some factors attributing to this domain are students' interest, self-efficacy, and positive and negative emotions within their learning, such as enjoyment and fear. This thesis investigated factors behind the affective domain that have been previously identified as impacting STEM student learning, specifically for women in STEM, but have been relatively understudied in Australian student cohorts. Three key factors attributing to the affective domain of student learning identified in previous STEM education research are self-efficacy, belonging, and science identity (Trujillo & Tanner, 2014). A final factor of gender bias in STEM will also be examined in this work, due to the role it plays in the development of these domains within science student cohorts (Ramsey & Sekaquaptewa, 2011; Walton & Cohen, 2007). The following sections will give a brief introduction to these main factors. However, a more comprehensive review of the literature is presented in **Chapter 3** of this thesis, which is a published systematic review on factors contributing to this gendered experience in an Australian context.

1.2.1 Self-efficacy

Self-efficacy describes an individual's belief in their ability to succeed in a given area (Bandura, 1997). Self-efficacy is a core component of social cognitive theory, which is a key theoretical framework used when studying student motivation and persistence in their educational studies (Lent et al., 1994). A student's belief in their own ability is subjective and often not reflective of their actual ability. A key example of this is women studying STEM degrees, who typically perceive their skills as below average despite academically performing well (Robnett & Thoman, 2017).

It has been established that female STEM students at university tend to have lower science self-efficacy levels than male students (Ainscough et al., 2016; Williams & George-Jackson, 2014). These lower rates of self-efficacy in female STEM students are a major concern for attrition (Sax, 1994). For example, Ellis, Fosdick, and Rasmussen (2016) found that women were 1.5 times more likely to leave a first-year calculus college course when compared to their male counterparts. Specifically, this attrition was driven by female students' lower confidence in their mathematical ability.

Lower confidence in STEM abilities can also interact with the other affective domains, such as belonging and science identity. In the study by Robnett and Thoman (2017), women who had low expectations for their success in STEM and still were high achievers reported lower STEM identity and peer support. Other studies have also shown that female students with self-doubt in their STEM skills also have lower science identity and value (Deechuay, Koul, Maneewan, & Lerdpornkulrat, 2016).

1.2.2 A sense of belonging

A lack of belonging is another reason why women may also choose to leave STEM majors (Seymour & Hewitt, 1997). A sense of belonging is critical for an individual's well-being (Baumeister & Leary, 1995). In a higher education setting, belonging refers to one's self-belief that they "fit in" and that their contributions are valued within an academic field (Good, Rattan, & Dweck, 2012). For the purposes of this thesis, the definition of belonging in the sciences follows work by Good et al. (2012) on student belonging in mathematics. When defining belonging, Good et al. (2012) conceptualised it as involving "one's personal feelings of membership and acceptance in an academic community in which positive affect, trust levels, and willingness to engage remain high" (p. 702, Good et al. 2012).

Belonging, or "perceived similarity" to fellow students in their discipline, has been shown to be associated with increased intent to pursue further studies in STEM disciplines (Cheryan & Plaut, 2010). One of the causes behind women's lower belonging in STEM is due to the continued stereotypes of the type of students who pursue science. For example, science fiction paraphernalia often depicts scientists as male geniuses, which can result in women not perceiving themselves as similar to students in STEM (Carli, Alawa, Lee, Zhao, & Kim, 2016). In particular, research has shown when these stereotypes portrayed through such paraphernalia (i.e., science fiction posters) are reduced in students' classroom environments, women's desire to pursue the STEM fields increases (Master, Cheryan, & Meltzoff, 2016).

1.2.3 Science identity

The affective domain of belonging is very closely linked to the concept of science identity. Science identity can be defined as how important it is to an individual to be recognised as a scientist, or a science person, by their peers. This theoretical framework was defined by Carlone and Johnson (2007), who defined science identity as being attributed to recognition, competence and performance. Recognition refers to being perceived by others as a “science person”, performance refers to the act of doing science and scientific methods, and competence refers to one’s knowledge of science. From this framework, it is clear how the previously discussed domains of self-efficacy (i.e., confidence in one’s abilities or competence) and belonging can interact with students’ perception of their own science identity.

Gendered differences have been found when investigating the science identities of university students (Hazari, Sadler, & Sonnert, 2013; Williams & George-Jackson, 2014). Previous research suggests that women typically have lower science identities than male students in STEM, particularly in the “gender-unbalanced” STEM fields (i.e. physics; Hazari et al., 2013; Seyranian et al., 2018). Low levels of science identity in students is another cause of attrition from this science career pathway, as it has been shown to be associated with one’s intention to pursue a scientific career path (Hazari, Sonnert, Sadler, & Shanahan, 2010; Stets, Brenner, Burke, & Serpe, 2017). Specifically, students with high levels of science identity have more desire to pursue this career pathway.

1.2.4 Experiences of gender bias

Although not typically classed as an affective domain, a final factor to discuss for the gendered experience of university STEM students is discrimination. Specifically, gender bias and discrimination in the STEM fields is a critical factor when studying the experience and persistence of women in the STEM fields. Discrimination can be divided into explicit and implicit forms of bias (Kuchynka et al., 2018). A key example of explicit bias is sexual harassment. Understandably, workplaces and institutions have worked to reduce this type of bias by incorporating policies and consequences for this type of behaviour. However, implicit biases, such as the stereotype that men are more suited to STEM fields than women, are engrained from a young age and are difficult to remove (Farrell & McHugh, 2017; Smyth & Nosek, 2015).

Implicit bias leads to weaker self-identification with science for women (i.e., science identity), lower desire to pursue a science career in the future, and can even impact course performance for female students (Lane, To, Shelley, & Henson, 2012;

Ramsey & Sekaquaptewa, 2011). Thus, experiences of discrimination can impact the affective domains previously discussed. Overall, previous research highlights the complex relationships between these factors and how they can impact female students' intentions to remain in the science career path.

1.3 Conceptual framework

These previously described affective domains are common components of theoretical frameworks used to study the gender inequality problem in STEM. The two most common frameworks are Eccles' Expectancy-Value Theory (EVT; Wigfield & Eccles, 2000) and Social Cognitive Career Theory (SCCT; Lent et al., 1994). Both of these frameworks study the motivations of students to pursue science, and share similar components. The two core components of EVT are **expectancy** (i.e. "Am I able to do this task?") and **task value** (i.e. "Why should I do this task?"). SCT is similar to EVT, as they both have an efficacy and value component, but there are slight differences in their definitions of these terms (Cook & Artino Jr, 2016). A more recent framework that investigates the affective domain of science identity has also been developed (Carlone & Johnson, 2007). As science identity gains more recognition in the research, it is being added to more frameworks. For example, EVT was recently adapted to include the influencing factor of identity in students' motivations (Eccles, 2009).

While these frameworks are the foundations of many gender inequality studies in STEM, the focus of this thesis was on how these factors were impacting students persistence, both in their current science majors and their science career pathway. To study this, student's persistence *intentions* were measured. This is based on the theoretical framework of the theory of planned behaviour (TBP; Ajzen, 1991), which states that an individual's behaviour is primarily driven by their intentions. Previous research has demonstrated that when studying persistence in STEM student cohorts, intention is an accurate measure of student persistence (Moore & Burrus, 2019).

1.4 Gaps in gender inequality research

Despite the previous research exploring gender inequality in STEM, there are still gaps in this field of study. In particular, Australian research on the undergraduate experience is an area for further investigation. Most studies on the gendered experience of undergraduate science students are based in the United States (US; Blackburn, 2017), while Australian studies in this field are relatively limited. Yet, there are differences between the US and Australia when it comes to the science disciplines. A key example is the field of mathematics, which has managed to reduce the gender gap in the US but is still a relatively "gender-unbalanced" science field in Australia (Cheryan et al., 2017; Department of Education and Training, 2018). Additionally, research by Watt et al. (2017) demonstrated that gendered motivations to pursue certain STEM career pathways may be greater in Australian populations when compared to the US. While international studies provide a good framework for researchers, these findings may have limited generalisability in an Australian context because of the differences between these two countries when it comes to reducing the gender imbalances in the STEM fields. Australian research on the gendered experience of undergraduate science students is also sparse. For example, most research on gender issues in STEM fields focuses on the secondary or post-graduate levels (Asmar, 1999; Lyons & Quinn, 2010). The findings from the limited number of Australian studies do suggest gender differences in the Australian undergraduate science student experience exist (for an extensive review see **Chapter 3**; Fisher et al., 2020a).

Finally, the more male-dominated science fields are often the focus of STEM inequality research in Australia, with most research focusing on why women do not pursue careers in engineering, mathematics, computer science or physics (Godfrey, Aubrey, Crosthwaite, & King, 2010; Lloyd & Szymakowski, 2017; Steele, James, & Barnett, 2002). This means that research into the STEM fields with a relatively higher presence of women, such as biology, has been relatively limited in comparison. Despite these science fields being more "gender-balanced", previous research has shown that equal gender ratios in a science field does not necessarily result in gender equality. For example, STEM disciplines with a greater female presence at an undergraduate level can still face under-representation at a post-doctoral level and later on in the science career pathway (Case & Richley, 2013). In addition, undergraduate women in STEM fields with a greater female presence, such as biology, still participate less than their male peers, and still identify male students as the top-performers in the classroom (Eddy, Brownell, & Wenderoth, 2014; Grunspan et al., 2016). Consequently, further research is warranted into the experiences of students in science fields with greater female representation in an Australian context, to understand the lingering gender issues that remain in these fields.

1.5 Research questions

This thesis aims to identify factors associated with the gendered experience of Australian undergraduate science students. Doing so will help guide future interventions and programs to improve the experience of female students in science, ultimately increasing their persistence in the science educational and career pathway. The main research question and sub-questions that this thesis will address include:

- **How can we increase the persistence of female students in Australian science degrees?**
    1. What factors are associated with the gendered experience of Australian undergraduate science students?
    2. To what extent do these experiences differ for students studying in the "gender-balanced" science disciplines (i.e., biology, chemistry)?

1.6 Thesis synopsis

This thesis by publication is separated into four main sections (See: **Figure 1.2**). **Section 1** is an introductory section, comprised of two chapters. The first gives a brief background to the topic of this thesis (**Chapter 1**) and the second summarises the methodology of this project (**Chapter 2**).

Section 2 aims to answer the first research question of this thesis: "*What factors are associated with the 'gendered experience' of Australian undergraduate* *science students?*". This section consists of **Chapters 3** and **4**. **Chapter 3** is a detailed systematic review outlining the factors previously established in the Australian literature that result in gender differences in the university STEM student experience. **Chapter 4** provides an insight into the gendered experience of commencing science students through a case study at Monash University. It also begins a comparison on the experience of students in the "gender-balanced" and "gender-unbalanced" science fields, suggesting further examination into the student experience in these two fields.

Section 3 aims to answer the second main research question of this thesis: "*To what extent do these experiences differ for students studying in the 'gender-balanced' science disciplines?*". This section is divided into three main chapters. **Chapter 5** presents the results of a pilot study at Monash University investigating the experience of male and female students in the "gender-balanced" fields of biology and chemistry. **Chapter 6** extends on this by presenting the results of a comparative study between the "gender-balanced" science disciplines and the "gender-unbalanced" science disciplines across eight different Australian universities. This cross-institutional study allows for an in-depth comparison between the genders and their experience within these disciplines of science. **Chapter 7** extends on this by using a qualitative approach, presenting the results of interviews with a sub-sample of these undergraduate science students across Australia. This qualitative study helps demonstrate how undergraduate science students define the concepts of the factors impacting student persistence in science, with participants from the "gender-balanced" science fields only.

Finally, the last section of this thesis, **Section 4**, presents the overall conclusions and implications for future research, as well as provides recommendations for science educators from this project (**Chapter 8**). A visual representation of this thesis roadmap is depicted in **Figure 1.2**. As mentioned, this is a thesis by publication and there are four published papers (**Chapters 3 - 6**).

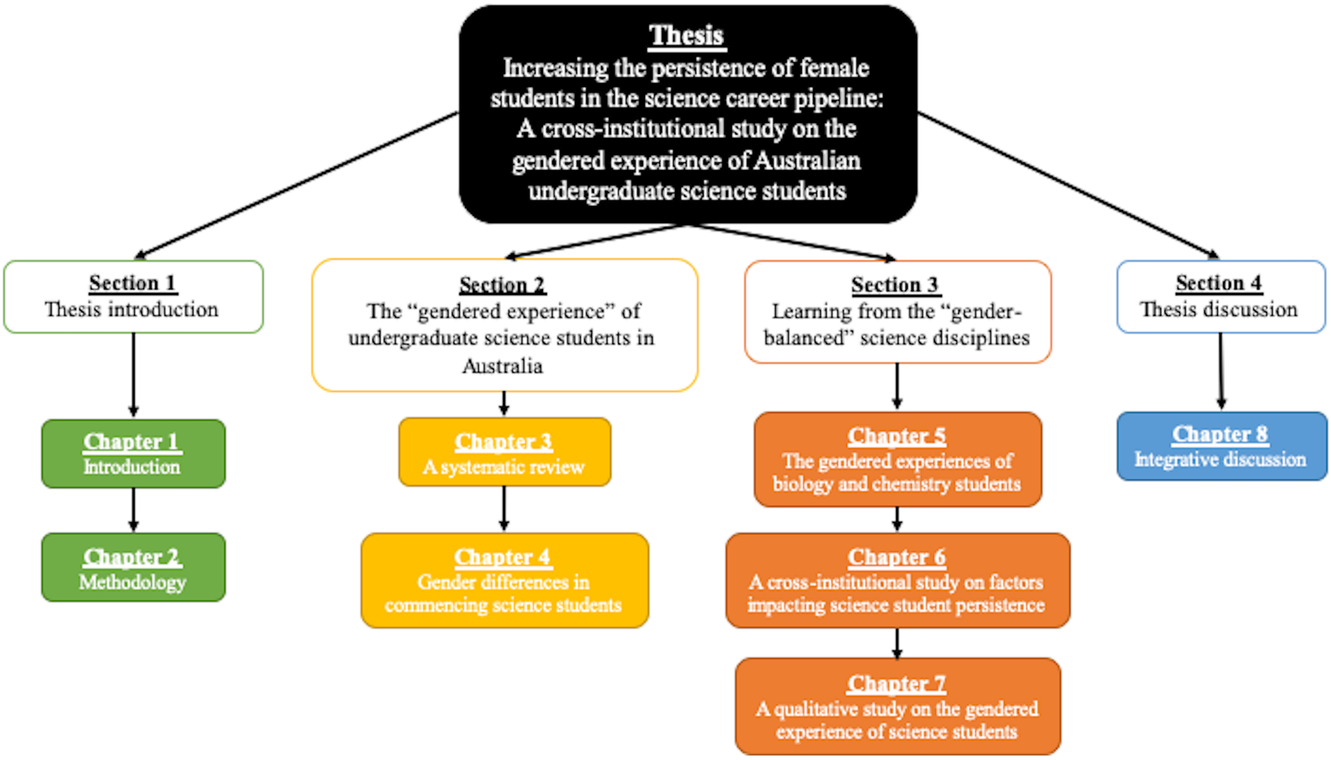

Figure 1.2: Thesis Roadmap

Chapter 2

Methodology

2.1 Research design

To explore the research questions of this thesis a mixed-methods sequential explanatory approach was used (Creswell, 2003). This design involves two distinct data collection phases: quantitative (numeric) data collection followed by qualitative (text) data collection. Quantitative data was collected through a single online questionnaire on the gendered experience of Australian undergraduate science students that was deployed across multiple time points. Qualitative data was collected through semi-structured interviews with a sub-sample of students who responded to the online questionnaire. This mixed-methods approach is desirable as the quantitative data provides generalisability of the findings, while the qualitative data adds in-depth student responses to these issues (Creswell, 2014). An emphasis was placed on the quantitative data within this mixed-methodology design (QUANT-qual) as the aim was to get a national snapshot on the gendered experience of undergraduate science students in Australia, and quantitative data collected via a questionnaire ensured a large and generalisable sample size. A visual representation of this research design, as guided by Ivankova, Creswell, and Stick (2006), is depicted in **Figure 2.1**.

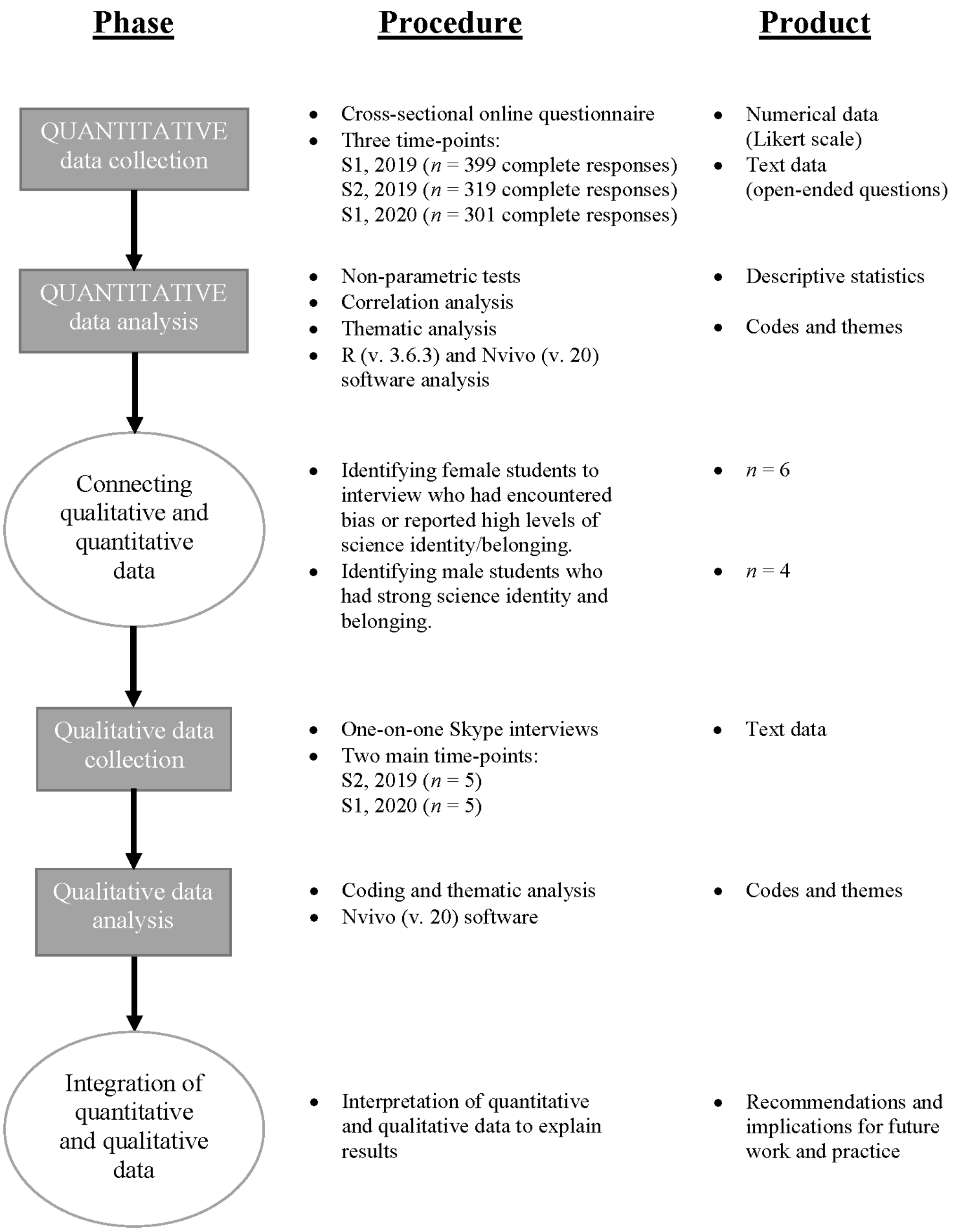

Figure 2.1: Visual representation of mixed-methods research design

2.2 Data collection

2.2.1 Quantitative data

Quantitative data was collected through an online questionnaire distributed using the Qualtrics software. An online questionnaire, opposed to a traditional paper-based method, was necessary for this project in order to reach a national sample of students across Australia. To ensure a high response rate from participants to validate the questionnaire sub-scales, a paper-based questionnaire was used in the pilot study of this work (**Chapter 5**). A voluntary, convenience sampling method was used to deploy the online questionnaire, with science educators being contacted to distribute the questionnaire to their students. For the questionnaire, a voluntary sample was used, which is not random and so inherently may have introduced bias in the cohort tested. A randomised approach to sampling could not be undertaken due to the difficulty in achieving high response rates within online questionnaires. To ensure a high sample size for statistical analysis, as many students as possible were targeted and asked to participate.

The purpose of the questionnaire was to identify factors that were contributing to gender differences in the Australian undergraduate science student experience and potentially affecting the persistence of these students. The questionnaire comprised of previously validated sub-scales investigating the factors of interest within this project (i.e., belonging, science identity) and students' persistence intentions. Previous sub-scales were used as these factors have been well-studied internationally with established question items, but had yet to be applied to Australian student populations. The questionnaire was primarily based off a previous study by Findley-Van Nostrand and Pollenz (2017), which investigated undergraduate student persistence in STEM after a pre-college science preparation course. As the Findley-Van Nostrand and Pollenz (2017) study did not investigate issues of gender (i.e., experiences of gender bias), the questionnaire was altered slightly to address the research questions of this thesis:

- All "STEM" references were altered to "science", as the scope of this project was focused primarily on the four science disciplines of biology, chemistry, mathematics, and physics.

- To reduce the size of the questionnaire to prevent survey fatigue from participants, three sub-scales were removed. Self-efficacy sub-scales (*Academic self-efficacy for STEM*, *science task self-efficacy*) were removed after the pilot study, as self-efficacy is already a well-established factor contributing to the gendered experience of Australian undergraduate students (see: **Chapter 3**). In addition, the "*Belonging to university*" sub-scale was removed, as the "*Belonging to science*" sub-scale was deemed appropriate to explore the affective domain of belonging within this study.

- To explore issues of gender, two gender focused sub-scales were added to the questionnaire: "*Perceived identity compatibility between gender and major*" (London, Rosenthal, Levy, & Lobel, 2011) and "*Gender biased science majors*" (Ganley, George, Cimpian, & Makowski, 2018).

- A single open-ended question was included at the end of the questionnaire, asking for student experiences of discrimination faced during their time at university in a science degree. This was preceded with a definition of discrimination provided by Robnett (2016):

  "*Gender bias occurs when people treat others unfairly due to their gender. Please describe if you have had any experiences with gender bias in your discipline during your science degree.*"

A five-point Likert scale was used for all sub-scales (strongly disagree to strongly agree). In addition to the factors examined above (i.e., science identity, belonging, experiences of gender bias), this study investigated two dependent variables, which were students' intentions persist in their current science major and the overall science career pathway. This is based on previous behavioural studies that have demonstrated that students' intentions are the best predictors for their behaviour, which has also been demonstrated within science student populations (Ajzen, 1991; Moore & Burrus, 2019). The final questionnaire design, alongside question items and the original authors of the sub-scales are shown in **Table 2.1**. Piloting of the survey was conducted in late 2018 on a sample of third-year science students (n = 55) at Monash University, the results of which can be found in **Chapter 5**.

Quantitative data collection occurred at four main time points. The same questionnaire was used at each time point as the purpose of these multiple time points was to increase the sample size of this national study. Data collection occurred at the end of Semester 2, 2018 (data presented in **Chapter 5**), in the commencing weeks of Semester 1, 2019 (data presented in **Chapter 4**), in the final weeks of Semester 2, 2019, and in the first half of Semester 1, 2020 (data presented in **Chapter 6**). The questionnaire remained active for an average of four weeks during these data collection time points. The only exception was data collection

Theme	**Items**	**Reference**
Science identity	In general, my interest in science is an important part of my self-image	(Chemers, Zurbriggen, Syed, Goza, & Bearman, 2011)
	My interest in science is an important reflection of who I am	
	I feel like I belong in the field of science	
	I have a strong sense of belonging to the community of scientists	
	I am a scientist	
Belonging	I feel that I belong to the scientific community	(Good et al., 2012)
1. Membership	I consider myself a member of the scientific community	
	I feel like I am part of the scientific community	
	I feel a connection with the scientific community	
2. Acceptance	I feel like an outsider	
	I feel accepted	
	I feel respected	
	I feel disregarded	
	I feel valued	
	I feel neglected	
	I feel appreciated	
	I feel excluded	
	I feel like I fit in	
	I feel insignificant	
3. Affect	I feel at ease	
	I feel anxious	
	I feel comfortable	
	I feel tense	
	I feel nervous	
	I feel content	
	I feel calm	
	I feel inadequate	
4. Desire to fade	I wish I could fade into the background and not be noticed	
	I try to say as little as possible	
	I enjoy being an active participant	
	I wish I were invisible	
Compatibility between	I don't think that my gender will affect how others view me in my major	(London et al., 2011)
gender and major	I don't think that my gender will affect how well I do in my major	
	I think my gender and my major are very compatible	
	I think I have experienced difficulties in my major because of my gender	
	I think my gender will be an important factor in the type of career I decide to pursue	
	I don't think I would pursue certain fields because of my gender	
Gender bias	Women in my major experience discrimination	(Ganley et al., 2018)
	Women have a hard time succeeding in my major	
	My major is more welcoming to men than it is to women	
	What percentage of students in this major do you estimate are women?	
Intent to leave STEM	During your degree, have you considered switching to a non-science discipline?	(Perez, Cromley, & Kaplan, 2014)
Career intentions	I would like to have a career in science	(Stake & Mares, 2001)

Table 2.1: Final questionnaire design

during Semester 1, 2020, when the questionnaire remained active for several months (February - May) due to the COVID-19 pandemic and low response rates from students.

2.2.2 Qualitative data

The purpose of subsequent qualitative data collection through student interviews was to enrich the quantitative data already obtained through the questionnaire. While some students had briefly discussed experiences of gender bias, more in-depth qualitative data was needed to investigate how these experiences were impacting their persistence as well as the other affective domains investigated in this project. Consequently, belonging, science identity, and experiences of gender bias and discrimination were the key themes explored in these interviews.

A purposive, convenience sampling technique was used to recruit students (Merriam & Tisdell, 2015), with students who provided their contact details in the online questionnaire invited to participate. Similar to the quantitative data collection, a non-randomised sampling method was used. Due to the difficulty in getting students to participate in online interviews, particularly at the start of the COVID-19 pandemic, and purposively targeting students for certain criteria, a randomised approach could not be used. Students who had described experiences of discrimination, as well as those who identified as having high levels of science identity and belonging were targeted for interviews. This was undertaken to try and capture those at risk of dropping out, as well as those who were most likely to persist in this career pathway. All participants received a $20 gift voucher for their time. As this was a national study, interviews needed to be conducted at universities across Australia. Therefore, to access interstate students video interviews were conducted via Skype or Zoom. All interviews were recorded and the audio was later transcribed for qualitative analysis. Written informed consent was obtained from all participants prior to participating in an interview.

A break-down of the final interview participants and their demographics is depicted in **Table 2.2**. Students were from four different Australian universities, which spanned across three states within Australia. Although the questionnaire was not solely completed by female and male students, only male and female-identifying students volunteered to participate in these interviews.

University	Gender	Science major
Deakin University	Male	Biology
Deakin University	Male	Biology
Monash University	Female	Biology
Monash University	Female	Genetics
Monash University	Male	Chemistry
University of Sydney	Male	Chemistry
University of Sydney	Female	Chemistry
University of Sydney	Female	Biology and chemistry
University of Western Australia	Female	Chemistry
University of Western Australia	Female	Anatomy, human biology and genetics

Table 2.2: Interview participants

Interviews were conducted in a semi-structured format, typically lasting 10 - 15 minutes. The three core themes in the questionnaire were explored in these interviews; science identity, belonging, and gender bias in science. Open-ended questions were derived from previous work exploring these themes on previous university cohorts (Lane, 2016). The main questions asked in each section of the interviews are depicted in **Table 2.3**. A more in-depth description of the qualitative methodology can be found in **Chapter 7**.

2.3 Sampling methods

2.3.1 Participating universities

To capture a national snapshot of the gendered experience of Australian undergraduate science students, multiple universities across Australia were targeted for this project. Institutions were recruited through networking at Australian science education conferences (e.g., *Australian Conference for Science and Mathematics Education*; ACSME), through social media (e.g., LinkedIn, Twitter), and through personal networks. Educators at these institutions who coordinated science courses then distributed the online questionnaire to their students either in

Section	Question
Science identity	Have you come across any of your classmates who think have strong science identity? What characteristics do they have? Do you think female students struggle to identify as scientists in your field?
Belonging	Can you describe times when you felt like you "belong" in your science classes? Do you think female students may struggle to belong in science?
Gender bias in science	Have you ever felt like you have been discriminated against or experienced bias because of your gender in your science field? Do you think it is common for female students in your field to feel discriminated against or experience bias?

Table 2.3: Questions used in interviews and corresponding themes

class or advertised it to them on a centralised learning platform. The final list of participating universities is shown in **Table 2.4**, along with the number of responses obtained from each. A total of 1,019 students completed the online questionnaire. While 877 students recorded their university, 142 students did not. Participating universities were categorised into Group of Eight (Go8) or non-Go8 institutions. Go8 universities in Australia are top-tier research intensive institutions, which are recognised as leading institutions in education and research. The majority of responses came from Go8 universities. Ethics approval was obtained from the Monash University Human Research Ethics Committee (MUHREC; project ID: 16341).

2.3.2 Inclusion and exclusion criteria

Undergraduate science students ranging from their first to final year of study took part in this project. First-year students were targeted as this is when students may make the decision to opt-out of their science degrees, thus making it a critical time point for understanding what factors are impacting students' intentions to persist in these degrees. This has been a common approach in other undergraduate level

University	Location	Descriptive	Response numbers (*n*, %)
Deakin University	Victoria	non-Go8	124, 12.2%
Edith Cowen University	Western Australia	non-Go8	1, 0.1%
Federation University	Victoria	non-Go8	9, 0.9%
Flinders University	South Australia	non-Go8	50, 4.9%
Monash University	Victoria	Go8	427, 41.9%
University of New South Wales	New South Wales	Go8	17, 1.7%
University of Queensland	Queensland	Go8	19, 1.9%
University of Sydney	New South Wales	Go8	94, 9.2%
University of Tasmania	Tasmania	non-Go8	2, 0.2%
University of Western Australia	Western Australia	Go8	134, 13.2%

Table 2.4: Participating universities

studies when investigating gender inequality in the STEM fields (Ainscough et al., 2016; Lehman, Sax, & Zimmerman, 2016; Reid, Smith, Iamsuk, & Miller, 2016). In addition, the larger cohort sizes available in first-year science units ensured large sample sizes for statistical analysis.

Mid-degree and final year science students were also targeted in this project. Doing so captured responses from students on the gender issues that arise throughout the university experience. This approach was also used as Australian university students do not necessarily commit to a specific science major until the second or third year of their degree, and so typically have not decided on their science major at the start of their degree. Therefore, to obtain a comparative study between the "gender-balanced" and "gender-unbalanced" science fields, later year science student cohorts (i.e., second-years and third-years) needed to be sampled.

The science fields of biology, chemistry, mathematics, and physics were targeted in this study. Though it is established that gender issues exist within all STEM disciplines, the Australian literature typically focused on the male-dominated engineering and computer science fields when researching gender issues of STEM students. Consequently, the Australian literature has often neglected the other science fields. These four disciplines were also selected to compare the experience in the "gender-balanced" and "gender-unbalanced" science fields at a university level. As this research was based in an Australian context, biology and chemistry were targeted as the "gender-balanced" science fields, while mathematics and physics were classified as the "gender-unbalanced" fields. While these four main disciplines were targeted, if participants were in other science fields that could be classed as male-dominated (e.g., computer science) or more female-dominated (e.g., psychology), they were still included in this study and classed into the previous categories. This was to avoid introducing any bias in results by having too strict or refined selection criteria to be included in the study.

Finally, it should be noted that data was collected from both male, female, transgender and non-binary identifying students. Previously, science education research has treated gender as binary (i.e., male and female) when studying the experience of students and so can often exclude the experiences of other genders within this spectrum. Consequently, in the preliminary stages of this project, a binary classification of gender was used (i.e., male and female students; **Chapter 5**). However, after consultation with gender academics and further developing an understanding of the spectrum of genders as a researcher, transgender and non-binary student experiences were included in future analysis (**Chapters 4** and **6**). For the purpose of this study, while proportions of non-binary or transgender self-identified students was low for quantitative analysis, their qualitative responses were captured and discussed in the results of this project.

2.4 Data analysis techniques

2.4.1 Quantitative data analysis

Quantitative data was analysed using both R (version 3.6.3) and the Statistical Package for the Social Sciences (SPSS) software (version 25). All quantitative data was collected via Likert scales. This data is classified as ordinal, meaning that the intervals between two points on a Likert scale are unknown (i.e., the distance between agree and strongly agree is non quantifiable). Ordinal data cannot be analysed using parametric tests (e.g., t-tests) as they assume an assumption of normality (Sullivan & Artino Jr, 2013). Thus, non-parametric tests were used in all statistical analysis except when testing for the internal consistency and reliability of the questionnaire (i.e., Cronbach's α and exploratory factor analysis). The main statistical tests used were:

- **Cronbach's α**: The internal consistency reliability of a questionnaire sub-scale determines how much the items in the sub-scale measure the theme being tested (e.g., science identity), and is measured by the statistic Cronbach's α (DeVellis, 2003). Typically, a Cronbach's α value of 0.7 or above is accepted as a reliable sub-scale.

- **Exploratory factor analysis**: Exploratory factor analysis (EFA) was also used to ensure the internal reliability of the questionnaire. While Cronbach's α ensured that the sub-scales were measuring the same concept, EFA was used as an additional test to ensure that these sub-scales were examining the concepts of interest by examining the total number of factors/dimensions within the questionnaire (Knekta, Runyon, & Eddy, 2019).

- **Kruskal-Wallis test**: this is a non-parametric test used to compare the differences between independent groups when there are more than two categories (Corder & Foreman, 2014). As there were three gender categories classified in this project (i.e., female, male, and non-binary), the Kruskal-Wallis test was used to test if levels of factors (e.g., science identity) were equal between groups. If significant effects were found, pairwise comparisons using Mann-Whitney U tests were conducted using Bonferroni corrections for multiple comparisons.

- **Spearman correlation**: This test is another non-parametric test, which is used to test the relationship between two variables on an ordinal scale (Corder & Foreman, 2014). In this project, correlation analyses were used to assess how strongly factors, such as science identity, are correlated with students' intentions to persist in the science educational and career pipeline. The null hypothesis is that there is no association between variables, with statistical significance suggesting a positive or negative association between the factor and students' intentions to persist in the sciences.

- **χ^2 test**: the χ^2 test is a non-parametric test that was used to test for equal frequencies between demographic variables in study cohorts (Corder

& Foreman, 2014). It was used to test if demographic variables (e.g., first-generation student status) differed significantly between male and female student samples, which would identify if any confounding variables could be impacting the results.

- **Descriptive statistics**: when providing a summary of the dataset within the chapters of this thesis, summary descriptive statistics were used to portray the general trends of the data, such as averages of a Likert scale question item response. While this is a parametric test that relies on the normality of the data, with larger datasets, such as the one in **Chapter 6**, this is an acceptable practice due to the conformation to normality as a datasets sample size increases.

Statistical significance was defined at the $p < 0.05$ level for all tests.

2.4.2 Qualitative data analysis

For qualitative data analysis, the NVivo (version 20) software was used. Qualitative data was present in both the open-ended response in the questionnaire and the interview transcripts. A thematic analysis framework was used for coding this qualitative data (Braun & Clarke, 2006). The first phase involves the primary researcher reading through the qualitative data multiple times to gain familiarity with it. The second phase involved generating an initial codebook. In the pilot study and separate qualitative study of this project, this involved an inductive approach to generating codes, with codes and themes emerging from the text through rereading through the data. In subsequent qualitative analysis, a combination of inductive and deductive coding was used. Deductive coding uses themes that are established previously (*a priori*) (Crabtree and Miller 1992), which in this case was the codebook generated from the pilot study. New codes were added to these subsequent codebooks using the same inductive approach as before.

The following phases in coding the qualitative data involve refining, reviewing and defining the codes. A critical step in this process to prevent any pre-conceived bias, is ensuring interrater reliability (Creswell, 2014). Interrater reliability involves experienced educational researchers coding parts of the text using the established codebook, and then comparing this to the original coding of the text by the primary researcher using percentage agreement as a way to measure accuracy. Interrater reliability of data within the studies in this project was done with other experienced researchers in the Monash Chemistry and Science Eduction Researchers (ChaSERs) group who were independent to the project and unfamiliar with the data. Consensus was reached when there were no new themes in this coding process, and percentage agreement was above 80%. The frequency of qualitative themes was also recorded. This meant that the frequencies of certain factors and issues could be analysed by their presence in certain cohorts (i.e., male and female student responses).

Chapter 3

Gender differences in the Australian undergraduate STEM student experience: a systematic review

3.1 Preamble

The first research question of this thesis was to identify what factors were contributing to the gendered experience of Australian undergraduate science students. The first step in answering this question involved an in-depth systematic review. This systematic review was conducted at the beginning of this project, throughout November - December, 2018. Four data bases (ERIC, PsycInfo, ProQuest and Scopus) were searched, and after screening and filtering for exclusion criteria, a total of 36 studies were found. These studies were then classified by theme to establish what common trends already existed in the Australian literature on this topic, and how it compared to work done internationally. This systematic review has been published in the journal *Higher Education Research & Development* (*HERD*), a Q1 education journal, and is shown on the following pages.

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Gender differences in the Australian undergraduate STEM student experience: a systematic review

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ABSTRACT

In Australia, the number of female graduates in some science, technology, engineering, and mathematics (STEM) disciplines is as low as 15%. Previous reviews exploring the issues affecting female undergraduate STEM students are primarily based in North America and there is yet to be an Australian focused review. This review identifies the factors contributing to the gendered experience of Australian undergraduate STEM students. A systematic review was conducted in November – December 2018 using ERIC, PsycInfo, ProQuest and Scopus databases. From this review, 36 papers that focus on gender differences and university STEM students in Australia were identified. The Australian research suggests the most prominent issue for female STEM students is their lower self-efficacy. Gendered preferences for learning, gendered motivations to pursue STEM degrees, the masculine culture of these fields and gender differences in science identity were also themes identified through the review. This review indicates some gaps in the Australian literature, namely that identity, and other emotional factors, are understudied in the Australian context and an avenue for future research. The findings suggest that science educators should be aware of the gendered experiences of their students to ensure female persistence in university STEM degrees.

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Introduction

The diminishing presence of women in the science, technology, engineering, and mathematics (STEM) educational and career pathway is often referred to as the 'leaky pipeline' (Blickenstaff, 2005). Policy makers and researchers have been trying to find ways to repair these 'leaks' to retain women in STEM (Olson & Riordan, 2012; Valantine & Collins, 2015), and while progress has been made in some disciplines and in some countries (Luckenbill-Edds, 2002), gender equality has still not been attained in STEM. To understand why STEM fields are still not equal, researchers focus on the critical stages in this pipeline where women are thought to be lost. While secondary and post-graduate stages have been reviewed in the Australian literature, or studied on a large scale (Lyons & Quinn, 2010; White, 2004), the issues affecting undergraduate STEM students remain poorly understood.

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The tertiary level is an important stage in the STEM career pathway, and understanding the reasons behind gender imbalance at the bachelor's level can shed light on the lack of female representation later on (Miller & Wai, 2015). In Australia, the number of female graduates in disciplines such as engineering, physics or information technology (IT) is lower than 15% (Office of the Chief Scientist, 2016). While the disciplines of biology and chemistry have higher female graduation rates (59% and 42% respectively), this gender balance has still not been attained in later career stages of these fields (Office of the Chief Scientist, 2016).

Previous reviews examining literature predominantly from America have identified several factors contributing to the 'gendered experience' in STEM education, describing how the university experience differs for male and female STEM students (Cheryan, Ziegler, Montoya, & Jiang, 2017; Eddy & Brownell, 2016). For example, female STEM students have lower levels of science self-efficacy and belonging compared to male students (Seymour & Hewitt, 1997; Tellhed, Bäckström, & Björklund, 2017). While previous reviews provided a framework for researchers, they have limited generalisability in Australia due to the known differences between America and Australia. For example, levels of bias and gendered motivations for pursuing mathematics have been found to be stronger in Australia compared to American populations (Bardoel, Drago, Cooper, & Colbeck, 2009; Watt et al., 2017). Despite the national importance of increasing women in STEM, there is still no review to date of Australian studies in the literature focused at the undergraduate level. Without a clear understanding of what issues are affecting female STEM students at university, improving their persistence in these degrees is difficult.

Therefore, the aim of this systematic review is to identify what factors are impacting Australian female STEM students at a university level. By identifying these factors, future directions on gender inequality in STEM research and changes in educational practice will be proposed. This systematic review aims to answer the following question:

> What factors have been identified that contribute to the gendered experience of Australian undergraduate STEM students?

Methodology

Article collection

The databases ERIC, PsycInfo and ProQuest were searched in November 2018 with the key terms of *gender* (gender*, female* OR 'sex difference*') and *science* (scienc*, STEM, biolog*, chemist*, math*, comput*, engineer* OR physic*). To restrict the results to an Australian context, Australian locations were used as keywords (Australia*, Melbourne, Victoria*, Sydney, Queensland, Tasmania, OR 'New South Wales'), or through refinement options on databases. To restrict the findings to studies at the undergraduate level, *higher education* was used as a key term (undergrad*, 'higher education', tertiary, postsecondary OR universit*), or applied to refinement criteria on certain databases. No date criteria were used due to the limited number of Australian studies in this field. A total of 178, 227 and 28 articles were returned in the ERIC, PsycInfo and ProQuest databases respectively. After the initial identification of articles in November 2018, the Scopus database was searched in December 2018 using the same terms. As this is an interdisciplinary field, Scopus was used to retrieve any articles not on educational databases, returning a total of 885 articles.

Inclusion and exclusion criteria

The screening process followed the PRISMA protocol (Figure 1), and was undertaken by a single author. While most systematic reviews are recommended to have two independent reviewers, single reviewers still have considerable accuracy in the process (Doust, Pietrzak, Sanders, & Glasziou, 2005). Only peer reviewed research articles and conference papers were included. All types of studies (e.g., observational, case studies) were included. Due to the limited number of studies in this field, the quality of the studies was not used as an exclusion criterion. Reviews, dissertations and books were excluded. Retrospective and prospective studies were excluded, as the aim of this review was to determine what factors were impacting students solely at an undergraduate level. Perspectives of students at pre or post-graduate stages would be influenced by their current environment (i.e., secondary school or the workforce), which may surface different gender issues than those predominantly at the tertiary level. Articles that did not focus specifically on STEM students were excluded. Articles that collected demographic information, but did not analyse student experience by gender, were also excluded.

Theme classification

To detect the factors previously identified as contributing to the gendered experience of Australian university STEM students, the studies were classified into emerging themes. Some studies explored these factors directly (e.g., self-efficacy), while others were grouped based on their findings. For example, Aslanides and Savage (2013) investigated the potential gender bias of physics assessments, but indirectly found lower self-efficacy in female STEM students. Once minor themes had emerged, these were classed into topics that had been well studied in the literature previously (e.g., masculine culture of STEM fields) if possible.

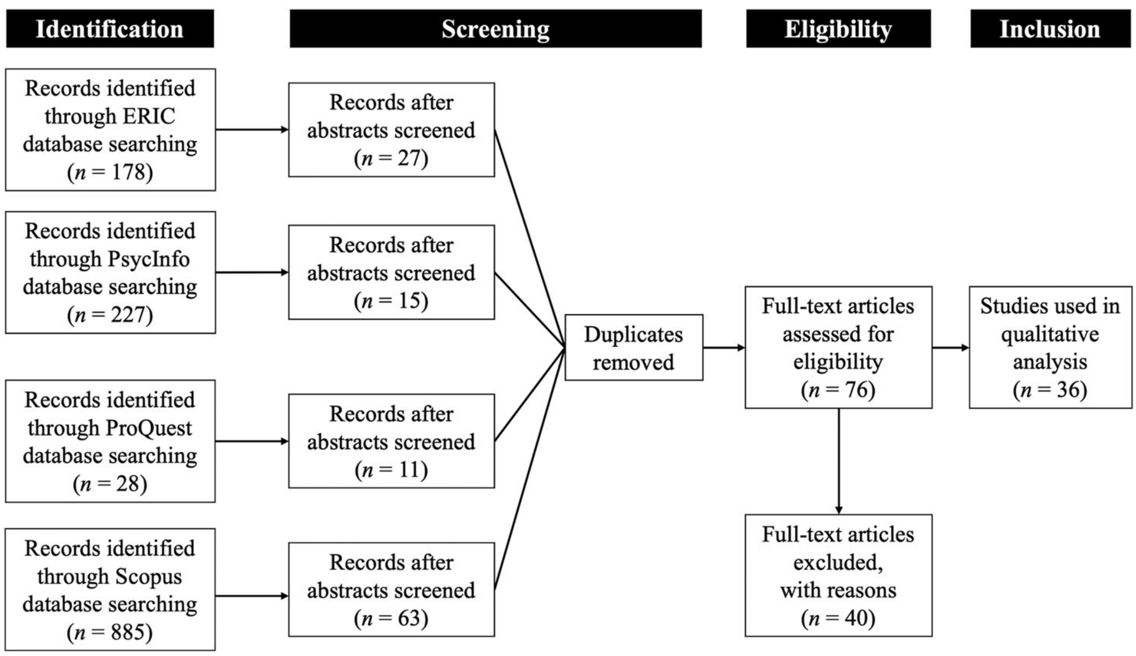

Figure 1. PRISMA flow diagram.

Results

After screening using the inclusion criteria, a final 36 studies were selected for analysis (Table 1). Twenty-five of the studies were quantitative, while only three studies used qualitative methods (Lang, 2010; Michell, Szorenyi, Falkner, & Szabo, 2017; Oo, Li, & Zhang, 2018). The remaining eight studies used mixed-method techniques. Twenty-six of the studies were based at single institutions, with the largest cross-institutional studies investigating three Australian universities (Forgasz, 1998; Fyfe et al., 2014; Sanders et al., 2007). Study cohorts were predominantly first-year students, with only three studies investigating final-year students (Paimin, Hadgraft, Prpic, & Alias, 2011; Smith, Mazzurco, & Compston, 2018; Varsavsky, Matthews, & Hodgson, 2014). Eight studies were longitudinal, and there were only four intervention studies (Everingham, Gyuris, & Sexton, 2013; Lloyd & Szymakowski, 2017; Reid, Smith, Iamsuk, & Miller, 2016; Staehr, Martin, & Byrne, 2001), with most studies being exploratory/observational. The discipline focus of the studies varied with seven of the studies investigating STEM as an aggregate, four comparing STEM and non-STEM students, seven focusing on engineering, six studied computer science, three focused on chemistry, three focused on biology and only one investigated physics students (see Table 1).

Major and minor themes arose within this review (Table 1). Only one study could not be grouped into these themes (Godfrey, Aubrey, Crosthwaite, & King, 2010), as the authors focused on gendered patterns of attrition and retention making the study difficult to group into the other themes relating to the experience of gender for STEM students.

Discussion

The aim of this systematic review was to investigate what factors are contributing to the gendered experience of Australian undergraduate STEM students. Major and minor themes identified several factors that result in gender differences in the STEM undergraduate student experience. These factors included: self-efficacy, learning and assessment styles, motivations to pursue STEM, the masculine cultures of STEM fields and science identity. These themes will be explored alongside what they implicate for future research and science educators.

Gender differences in self-efficacy

Twenty of the studies found a gendered effect in self-efficacy levels, with male students having higher self-efficacy than female students. For example, Atherton (2015, 2017) showed that female students rank themselves lower in performance than a fictitious third person. Similarly, in computing women have more self-doubt in their abilities (Lang, 2010; Volet & Styles, 1992). Female students were also found to have lower confidence in their mathematical abilities, despite no differences in prior knowledge or previous academic performance (Carmichael & Taylor, 2005; Forgasz, 1998; Guo, Parker, Marsh, & Morin, 2015; Nakakoji, Wilson, & Poladian, 2014; Wilson & Macgillivray, 2007). Low self-efficacy in female STEM students and the consequences this has on their persistence in STEM majors is established in the international literature (Tellhed et al., 2017; Williams & George-Jackson, 2014).

Table 1. Articles included in systematic review.

Study	Sample size/Gender (F/M)	STEM discipline	Theme
Ainscough et al. (2016)	614 (354 F, 260 M)	Biology	Self-efficacy
Aslanides and Savage (2013)	53 (15 F, 38 M)	Physics	Learning and assessment; self-efficacy
Atherton (2015)	142 (91 F, 51 M)	Science	Self-efficacy; learning and assessment
Atherton (2017)	49 (30 F, 19 M)	Chemistry	Self-efficacy; learning and assessment
Atherton et al. (2017)	303 (158 F, 145 M)	Science	Learning and assessment; self-efficacy
Burton and Dowling (2010)	131 (18 F, 113M)	Engineering	Learning and assessment
Carmichael and Taylor (2005)	129 (79 F, 50 M)	Mathematics	Self-efficacy
Clarke and Chambers (1989)	222 (112 F, 110 M)	Statistics; computing	Masculine culture of STEM fields; self-efficacy; motivation to pursue science
Doube and Lang (2012)	85 (39 F, 46 M)	IT	Self-efficacy; motivation to pursue science
Everingham et al. (2013)	130 (71 F, 59 M)	Science	Learning and assessment; self-efficacy
Forgasz (1998)	1072 (448 F, 619 M)	Mathematics	Motivation to pursue science; self-efficacy
Fyfe et al. (2014)	277 (213 F, 64 M)	Biology	Learning and assessment
Garner (2009)	49 (17 F, 32 M)	Programing	Learning and assessment
Godfrey et al. (2010)	840 (119 F, 721 M)	Engineering	Retention and attrition
Guo et al. (2015)	10,370 (5149 F, 5221 M)	*N/A*	Self-efficacy; motivation to pursue science
Hudson and Matthews (2012)	429*	Science	Identity
Lang (2010)	37 (22 F, 15 M)	Computing	Masculine culture of STEM fields; motivation to pursue science; self-efficacy
Lloyd and Szymakowski (2017)	116 (78 F, 38 M)	Engineering	Learning and assessment; masculine culture of STEM fields
Michell et al. (2017)	18 (11 F, 7 M)	Computer science; non-STEM	Masculine culture of STEM fields; identity
Miliszewska et al. (2006)	210 (47 F, 163 M)	Computer science	Learning and assessment
Morante et al. (2017)	124 (80 F, 44 M)	Mathematics	Learning and assessment; self-efficacy
Nakakoji et al. (2014)	4860 (2022 F, 2838 M)	Mathematics	Self-efficacy
Ogunde et al. (2017)	972 (525 F, 447 M)	Chemistry	Motivation to pursue science; self-efficacy
Oo et al. (2018)	33 (33 F, 0 M)	Engineering	Motivation to pursue science
Paimin et al. (2011)	122 (29 F, 93 M)	Engineering	Learning and assessment
Reid et al. (2016)	67 (54 F, 13 M)	Science	Masculine culture of STEM fields
Sanders et al. (2007)	1161 (816 F, 345 M)	Biology	Learning and assessment
Smith et al. (2018)	200 (48 F, 152 M)	Engineering	Motivation to pursue science
Staehr et al. (2001)	34 (34 F, 0 M)	Computer Science	Masculine culture of STEM fields
Thomas and Allen (2006)	98 (36 F, 62 M)	Information Systems; Business	Masculine culture of STEM fields; self-efficacy
Tully and Jacobs (2010)	112 (39 F, 73 M)	Engineering	Self-efficacy; motivation to pursue science
Varsavsky et al. (2014)	400 (224 F, 176 M)	Science	Learning and assessment; self-efficacy
Volet and Styles (1992)	55 (13 F, 42 M)	Mathematics; computer science; science	Motivation to pursue science; self-efficacy
Watkins and Hattie (1981)	518 (236 F, 282 M)	Arts; Science; Economics	Learning and assessment
Wilson and Macgillivray (2007)	552 (264 F, 288 M)	Mathematics; non-Mathematics	Self-efficacy
Zeegers (2001)	200 (99 F, 101 M)	Chemistry	Learning and assessment

Note: Samples marked with '*' represent studies that did not explicitly state the gender ratio of their participants. N/A refers to studies that focused on students across all disciplines. F = female, M = male.

Even female students in STEM disciplines that are more 'gender-balanced', such as biology, exhibited gender differences in self-efficacy: female students in biology had lower self-efficacy than male students (Ainscough et al., 2016); female students in the more gender-balanced IT field of multimedia had lower expectations for success (Doube & Lang, 2012); and female students studying computing in a business stream expressed more modesty in their abilities than male students (Lang, 2010). Lower self-efficacy of female students in the more gender-balanced STEM disciplines has been supported by previous work internationally (Grunspan et al., 2016), with findings from this review reaffirming that a gendered experience still exists in these gender-balanced STEM disciplines.

Self-efficacy is a main component of the motivational theoretical framework of social cognitive career theory (SCCT; Lent, Brown, & Hackett, 1994), and findings from this review support that Australian students' reasons for pursuing STEM degrees are related to their self-efficacy levels. When exploring the motivations for pursuing chemistry, male students reported being good at chemistry as a motivating factor (Ogunde, Overton, Thompson, Mewis, & Boniface, 2017). Female engineering students also reported being good at mathematics as a reason for pursuing engineering (Tully & Jacobs, 2010). When identifying potential reasons for female students discontinuing computing, being 'computer illiterate' was a main reason, while male students associated their attrition with other factors (Thomas & Allen, 2006). Similarly, in a study of first-year computer science students, female students rated their ability as contributing to their failure more than male students (Clarke & Chambers, 1989).

Even when not investigating self-efficacy directly, studies still found a gender difference in confidence. Aslanides and Savage (2013) explored the validation of a new inventory in physics. By allowing students to rate their confidence in their answers they found that male students were more confident than female students. A similar trend was found with online engagement in open access courses for STEM students (Atherton et al., 2017; Morante, Djenidi, Clark, & West, 2017), demonstrating that male students engaged less with the content than female students potentially due to their over-confidence. Additionally, when assessing the learning gains of undergraduate science students, it was found that male students ranked their confidence in scientific content knowledge and quantitative skills higher than female students (Varsavsky et al., 2014).

While self-efficacy was identified as a prominent factor contributing to this gendered experience in STEM students, there was only one intervention study that aimed to increase the confidence of these students. Everingham et al. (2013) managed to reduce math anxiety and increase computing confidence in their study by restructuring their course. The lack of intervention studies that attempt to address this self-efficacy issue in STEM suggests a gap in the Australian literature. Previous reviews have already explored intervention programs developed to increase self-efficacy of university students (Bartimote-Aufflick, Bridgeman, Walker, Sharma, & Smith, 2016). Science educators now need to be evaluating and implementing these intervention programs to help improve the experience of their female STEM students.

Gendered preference for learning and assessment

The next major theme that emerged from this review was the gendered preferences for learning and assessment by STEM students (15 studies). These studies explored gender differences for learning in STEM by investigating gendered preferences in assessments, classrooms, study habits and overall student engagement.

Four studies in this review explored the potential gender bias of STEM assessments (Aslanides & Savage, 2013; Atherton, 2015, 2017; Garner, 2009). Aslanides and Savage (2013) showed that male students performed better on a physics concept inventory, suggesting gender bias in the assessment design. In contrast, a study on computer programing students did not find any gender bias in their assessment methods (Garner, 2009). Two studies investigated assessment anxiety and demonstrated that female students predicted their performance would be worse in exams relative to other assessment items (e.g., tests and quizzes) (Atherton, 2015, 2017). Assessment anxiety is such a problem for female STEM students that international educators have altered assessment methods by reducing the amount of marks associated with large pieces of assessments like exams (Cotner & Ballen, 2017). This anxiety would be linked to the lower self-efficacy in female STEM students, emphasizing again the importance of increasing confidence of female students through interventions.

Two studies explored gendered preferences in classroom environments (Lloyd & Szymakowski, 2017; Miliszewska, Barker, Henderson, & Sztendur, 2006). While Miliszewska et al. (2006) found no gender bias in the teaching practices for computer science students, Lloyd and Szymakowski (2017) established that in engineering classrooms, greater female representation in small groups resulted in increased engagement. The benefits of greater female representation in the classroom and small groups has been established in the international literature (Neill, Cotner, Driessen, & Ballen, 2019; Sullivan, Ballen, & Cotner, 2018), and is another factor that science educators need to be aware of for their classroom environments.

Three studies investigated gender differences in the study habits and learning profiles of STEM students. Overall, studies showed no gender differences in study habits (Watkins & Hattie, 1981; Zeegers, 2001), but in an engineering cohort learning profiles differed for male and female students. Learning *interest*, associated with a deep interest in engineering, and learning *intent*, associated with persistence, were predictors of male and female engineering student performance respectively (Paimin et al., 2011).

A final sub-theme was student engagement. Four studies in this review chose to assess engagement by the use of online course content, finding that female students were more engaged in online course content than male students (Atherton et al., 2017; Fyfe et al., 2014; Morante et al., 2017; Sanders et al., 2007). Some authors linked these findings to the lower confidence in female students in their knowledge of the course content, related to their self-efficacy.

Gendered motivations to pursue science

A final major theme contributing to the gendered experience of undergraduate STEM students was the gendered motivation to pursue science, with 10 studies examining this theme. Gender differences in motivations to pursue STEM fields is a well-established area of research, with various factors (e.g., lifestyle values, mathematical achievement) identified as contributing to this effect (Eccles & Wang, 2016; Wang, 2013). While many factors were identified as contributing to student motivations to study STEM in Australia, mathematics value, interest and ability were prominent. In a large-scale study on Australian youth by Guo et al. (2015), intrinsic value for mathematics was an important mediating factor in STEM major choice for male students. In the Tully and Jacobs (2010) study, female students reported being good at mathematics as a motivating factor for pursuing engineering at university. Forgasz (1998) found that mathematics subject enjoyment declined for female students as they progressed from high school to university. The importance of mathematical ability and achievement for Australian STEM students may be linked to differences in the perceptions of mathematics by the Australian public compared to other countries, as other countries have reduced gendered associations with mathematics and this gender imbalance at a university level (Cheryan et al., 2017; Watt et al., 2017).

A motivator identified in this review for female students enrolling in STEM courses is because they are compulsory for certain STEM degrees, while male students report interest as the main reason (Clarke & Chambers, 1989; Ogunde et al., 2017). That is not to say female students have less interest in STEM fields. Some studies in this review showed that female students pursued STEM fields primarily because of their interest (Oo et al., 2018; Volet & Styles, 1992). Additionally, a recent study by Smith et al. (2018) found no gender differences in motivations to pursue an engineering degree. However, making STEM subjects compulsory for students, especially computer science, has been suggested because early exposure to these fields is an underlying reason why male students often pursue these more male-dominated STEM fields (Alshahrani, Ross, & Wood, 2018; Cheryan et al., 2017).

Masculine culture of STEM fields

Seven studies explored the masculine culture of STEM fields as contributing to the gendered experience of female students. This masculine culture was attributed to lower levels of belonging in female STEM students, caused by stereotypes of those who study STEM and a lack of female role models. These findings align with theoretical models derived from international reviews, with a major component of Cheryan and colleagues' (2017) model being the masculine culture of STEM fields. The sub-themes attributed to this masculine culture were similar to those identified within this review.

Some studies showed that female students who discontinue computer science do so because they do not identify with the 'geeky' stereotype of computing (Michell et al., 2017; Thomas & Allen, 2006). This stereotype impacts their belonging in STEM, with female students in IT more likely to report that they struggle to belong (Lang, 2010). While Lloyd and Szymakowski (2017) found no gendered experience relating to stereotyping or discrimination in an engineering course, the number of female students participating in the survey was small ($n = 4$). Only one intervention study attempted to increase the belonging of female computer science students, via female-only study groups, which was shown to improve female persistence in these classes (Staehr et al., 2001). Belonging has been established as a contributor to this gendered experience in the international literature (Good, Rattan, & Dweck, 2012; Tellhed et al., 2017). Yet, compared to the international research, belonging is relatively understudied in Australia and, similarly to self-efficacy, researchers and educators need to be increasing the number of intervention studies in this emotional domain.

Few studies in this review explored the impact of role models as a contributing factor to fewer women in STEM at an undergraduate level (Clarke & Chambers, 1989; Reid et al., 2016; Thomas & Allen, 2006). Clarke and Chambers (1989) investigated the presence of role models for computer science students, finding more male role models at home for these students. Thomas and Allen's (2006) study on IT students showed that over half of the students could not name one woman they knew in IT, suggesting a lack of female role models for female students. Reid et al. (2016) used an intervention study to investigate the impact of a mentoring program on female STEM students. They found mentoring had a positive effect on the students with mentees having increased or similar rates of optimism and confidence about a career in STEM by the end of the program (Reid et al., 2016).

Gender differences in science identity

Only two studies focused on science identity, making it a minor theme in the Australian literature. Hudson and Matthews (2012) investigated the science and mathematical identities of undergraduate science students, with male students reporting higher mathematical identities than female students, despite having similar educational backgrounds. No gender effect was observed for science identities. Interviews with computer science students also demonstrated that female students struggle to negotiate their identities against the typical stereotypes in these fields (Michell et al., 2017).

Similarly to belonging, the emotional factor of science identity receives little attention in Australian research, yet it has been established by international researchers that female students typically have lower science identity than male students (Hazari, Sadler, & Sonnert, 2013; Li & Loverude, 2013). While it is a relatively new analytical lens for studying gender issues in STEM (Carlone & Johnson, 2007), findings from this systematic review suggest that identity may be an important area to focus on when studying the experience of Australian undergraduate STEM students.

Limitations and recommendations

There are some limitations in the search process of this systematic review. We attempted to capture all of the Australian literature, but it is acknowledged that not all published articles may have been found due to their availability on certain databases. Articles not including Australia or any Australian location as a keyword or within their abstract would have been missed during the identification stage. Additionally, articles were restricted to those written in English only.

In comparison to the amount and types of research presented in an international context, Australian research on university STEM students' experiences is limited in several ways. Firstly, Australian studies were limited in their methodology when compared to international studies. Cross-institutional studies were limited, and to make Australian findings more generalizable, a large-scale study in this research field is required. Additionally, many cohorts in these studies were from the male-dominated sciences of computing and engineering, but physics received little attention. As physics is a STEM discipline with a low number of female graduates (Office of the Chief Scientist, 2016), more Australian research is needed on the experiences of these students.

Secondly, some factors discussed internationally have not been explored thoroughly or even at all in Australian studies. For example, some international research suggests that women are less likely to pursue the more male-dominated sciences if they have strong communal interests, also termed altruistic beliefs (Boucher, Fuesting, Diekman, & Murphy, 2017; Struyf, Boeve-de Pauw, & Van Petegem, 2017). Smith et al. (2018) was the only study that could have investigated altruism as a factor for this gender disparity, yet no gender differences arose in student motivations to pursue humanitarian engineering. Another example is the impact of role models, which has been studied thoroughly internationally (Cheryan, Drury, & Vichayapai, 2013; Schinske, Perkins, Snyder, & Wyer, 2016; Young, Rudman, Buettner, & McLean, 2013). This was a minor sub-theme found from this review, with only three Australian studies investigating the impact of role models at the university level. To aid in the development of a comprehensive framework behind the gendered experience of Australian STEM students at the undergraduate level, more research is needed in these understudied areas.

Finally, most Australian studies were observational, with some finding a gendered experience by chance (e.g., Aslanides & Savage, 2013). Only one study focused on an intervention program for increasing the self-efficacy of STEM students despite self-efficacy being a well-established issue in the literature. Science educators need to be aware this gendered experience is occurring in their classrooms, as low-self efficacy is not related to poor academic performance (Ainscough et al., 2016; Volet & Styles, 1992), but it is a concern for attrition. Overall, these limitations suggest several avenues for future research in Australia, while providing cultural comparisons for international educators.

Conclusion

The studies explored in this systematic review have demonstrated that a gendered experience exists for Australian tertiary STEM students, with lower levels of self-efficacy in female students as the primary factor and other well-established factors contributing to this effect that draws parallels to the international literature. Science educators need to be aware of this gendered experience in STEM, and should work towards creating interventions to reduce gender differences in STEM education. In comparison to international studies in the same field, Australian research is limited and so has identified fewer factors contributing to gender issues for students studying STEM. Future research in this field is required to understand what issues exist for female students in STEM degrees in Australia, and develop interventions that will increase their persistence in this career pathway.

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3.2 Summary

Findings from the systematic review established the following key points:

- Australian research on the gendered experience of undergraduate science students is limited in comparison to the international literature.
- Of the Australian studies that do exist, research has established a gendered effect for self-efficacy within undergraduate science students, demonstrating that female students typically have lower self-efficacy in science subjects compared to male students.
- In comparison to what has been done internationally, the affective domains of science identity and belonging are relatively understudied in an Australian context.

These key points established that the focus of this thesis on investigating gender issues for Australian undergraduate science students was warranted due to gaps in the current literature. In particular, the results of this literature review shifted the focus of this project onto the key affective domains of science identity and belonging due to lack of studies on these factors within an Australian context. While early stages in this project design incorporated self-efficacy (**Chapter 5**), the results from this systematic review demonstrated a clear gendered effect relating to self-efficacy has already been well-established in the Australian literature, with numerous studies finding this effect in undergraduate science student cohorts. Subsequently, the focus of this thesis shifted to more understudied effects in Australian undergraduate student cohorts for the core part of this thesis.

Chapter 4

Gender differences in commencing undergraduate science students

4.1 Preamble

While Chapter 3 summarised factors previously identified in the literature as contributing to the gendered experience of Australian undergraduate science students, the purpose of this fourth chapter is to present data collected on current undergraduate student cohorts. This current chapter set out to identify the gender issues impacting undergraduate science students at the beginning of their university experience. Doing so helped establish a baseline for how levels of belonging or experiences of discrimination might change during this time and also identify the most pressing issues that put students at risk for attrition from their science majors. This was achieved by surveying commencing science students at Monash University within the first four weeks of their degree in Semester 1, 2019. The results of this case study have been submitted for publication in the *The Australian Educational Researcher*, a Q1 education journal, and is on the following pages. Supplementary information referred to in this paper can be found in **Appendix A**.

Levels of science identity, belonging and experiences of discrimination for commencing science students at an Australian university

A key step in achieving gender equality in the science, technology, engineering, and mathematics (STEM) workforce is recruiting more women into undergraduate STEM degrees. Some disciplines, such as biology, have been more successful at this than others. Yet, gender issues at university still exist in these science disciplines, which may be deterring women from remaining in this career pathway. This case study at an Australian university explored known risk factors for attrition by surveying 215 first-year undergraduate science students. It also investigated how these factors differ for students in the 'gender-balanced' and 'gender-unbalanced' science fields. Findings showed that female students in both the 'gender-balanced' and 'gender-unbalanced' science fields begin university with low levels of belonging, and encounter experiences of discrimination early on. These findings highlight potential risk factors for attrition for incoming Australian science undergraduates, and some potential challenges tertiary educators need to be aware of within their first-year classrooms.

Keywords: gender bias, gender equity, higher education, science education

Introduction

Addressing gender inequality in science, technology, engineering, and mathematics (STEM) is a top priority in Australia (Australian Academy of Science 2019). Gender inequality in STEM is reflected in fewer women in the STEM qualified workforce (29%) and the gender pay gap that persists in these fields. Increasing the number of women in STEM would not only have societal benefits, but would also have economic benefits, helping meet the growing demand for STEM qualified individuals (Department of the Prime Minister and Cabinet 2017).

One way to rectify the gender imbalance in STEM is to increase the number of enrolling female students in undergraduate science degrees. The university experience is a key stage in the science career pathway, and the first year of university has been a focus in higher education research (Jansen and Van der Meer 2012; Lyons et al. 2012). Studying the first-year student experience is critical, as introductory STEM courses often act as 'gatekeepers' for these career pathways (Gasiewski, Eagan, Garcia, Hurtado, and Chang 2012). This is particularly relevant for female STEM students. For example, Fink, Frey, and Solomon (2020) demonstrated that female students in introductory chemistry courses have decreased levels of belonging and increased uncertainty when compared to male students. This lack of belonging and feelings of uncertainty were then associated with decreased performance and increased attrition for these female students. Studying commencing first-year cohorts also helps establish a baseline of these factors associated with attrition within commencing university student cohorts (Gyuris, Everingham, and Sexton 2012).

Women are more likely to switch out of a science major at university than male students, regardless of their academic performance (Astorne-Figari and Speer 2018; Bettinger 2010). This raises the question as to why women are deciding to leave the sciences at university. Recent focus has been placed on the affective domains, which acknowledges the impact that emotions can have on the student learning experience (National Research Council 2012; Trujillo and Tanner 2014). While several affective factors have been identified as impacting the student experience in a STEM university classroom, this current study will be restricted to the three domains of belonging, science identity, and gender discrimination. Belonging and science identity were selected due to the limited research of these constructs on Australian university cohorts (Fisher, Brookes, & Thompson, 2020b), despite international literature demonstrating the importance of these domains for student persistence in the STEM fields (Hazari, Sadler and Sonnet 2013; Seymour and Hewitt 1997). Gender discrimination was also selected due to the interaction these discriminatory experiences and biases can have on students' feelings of belonging and identity (Ramsey and Sekaquaptewa 2011; Walton and Cohen 2007).

The first affective domain investigated was belonging. The definition of belonging used within this study follows from the work of Good, Rattan, and Dweck (2012). When defining ‘academic’ belonging, Good et al. (2012) emphasised the importance of membership and acceptance in these fields. Additional compounding factors were also highlighted, such as how positive feelings (i.e., affect) and willingness to engage also reflect on one’s belonging. A sense of belonging has proven to be critical for students’ interest and persistence in university majors where their gender is not the majority (Tellhed, Bäckström, & Björklund, 2017), with a key example of this being female students pursuing the male-dominated science fields.

A lack of belonging is one of the reasons why female university students may decide to leave the sciences (Seymour and Hewitt 1997). One of the causes of decreased belonging in female science students is the stereotype of people who study science often being depicted as ‘male geniuses’ (Leslie, Cimpian, Meyer and Freeland 2015). Consequently, this perception has been shown to then lower women’s belonging and interest in a science career (Carli, Alawa, Lee, Zhao and Kim 2016; Master, Cheryan and Meltzoff 2016).

Another affective domain closely linked to one’s sense of belonging is their identity, or specifically their science identity. Science identity can be defined as how important it is for an individual to be recognised as a scientist by their peers and is an analytical lens used to study gender inequality in science education (Carlone and Johnson 2007). The theoretical background of science identity is continually evolving, though Carlone and Johnson’s (2007) definition includes the three core concepts of recognition, performance and competence. Recognition refers to being recognised by both yourself and peers as a ‘science person’, performance refers to the act of doing science, and competence refers to one’s knowledge in the sciences. However, additional concepts, such as interest and even belonging, are starting to be incorporated into this framework (Kim and Sinatra 2018).

Science identity is associated with one's intention to pursue a scientific career path (Hazari et al. 2013; Stets, Brenner, Burke and Serpe 2017). Gender differences have been found when investigating the science identities of university students, particularly in the 'gender-unbalanced' science fields, such as physics (Hazari et al., 2013). By investigating how these affective domains might be impacting science students' university experiences, educators may be able to develop more effective intervention programs to retain and improve the experience for women in science.

The final factor that will be investigated as part of this study is gender bias and discrimination. Discrimination can be divided into explicit and implicit forms (Kuchynka et al. 2018). While explicit discrimination is overt, such as sexual harassment, implicit discrimination is more subtle and driven by unconscious biases engrained from a young age (Smyth and Nosek 2015). Students from minoritized groups have been shown to have decreased belonging, or *belonging uncertainty*, when facing stigma or stereotypes in their academic environment (Walton and Cohen 2007). An example of a stereotype is that men are more suited to science than women. Experiences of implicit discrimination may result in lower levels of science identity for women, which may also impact their academic performance (Lane, Goh and Driver-Linn 2012; Ramsey and Sekaquaptewa 2011). Therefore, experiences of discrimination can impact the affective domains of belonging and science identity, which are known to play a vital role in female students' intentions to persist in a science career.

While the literature on gender differences in the STEM university experience is primarily based in an American context (Cheryan, Ziegler, Montoya and Jiang 2017; Eddy and Brownell 2016), some Australian research into gender issues within the first-year STEM university experience has been conducted. For example, a cross-institutional Australian study by Lyons et al. (2012) investigated why students chose to study these fields as well as the experience of female students in the more male-dominated STEM fields (i.e., engineering, physics). However, of the Australian research that does exist, the majority of first-year studies investigate the more male-dominated, or ‘gender-unbalanced’, STEM fields, such as engineering and computer science (Lloyd and Szymakowski 2017; Staehr, Martin and Byrne 2001; for a more extensive review see: Fisher, Thompson, & Brookes, 2020b). Consequently, research into the more female-dominated, or ‘gender-balanced’, science fields in an Australian context is limited.

The aim of this study was to investigate how the affective domains are impacting Australian undergraduate science students at the beginning of their university experience. Doing so will help to provide a baseline to measure how these factors may change over the course of an undergraduate degree, while also highlighting potential risk factors for attrition within incoming science student cohorts. Therefore, the research questions this study sets out to answer are:

What are the levels of science identity, belonging and perceived bias in science for commencing undergraduate science students?

a. How do these factors differ by gender?
b. How do these factors differ within the ‘gender-balanced’ and ‘gender-unbalanced’ science disciplines?

Methodology

A case study survey research design was used in this study (Mills, Durepos and Wiebe 2013). A single Australian university was sampled to investigate the gendered experience of commencing undergraduate science students. This was a cross-sectional study, with an online questionnaire given to first-year science students during the first four weeks of Semester 1, 2019. The questionnaire had both closed and open-ended questions. Quantitative data was collected to compare levels of science identity, belonging and perceived bias. Qualitative data was collected through an open-ended question, allowing students to describe experiences of discrimination they had faced while at university in their science discipline. Ethics approval for this project was granted by Monash University's Human Research Ethics Committee (project ID: 16341).

Participants

First-year unit coordinators at a research-intensive university located in Melbourne, Victoria, in the fields of biology, chemistry, mathematics, and physics were recruited to distribute an online questionnaire to their students during class time, or advertise it online through a centralised learning management platform. The questionnaire was accessible to students during the first semester of their undergraduate degree, with most students completing the questionnaire within the first four weeks. There was no monetary incentive to complete the questionnaire for students.

In total, 222 complete responses were collected. As first-year science units were targeted in this study, it was assumed that students would be enrolled in undergraduate science degrees. At this university in 2019, 1,655 students enrolled in undergraduate science degrees, therefore these 222 responses reflect approximately 15% of the overall incoming science student cohort. This lower response rate is to be expected with online questionnaires (Nulty 2008). Due to ethical considerations, analysis was restricted to adult participants only, with seven participants under the age of 18 excluded from analysis. This resulted in a final sample size of 215.

The demographics of the final participants are shown in **Table 1**. The majority of students did not identify as under-represented minorities (URMs) (91.1%) or first-generation students (80.0%). Students were categorised as high achieving if they were placed in the top 20^{th} percentile in their final year of schooling (i.e., ATAR score > 80 or equivalent). Most students (76.3%) were classed as high achieving and almost all students had been exposed to science in a high school setting (96.3%). While the exact degree that these students were enrolled in was not recorded, it was assumed the majority of students were enrolled in an undergraduate science degree with the majority declaring a major in a science field. Only a small portion of students declared not intending to major in the science fields (8.4%).

To classify students' planned science majors, science disciplines were separated into 'gender-unbalanced' and 'gender-balanced' fields. The 'gender-unbalanced' science fields were classified as science fields which have relatively low female participation rates (i.e., < 33% female enrolments). In Australia, these science disciplines are mathematics (32%) and physics (25%) (Department of Education and Training [DET] 2018). In comparison, the 'gender-balanced' science disciplines are defined as ones with relatively higher female participation (i.e., >33% female enrolments), which in Australia are the biology (57%) and chemistry (42%) disciplines (DET 2018). A separate classification was used for students who were planning to major in both a 'gender-balanced' and 'gender-unbalanced' science field, who were classed as a double major.

Table 1. Demographics of study participants (*n* = 215).

Variable		Frequency	(%)
Gender	Female	91	(42.3%)
	Male	121	(56.3%)
	Other/Prefer not to say	3	(1.4%)
Ethnicity	White/Caucasian	117	(54.4%)
	Asian	79	(36.7%)
	Black/African American	2	(0.9%)
	Latino/Hispanic	2	(0.9%)
	Aboriginal or Torres Strait Islander	0	(0.0%)
	Mixed or Other	15	(7.1%)
First in family to attend university?	Yes	41	(19.1%)
	No	172	(80.0%)
	Not specified	2	(0.9%)
Mature age?	Yes	20	(9.3%)
(21 years old or over)	No	194	(90.2%)
	Not specified	1	(0.5%)
High achieving student?	Yes	164	(76.3%)
(>80 in Year 12)	No	29	(13.5%)
	Not specified	22	(10.2%)
Previous experience in science?	Yes	207	(96.3%)
	No	8	(3.7%)
Science Major	'Gender-unbalanced'	95	(44.2%)
	'Gender-balanced'	94	(43.7%)
	Double Major	8	(3.7%)
	Other/not specified	18	(8.4%)

Survey instrument

The purpose of the questionnaire was to establish risk factors for attrition within Australian science undergraduate cohorts, by exploring their levels of science identity, belonging and perceived bias in science when commencing these degrees. The questionnaire was constructed from four pre-existing sub-scales. The first was a five-item scale that investigated science identity (Chemers, Zurbriggen, Syed, Goza and Bearman 2011). The second was a belonging scale that was modified to ask students on their current levels of belonging while at university (i.e., *When in a science classroom at university…*). This was an adapted 26-item scale, reduced for brevity, and was comprised of smaller sub-scales investigating the subfactors of a sense of belonging (i.e., membership, acceptance, affect, desire to fade) (Good et al. 2012). This scale was originally created for belonging in mathematics, so all references were changed to reflect the general science fields. The third scale was a 6-item scale on perceived identity compatibility between gender and major (London, Rosenthal, Levy and Lobel 2011), and the final scale was a four-item scale on students' perceptions of gender bias in their science major (Ganley, George, Cimpian and Makowski 2018) (**Table 2**). A five-point Likert scale (strongly disagree to strongly agree) was used for all question items. In addition, a single open-ended question asking students to provide any experiences of discrimination they had faced while at university was included ('*Gender bias occurs when people treat others unfairly due to their gender. Please describe if you have had any experiences with gender bias in your discipline during your degree'*; Robnett 2016). The questionnaire was distributed online using Qualtrics software.

Table 2. Question items used in online survey.

Theme	Question items	Reference
Science identity	In general, my interest in science is an important part of my self-image. My interest in science is an important reflection of who I am. I feel like I belong in the field of science. I have a strong sense of belonging to the community of scientists. I am a scientist.	Chemers et al. (2011)
Belonging 1. *Membership*	I feel that I belong to the scientific community. I consider myself a member of the scientific community. I feel like I am part of the scientific community. I feel a connection with the scientific community.	Good et al. (2012)
2. *Acceptance*	I feel like an outsider. I feel accepted. I feel respected. I feel disregarded. I feel valued. I feel neglected. I feel appreciated. I feel excluded. I feel like I fit in. I feel insignificant.	
3. *Affect*	I feel at ease. I feel anxious. I feel comfortable. I feel tense. I feel nervous. I feel content. I feel calm. I feel inadequate.	
4. *Desire to fade*	I wish I could fade into the background and not be noticed. I try to say as little as possible. I enjoy being an active participant. I wish I were invisible.	
Perceived identity compatibility between gender and major	I don't think that my gender will affect how others view me in my major. I don't think that my gender will affect how well I do in my major. I think my gender and my major are very compatible. I think I have experienced difficulties in my major because of my gender. I think my gender will be an important factor in the type of career I decide to pursue. I don't think I would pursue certain fields because of my gender.	London et al. (2011)
Gender biased science majors	Women in my major experience discrimination. Women have a hard time succeeding in my major. My major is more welcoming to men than it is to women. What percentage of students in this major do you estimate are women? (0-25, 26-35, 36-45, 46-55, 56-65, 66-75, 76-100%)	Ganley et al. (2018)

To control for confounding variables, a series of demographic questions were also asked. These questions covered variables that have been previously identified as impacting students' persistence at university, regardless of their gender. For example, students in URMs, or those who are first in their family to attend university, experience additional issues that may impact their university experience (Chemers et al. 2011; Wilson and Kittleson 2013). The demographic questions included: students' gender, ethnicity, first-generation student status, age, academic background, and previous experience in science. To analyse discipline-specific gender effects within the science fields, a question asking students' planned major was included. As the Australian university system allows students to determine their major later on in their degrees, the question asked to students to self-report their planned major. Finally, gender was self-identified by students from three categories (i.e., male, female, other/prefer not to say). When studying gender issues in higher education, researchers tend to use a binary classification of gender (i.e., male and female), which excludes other non-binary gender identities (Henderson and Nicolazzo 2018). For the purposes of this study, gender is not classed as binary and this study will attempt to highlight the non-binary and transgender experiences at university alongside the primarily studied male and female student experience.

Data analysis

For quantitative analysis, R (version 3.6.3) was used, using non-parametric tests for analysis as data was collected using Likert scales, which are ordinal. Ordinal data cannot be analysed using parametric tests as it does not conform to a normal distribution as the distance between two points on a Likert scale (e.g., strongly agree to agree) is non-quantifiable (Sullivan and Artino Jr 2013). To assess gender differences in questionnaire responses, the Kruskal-Wallis test was used when there were three gender categories to compare, followed by *post-hoc*

Mann-Whitney *U* tests using Bonferroni corrections to adjust for multiple comparisons. When only binary categories (i.e., female, male) for gender were within a subgroup, Mann-Whitney *U* tests were used for gender comparisons.

For qualitative data analysis, NVivo software (version 12) was used. A total of 91 valid responses from the open-ended question in the questionnaire were used for analysis. For qualitative analysis, a combination of deductive and inductive coding was used. A deductive coding approach was used to begin with (Boyatzis 1998), as the question had been asked on Australian university cohorts previously (Fisher, Thompson, & Brookes 2020a). Therefore, codes generated from previous studies (i.e., *a priori*) framed the beginning of the codebook, and new codes were added to this codebook as new themes emerged from the text via an inductive coding approach (Thomas 2006). The final codebook included six codes (Supplementary material: Table S1). To prevent bias, interrater reliability occurred with two other educational researchers, ensuring percentage agreement was over 70%.

Results

Questionnaire reliability

The internal consistency reliability of the questionnaire was measured using Cronbach's α. The sub-scales' α values were greater or approximately equal to 0.7 (**Table 3**), which is the widely accepted value for reliability (DeVellis 2003). Internal validity of the questionnaire was tested using exploratory factor analysis (EFA), with the 40-item Likert questions loading onto seven factors (see supplementary material: Table S2). While the positive and negatively worded items on the *acceptance* sub-scale loaded onto two separate factors, this effect was found in the original analysis of this scale (Good et al. 2012), and the high α value for the acceptance sub-scale (α = 0.90) suggests it is measuring this construct. Modelling suggested satisfactory fit (RMSEA = 0.056, RMSR = 0.03), and while some indices were slightly under appropriate cut-offs (TLI = 0.88), these may have been due to errors associated with smaller sample sizes for this type of statistical analysis ($N < 250$; Hu and Bentler 1999).

Table 3. Internal consistency reliability of survey sub-scales.

Scale	Cronbach's α
Science identity	0.83
Belonging – Membership	0.93
Belonging – Acceptance	0.90
Belonging – Affect	0.89
Belonging – Desire to fade	0.79
Perceived identity compatibility between gender and major	0.68
Gender biased science majors	0.86

Demographics of respondents

Analysis was restricted to students who identified as planning to major in the 'gender-unbalanced' or 'gender-balanced' science disciplines, comprising 87.9% of the study cohort. Students majoring in both a 'gender-balanced' and 'gender-unbalanced' fields (i.e., double majors), or those who did not specify a major, were excluded from analysis. To control for confounding variables, demographic information between the genders was tested. A Fisher's exact test was used, to account for the small sample sizes within some of the gender sub-groups. No statistically significant differences ($p < 0.05$) found between the genders and the background variables tested (Supplementary material: Table S3). Thus, it was assumed no substantial confounding effects would be present in this study cohort.

Gender differences for commencing undergraduate science students

Quantitative results

Science identity and belonging. No gender differences were observed in levels of science identity in the 'gender-balanced' or 'gender-unbalanced' science fields. However, multiple items on the belonging sub-scale had statistically significant gender differences in both of these fields. As there were only two reported genders (i.e., male and female) in the 'gender-balanced' science fields, a Mann-Whitney *U* test was used to compare belonging. Results showed that female students in these science fields self-reported lower levels of belonging when in a science classroom at university (**Table 4**). Specifically, female students had lower levels of acceptance and affect with regards to their belonging. For example, female students in these fields agreed more with feeling disregarded (U = 1363, Z = -2.067, p = 0.039, r = 0.214), excluded (U = 1420, Z = -2.527, p = 0.012, r = 261), insignificant (U = 1379, Z = -2.173, p = 0.030, r = 0.225), and inadequate (U = 1387, Z = -2.215, p = 0.027, r = 0.229) in a science classroom at university when compared to their male peers. All of these results were found to have small effect sizes ($r < 0.3$).

Table 4. Gender differences in belonging in the 'gender-balanced' science fields.

Question item	Female (mean)	Male (mean)	*U*	*Z*	*p*	Effect size (*r*)
I feel disregarded (-)	2.21	1.81	1363	-2.067	**0.039**	0.214
I feel valued	3.45	3.85	789.5	-2.569	**0.010**	0.265
I feel appreciated	3.32	3.79	788.5	-2.558	**0.011**	0.264
I feel excluded (-)	2.17	1.68	1420	-2.527	**0.012**	0.261
I feel insignificant (-)	2.47	1.96	1379	-2.173	**0.030**	0.225
I feel comfortable	3.47	3.83	847.5	-2.094	**0.036**	0.216
I feel inadequate (-)	2.79	2.28	1387	-2.215	**0.027**	0.229

Note: (-) = reverse-coded items.

To assess gender differences within the 'gender-unbalanced' fields, Kruskal-Wallis tests were used to find significant differences as there were non-binary identified students in these fields (n = 2). Similar to the 'gender-balanced' fields, no significant gender differences were found in levels of science identity, however aspects of belonging did differ between the genders. *Post-hoc* pairwise Mann-Whitney *U* tests were used to determine what sub-groups within the genders differed in their levels of belonging (**Table 5**). Overall, female students reported lower levels of belonging in a science classroom at university when compared to male students in regards to their acceptance, affect and desire to fade in these fields. Female students in this study agreed more with feeling disregarded ($U = 1300$, $Z = -2.226$, $p = 0.026$, $r = 0.273$) and not fitting in ($U = 668$, $Z = -2.457$, $p = 0.014$, $r = 0.293$) in a university science classroom. Female students also reported lower affect in these fields, feeling more uneasy ($U = 591$, $Z = -3.090$, $p = 0.002$, $r = 0.351$), less calm ($U = 634.5$, $Z = -2.652$, $p = 0.008$, $r = 0.314$) and more inadequate ($U = 1360.5$, $Z = -2.697$, $p = 0.007$, $r = 0.318$) in a university science classroom, all with medium effect sizes ($r > 0.3$). A significant effect was also recorded for one question item ('*I feel calm*') between male participants and those students who identified as non-binary ($U = 118.5$, $Z = -2.005$, $p = 0.045$, $r = 0.312$) with a medium effect size, with the latter sub-group of students feeling less calm. However, the small sample size of this cohort makes the generalisability of these findings limited.

Table 5. Pairwise comparisons between gender differences in belonging in the 'gender-unbalanced' science fields.

Question item	**Female (mean)**	**Male (mean)**	**Non-binary (mean)**	***U***	***Z***	***p* adjusted**	**Effect size (*r*)**
I feel disregarded (-)	2.39	1.88	-	1300	-2.226	**0.026**	0.273
I feel like I fit in	3.42	3.88	-	668	-2.457	**0.014**	0.293
I feel at ease	3.18	3.85	-	591	-3.090	**0.002**	0.351
I feel calm	3.24	3.82	-	634.5	-2.652	**0.008**	0.314
	-	3.82	1.50	118.5	-2.005	**0.045**	0.312
I feel inadequate (-)	3.24	2.50	-	1360.5	-2.697	**0.007**	0.318
I enjoy being an active participant	3.30	3.92	-	698.5	-2.044	**0.041**	0.256

Note: only statistically significant pairwise comparisons are shown. (-) = reverse coded items.

Perceptions of bias and discrimination in science. Several items on the gender-focused sub-scales (i.e., *Perceived identity compatibility between gender and major* and *Gender biased science majors*) had statistically significant gender differences in both the 'gender-balanced' and 'gender-unbalanced' science fields (**Table 6**). Overall, female students reported higher levels of perceived gender bias in their science classrooms than male students and male students often disagreed with the presence of gender bias in their science major. For example, in the 'gender-balanced' fields, female students agreed more that women would have a hard time succeeding in their major (U = 1446, Z = -2.702, p = 0.007, r = 0.279), and that their major was more welcoming to men than to women (U =1373.5, Z = -2.108, p = 0.035, r = 0.218), both with small effect sizes (r < 0.3). In the 'gender-unbalanced' fields, female students agreed more that women experience discrimination in their major (U = 1295.5, Z = -2.108, p = 0.035, r = 0.262) and that they themselves had experienced difficulties due to their gender (U = 1353, Z = -2.968, p = 0.003, r = 0.339), with small and medium effect sizes respectively. It should also be noted that a significant effect was observed with non-binary students in the 'gender-unbalanced' disciplines, with these students agreeing more that they have faced gender issues in their science major when compared to male students (U = 5, Z = -2.183, p = 0.029), with a medium effect size (r = 0.331).

Table 6. Pairwise comparisons between gender differences in belonging in the 'gender-unbalanced' science fields.

Science major	Question item	Female (mean)	Male (mean)	Non-binary (mean)	*U*	*Z*	*p*-value	Effect size (*r*)
Gender-balanced	I don't think that my gender will affect how others view me in my major.	3.89	4.23	N/A	859	-1.986	**0.047**	0.205
	Women have a hard time succeeding in my major. (-)	2.53	1.87	N/A	1446	-2.702	**0.007**	0.279
	My major is more welcoming to men than it is to women. (-)	2.70	2.19	N/A	1373.5	-2.108	**0.035**	0.218
Gender-unbalanced	I don't think that my gender will affect how others view me in my major.	3.27	4.03	-	641	-2.576	**0.010***	0.304
	I don't think that my gender will affect how well I do in my major.	3.85	4.43	-	717.5	-1.995	**0.046***	0.252
	I think I have experienced difficulties in my major because of my gender. (-)	2.27	1.57	-	1353	-2.968	**0.003***	0.339
		-	1.57	4.00	5	-2.183	**0.029***	0.331
	Women in my major experience discrimination. (-)	2.94	2.25	-	1295.5	-2.108	**0.035***	0.262

Note: Only statistically pairwise comparisons are shown. (-) = reverse-coded items. * = *p*-value adjusted for multiple comparisons using Bonferroni correction.

Qualitative results

Perceptions of bias and discrimination in science. The most prominent theme (n = 76, 83.5%) from qualitative analysis was students believing that there were no gender issues in science (**Table 7**). In addition, most students stated that they had not encountered discrimination during the first few weeks of their degree. However, the second most prominent theme was self-reported experiences of discrimination by both male and female students (n = 11, 12.1%). While the majority of experiences were reported by female students (n = 8), male students also discussed experiences of discrimination against men (n = 3). One self-identified transgender male also spoke on issues relating to their gender in the science fields.

Table 7. Qualitative coding from open-ended responses.

Theme	Freq. (%)	Student Quote
No gender issues in science	76 (83.5%)	*I haven't had any experience with gender bias in my science degree* – Female #1
Discrimination	11 (12.1%)	
a. Against women	8 (8.8%)	*Male peers often disregard my comments when working on problem sets in maths tutorials* – Female #2
b. Against men	3 (3.3%)	*Females often get more attention because of studies such as this and an intentional active approach to including them. Some guys get ignored because everyone is trying to help women* – Male #2
Gender imbalance in STEM	4 (4.4%)	*I have been in classes that are primarily male, however that hasn't made me feel any different about my science degree* – Female #3
Confidence	3 (3.3%)	*…during physics classes majority of the answers are by boys […] I don't feel confident to share my own answers* – Female #5
Parents	1 (1.1%)	*…at home my parents have doubts that I will succeed* – Female #4
Transgender issues	1 (1.1%)	*As a trans guy, I have found it hard to study due to the discomfort and prejudice I face* – Transgender male #1

Note: frequency was calculated from valid responses (n = 91).

Discussion

The aim of this study was to determine the extent to which gender differences exist at the beginning of an undergraduate degree in key factors (i.e., belonging, science identity, experiences of discrimination) that are associated with student persistence in the science fields. Our findings showed that at the beginning of their science degrees the female students in this study in both the 'gender-balanced' and 'gender-unbalanced' disciplines reported lower levels of belonging than male students. In comparison to male students, female students were also more aware of the bias and discrimination they may face in the science fields at the start of their undergraduate degree, regardless of whether they were in a 'gender-balanced' or 'gender-unbalanced' science field. Experiences of discrimination were also self-reported by students within the first few weeks of commencing their undergraduate degree. While these reports were mainly from female students, examples from male students did also emerge within this cohort. These results will provide a baseline to help determine how the university experience impacts students' attitudes towards science, which is a critical time point in the science career pathway.

Low levels of belonging in female science students

Female undergraduate students in this study presented some factors (i.e., decreased belonging) that put them at risk for attrition from the science fields. Female students in both the 'gender-balanced' and 'gender-unbalanced' science fields reported lower levels of belonging than male students in the first few weeks of their university experience, particularly with regards to their feelings of acceptance and affect in a university science classroom. This is supported by international findings, with female students, particularly in the 'gender-unbalanced' science fields, reporting lower levels of belonging in university introductory courses (Lewis et al. 2017; Stout, Ito, Finkelstein and Pollock 2013). This is of concern as low levels of belonging are associated with decreased persistence in these fields (Lewis et al. 2017), putting these female students at risk for attrition from this career pathway.

Interestingly, no gender differences in science identity were found in this study at the beginning of the university experience. Yet, previous research has shown that female students in introductory male-dominated science courses often have lower science identity than male students (Hazari et al. 2013; Seyranian, Madva, Duong, Abramzon, Tibbetts and Harackiewicz 2018). The lack of this effect may be due to some of the limitations behind this study's current design. For example, discipline specific questionnaires, such as those looking at the physics identities of students, have shown gender differences (Seyranian et al. 2018). A lack of discipline specific identity questions may explain why science identity was not observed to have a gender effect. Additionally, the majority (96.3%) of students had experience in science at a pre-tertiary level. Therefore, secondary school experiences in STEM may have resulted in increased science identity of these students, particularly for female students depending on their secondary school science experiences (Prieto-Rodriguez, Sincock and Blackmore 2020).

Experiences of discrimination for commencing science students

Implicit discrimination has been previously identified as an issue for women in science degrees and is commonly experienced by female students in these fields (Smith and Gayles 2018). While over 80% of students in this study believed that there were no issues of gender in science, 12.1% (n = 11) of students reported experiences of discrimination or bias within the first few weeks of their university degree. These experiences were reported primarily by female students in the 'gender-unbalanced' science disciplines and involved experiences of implicit discrimination. Some examples of discrimination given by female students in our study involved their peers in the classroom not taking them seriously or disregarding their opinion:

> I will be the last person on the table people turn to for the answer to a question or advice, and often my contributions to the discussion are treated patronisingly. – Female #6

> In conversations with all other males, I've been ignored or my opinions have been set aside discreetly. Other than that, people are usually surprised when I get things correct or I seem 'smart', as if they assumed the opposite. – Female #7

These examples of feeling disregarded by peers aligns with the lower levels of acceptance seen in the quantitative belonging results, with female students reporting feeling disregarded and unvalued in a science classroom. Continued exposure to such discriminatory experiences has been shown to affect STEM engagement and lower academic performance in students (Lane et al. 2012; Ramsey and Sekaquaptwea 2011). Therefore, it is concerning that these experiences were occurring within the first few weeks of a university degree for women in this study, as it may be impacting their attitudes and performance in these science fields later on.

In this study cohort, women from the 'gender-unbalanced' science fields predominantly discussed experiences of discrimination. However, it has been shown that women in the 'gender-balanced' fields also experience forms of implicit discrimination by their peers. For example, in their US study, Grunspan, Eddy, Brownell, Wiggins, Crowe and Goodreau (2016), asked students in a biology classroom to nominate peers who they believed had mastered the subject. Male students over-nominated their male peers, ultimately underestimating the abilities of their female peers. This suggests that these experiences do take place during the university experience in the 'gender-balanced' fields, however students in our cohort were not aware of these experiences occurring. Preliminary research with

Australian undergraduate science students in these disciplines suggest that such experiences of discrimination may occur later in their degrees (Fisher, Thompson, & Brookes 2020a). Therefore, there is a need for longitudinal studies that investigate the experiences of women in these 'gender-balanced' fields as they progress through their degree to explore how these experiences manifest.

Finally, it should also be noted that one transgender male in this study noted their issues of prejudice and bias faced at university. While the number of transgender and non-binary students was low in this study, the results shed light on the issues this sub-sample of students may face while at university, though this is likely not to be exclusive to the STEM fields. Therefore, more information on what these challenges are for transgender students, both in an Australian and international context, is warranted.

Male students' opinions on gender equality in science

An interesting result emerged in the opinions of male students on the topic of discrimination towards women in science in this study. Instead of being aware of these issues, some male students reported feeling discriminated against themselves. In these experiences, these men linked the initiatives to help women in science as discrimination against males:

> I believe that gender bias has reverted. It is now my opinion that there are so many programs, scholarships, extra support, extra resources and pathways to get young girls involved in science at school and at university that men do not [get] the same opportunities that women now receive; and I believe that this is gender bias. – Male #4

> There should not be quotas for how many men or women are in a particular discipline […] For example, where there is a quota that 50% of the workforce must be female, if a male is better qualified for a job than a female colleague yet misses out because there are already 50% of males, he has been denied that job not because of her ability but because of the gender he was born into. THIS IS NOT EQUALITY OF OPPORTUNITY. – Male #5

This opinion towards the topic of gender equality in science held by these male students was also reflected in one female students' opinion:

> I feel like I'm not allowed to talk about gender inequality within my degree without being a 'feminazi'. – Female #8

This finding has been eluded to previously, with Handley, Brown, Moss-Racusin and Smith (2015) finding that men are more resistant to studies that explore this concept, and less willing to believe that there are issues of gender in science. This lack of acceptance towards the challenges that women face in science may explain why some of the male students in this study are starting to form these attitudes towards these initiatives and is a topic for future research.

Implications

Findings from this research present gender differences in commencing undergraduate science student cohorts in an Australian context. The issues present for female students in the both the 'gender-balanced' and 'gender-unbalanced' science fields, such as experiences of discrimination and lack of belonging, suggest a need for awareness of these issues by university educators to ensure the most gender equitable classroom environment as possible. Specifically, quantitative and qualitative findings highlighted lower feelings of acceptance in a university science classroom for female students. Previous research has highlighted that this may be due to the physical classroom environment, with female students having increased belonging in science classrooms with less stereotypical paraphernalia (Master et al. 2016). Yet, these belonging interventions have typically been centred on the male-dominated science disciplines (e.g., computer science). Findings from this current study reiterate that female students in the more ‘gender-balanced’ fields also experience this decreased belonging in their science fields.

These decreased feelings of belonging within female students in this cohort appear to be driven by the discriminatory experiences faced by these female students, which were often caused by their peers in these working environments. Female students associated these experiences with feeling less respected and valued in these environments, which were core concepts of the belonging sub-scale (Good et al. 2012). This is another focus for science educators and future research. Educators need to be aware of the potential gender discrimination occurring in small groupwork in their classroom in order to foster gender equitable environments for all students.

Implications for future research have already been highlighted. Studying these factors across diverse Australian institutions and at multiple timepoints of the university experience are needed to explore how these levels of belonging and science identity, and experiences of discrimination change throughout an undergraduate degree. These current findings provide a baseline for future studies to determine exactly how the affective domains are impacted during the undergraduate experience, and subsequently impact potential student attrition in these science fields. This will help inform educators and institutions on how to best address these issues and help retain more students, particularly women, in the science fields.

Limitations

While this study provided some insight into the experiences of commencing undergraduate science students in Australia, there were several limitations. Firstly, as it was a case study based at an Australian university, the generalisability of these findings is limited. This is supported by the demographics of the cohort, with the majority of students not identifying as URMs and most being high achieving students. Sampling students across several Australian institutions would help increase the generalisability of these findings and provide a more accurate national sample to act as a comparison for international studies. In addition, while transgender and non-binary students were included in this analysis, the generalisability of this statistical analysis is limited due to the small sample sizes. Further research on the issues faced by non-binary and transgender science students would aid in answering this question in future studies.

Secondly, data collection was at a single time-point, which occurred several weeks into the students' undergraduate degree. However, studies have shown the fluctuation of the factors tested during the first three weeks of university (London et al. 2011). Sampling students at multiple time points, or following a sub-sample of students, would help overcome this limitation in future studies. Additionally, while some students self-reported issues of discrimination, the large majority did not. This may have been due to sampling students within the first few weeks of their degree, as experiences of discrimination in the STEM fields appears to be reported more by final-year students compared to first-year students (Hall et al. 2020). Therefore, future studies should look at sampling students further along in their undergraduate degrees to truly capture these experiences.

Conclusion

Determining which factors are contributing to the gendered experience of undergraduate science students will help determine what issues may be causing female students to leave their science majors at university. This study showed that female science students in this study cohort in both the 'gender-balanced' and 'gender-unbalanced' fields commence their degrees with lower levels of belonging particularly in regards to feeling accepted in a science university classroom, putting them at risk for attrition. Findings also demonstrated that female science students in this study had higher levels of perceived gender bias in science and also encountered experiences of discrimination within the first four weeks of university. While it appears that most commencing science students did not believe gender was an issue within these fields, experiences of discrimination were still reported by some students. These findings provide a comparison to the international literature and will alert science educators at universities of the potential issues of gender occurring in their classrooms. Doing so will help ensure that Australian female university students are not potentially being deterred from a science career at this critical time point within this career pathway.

Declarations

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4.2 Summary

The key findings from this case study were:

- Female students began university with low levels of belonging in the science fields, putting them at risk for attrition from these degrees.
- Female students also self-reported experiences of gender bias within the first four weeks of university, which was predominantly linked to negative experiences with group work. These experiences were associated with female students not feeling accepted in the classroom, which in turn impacted their feelings of belonging.
- A small portion of male students reported diversity initiatives to recruit more women in STEM as discriminatory against men.

Overall, these findings highlight the factors putting students at risk for attrition at the start of their degree, namely low levels of belonging and experiences of gender bias. This demonstrates the importance of belonging and bias in the gendered experience of undergraduate science students, answering the first research question of this thesis. While gender differences were found in belonging, but not students' science identity, it is important to note that this questionnaire was taken at the start of the university experience and thus sampling of later year students was necessary, which is the focus of **Chapter 6**. In addition, this case study began a comparison on the student experience in different classifications of science fields (i.e., "gender-balanced" vs. "gender-unbalanced"). This approach begins to answer the second research question of this thesis, which will be the focus of the following chapters.

Chapter 5

The gendered experiences of biology and chemistry students

5.1 Preamble

The second section of this thesis set out to answer the question "*To what extent do these experiences differ for students studying in the 'gender-balanced' science disciplines*?". This was achieved by surveying a cohort of chemistry and biology students at a single Australian university in late 2018. This was a pilot study for the overall project and was the first step towards answering the question: "*What can we learn from the 'gender-balanced' science disciplines?*". The findings of this study were published in the *International Journal of Science Education* (*IJSE*), a Q1 education journal, and are on the following pages. Supplementary material referred to in this chapter can be found in **Appendix A**.

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'95% of the time things have been okay': the experience of undergraduate students in science disciplines with higher female representation

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ABSTRACT

Research has shown that achieving gender equality in science goes beyond equal gender ratios in the classroom. Female students in science disciplines with relatively higher female participation rates (e.g. biology and chemistry) still experience similar gender issues as students in male-dominated science disciplines (e.g. physics and mathematics). Yet, when studying gender inequality in science, these so-called 'gender-balanced' disciplines are frequently ignored. This study aimed to investigate gender issues for students in biology and chemistry and explore how these experiences were impacting their persistence in the science, technology, engineering, and mathematics (STEM) educational and career pipeline. Findings showed that both male and female students commonly believed that issues of gender were restricted to the male-dominated science disciplines. However, female students still reported experiences of gender bias, commonly through the form of implicit discrimination. The importance of the affective domains was also highlighted, with science identity and belonging impacting the female student experience and their intentions to persist in the sciences. Results from this study suggest further work is needed in 'gender-balanced' science disciplines, specifically in the emotional domains of science identity and belonging. This research may help educators develop more effective intervention programmes for increasing women's persistence in the STEM pipeline.

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Introduction

Gender equality in science, technology, engineering, and mathematics (STEM) fields is yet to be attained, with women leaving the STEM career pipeline at higher rates than men (Holman et al., 2018; Wang & Degol, 2017). To meet the demand of the future STEM workforce, efforts are being made to recruit and retain more women in STEM degrees (Australian Academy of Science, 2019). However, some STEM disciplines have been more successful than others in this attempt (Luckenbill-Edds, 2002; Sax & Newhouse,

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2018). The biological sciences are a key example of this. Biology is a science discipline that has been perceived to reverse the gender inequality problem, and has more female than male students at a tertiary level (Office of the Chief Scientist, 2016). Disciplines in STEM with increased female representation are often classed as ‘gender-balanced’ (Cheryan et al., 2016) and in Australia these disciplines include biology and chemistry. Understanding how these STEM fields have managed to recruit and retain more women in this career pathway is critical for improving the experiences of female students in other science disciplines with lower female participation rates.

Unfortunately, research into the experiences of women in STEM is often focused on the male-dominated STEM disciplines. Only recently have researchers started investigating the experiences of students in the ‘gender-balanced’ STEM fields (Ballen et al., 2017; Cotner et al., 2017; Wachsmuth et al., 2017). Research findings have shown that female students in these disciplines still experience issues relating to their gender at university, despite greater representation in the classroom. For example, female students in the biological sciences still have lower confidence in their ability than their male peers. This is reflected by their lower participation rates in the classroom, decreased self-efficacy and even lower performance in assessments (Ainscough et al., 2016; Eddy et al., 2014; Flanagan & Einarson, 2017). In addition, male students in the biological sciences still underestimate the ability of female students (Grunspan et al., 2016). This is thought to be driven by implicit biases (Greenwald & Krieger, 2006), which are difficult to reduce despite having equal gender ratios in classrooms. This previous research suggests that the issues related to gender inequality in STEM are more complex than simply attaining equal gender representation.

Reviews of the barriers faced by women pursuing STEM degrees have identified several critical factors associated with a ‘gendered experience’ for undergraduate students (Cheryan et al., 2016; Eddy & Brownell, 2016) contributing to the gender gap in STEM education. While cognitive factors were the focus of earlier studies (Kimura, 2000), researchers are now focusing on the affective domains, such as self-efficacy, science identity and belonging, as reasons behind the lower persistence rates of female students in the sciences (Skinner et al., 2017; Trujillo & Tanner, 2014). This research has shown that self-efficacy, or the belief in one’s ability to succeed in a given area (Bandura, 1997), is lower in female students and has been established as a reason why women leave STEM majors at university (Rosson et al., 2011; Sax, 1994). Belonging, or ‘perceived similarity’ to people in your academic major, can be reduced in female students in STEM, resulting in their attrition from these degrees (Cheryan & Plaut, 2010; Seymour & Hewitt, 1997). A relatively new analytical lens of science identity, which is how strongly one identifies as a scientist (Carlone & Johnson, 2007), is typically lower in female students in STEM fields and has also been identified as a necessary factor for students wanting to pursue a scientific career (Hazari et al., 2013; Williams & George-Jackson, 2014).

While there has been a call for more research into how these affective domains are impacting female undergraduate students’ experiences in the ‘gender-balanced’ STEM disciplines (Trujillo & Tanner, 2014), they remain relatively understudied in the Australian context (Fisher et al., 2020). Recent Australian studies have investigated levels of self-efficacy in female undergraduate students in the biological sciences (Ainscough et al., 2016), but few studies have explored the levels of science identity or belonging of

Australian female undergraduate students in these fields. The questions this study aims to answer are:

(1) What is the gendered experience of undergraduate students in science disciplines of biology and chemistry?
(2) How do these experiences impact students' intentions to persist in science majors at university and their overall science career intentions?

Method

Participants

A paper-based survey was administered to 145 students during class in two third-year science courses at Monash University, Australia in October 2018. Complete surveys were collected from 84.8% of the cohort. These science courses included students undertaking a broad range of majors, therefore analysis was restricted to the students completing majors with higher female representation (i.e. biology and chemistry). Transgender students ($n = 3$) were excluded from analysis, as their responses centred around issues of belonging relating to their sexual identity, which was not the research focus of this study. Demographic information of the final participants ($n = 55$) is shown in Table 1. Ethics for this project was approved by the Monash University Human Research Ethics Committee (project number: 16341).

Survey instrument

The purpose of the survey was to identify factors contributing to the gendered experience of undergraduate science students and how these experiences impact students' intentions to persist in the sciences at a university level and beyond. The survey is derived from a previous study exploring the undergraduate STEM student experience (Findley-Van Nostrand & Pollenz, 2017). As the Findley-Van Nostrand and Pollenz (2017) study did not investigate gender differences in the STEM student experience, the survey was altered

Table 1. Demographics of survey participants ($n = 55$).

Variable		Freq. (%)
Gender	Female	33 (60.0%)
	Male	22 (40.0%)
Ethnicity	White/Caucasian	29 (52.7%)
	Asian	22 (40.0%)
	Mixed/Other	3 (5.5%)
	Aboriginal or Torres Strait Islander	1 (1.8%)
First in family to attend university	Yes	19 (34.5%)
	No	35 (63.6%)
	Not specified	1 (1.8%)
Science major	Biology	34 (61.8%)
	Chemistry	21 (38.2%)
Course average	< 50%	1 (1.8%)
	51–60%	8 (14.5%)
	61–70%	24 (43.6%)
	71–80%	20 (36.4%)
	81–100%	2 (3.6%)

to address the research questions of this study. The original questionnaire was comprised of previously validated sub-scales in the literature focusing on self-efficacy, science identity, belonging and persistence in the sciences. To explore potential issues of gender, two gender specific sub-scales from the literature were added to the questionnaire: *Perceived identity compatibility between gender and major* (London et al., 2011) and *Gender biased science majors* (Ganley et al., 2018). All sub-scales had been validated on university student cohorts previously. To ensure the survey was appropriate for this study all 'STEM' references were altered to 'science'. The complete survey can be found in Table 2. A five-point Likert scale (Strongly disagree to Strongly agree) was used for all sub-scales.

Demographic questions were included so results could be analysed by gender, as well as collecting information on other co-variables that have been found to influence student persistence at university (e.g. ethnicity) (Chemers et al., 2011). Finally, five open-ended questions were included to capture more in-depth student responses around these issues. For instance, an open-ended question was included at the end of each of the gender focused sub-scales so students could elaborate on why they chose to agree or disagree with the statements in the gender specific sub-scales (i.e. '*Please explain why you have selected the above responses*'). Students were also asked why they had considered leaving their science major for a non-science and/or another science discipline (i.e. '*Which discipline/other science discipline did you consider switching to and why?*'), and if they had experienced any forms of gender bias following a definition derived from the literature (Robnett, 2016):

> Gender bias occurs when people treat others unfairly due to their gender. Please describe if you have had any experiences with gender bias in your discipline during your degree.

Data analysis

Quantitative analysis was conducted using IBM SPSS Statistics (version 25). Non-parametric tests (i.e. Mann–Whitney *U* test, Spearman's correlation) were used to test for gender effects, as Likert scales are ordinal and do not meet the assumption of normality (Sullivan & Artino Jr, 2013). Statistical significance was defined at the $p < 0.05$ level. Qualitative data from open-ended survey questions was analysed using thematic analysis in the NVivo software (version 12). Codes were derived using an inductive coding approach (Thomas, 2006), with common themes emerging through re-reading the open-ended responses to questions. To address the potential for researcher bias, the themes were validated through a process of triangulation with two other experienced educational researchers (Creswell, 2014). An acceptable inter-rater reliability score of 81.3% was achieved.

Results

Survey reliability

The internal consistency reliability measured by Cronbach's α was acceptable for almost all sub-scales (Table 3), with the majority being above the widely accepted cut-off of 0.70 (DeVellis, 2003). Sub-scales below this cut-off value had similar α values as previous studies conducted on university students (London et al., 2011).

Table 2. Sub-scales used in the final survey design.

Theme	Items	Reference
Academic self-efficacy	I feel confident in my ability to learn the material in my science courses	Findley-Van Nostrand and Pollenz (2017)
	I am capable of learning the material in my science courses	
	I am able to achieve my goals in my science courses	
	I feel able to meet the challenge of performing well in my science courses	
Science identity	In general, my interest in science is an important part of my self-image	Chemers et al. (2011)
	My interest in science is an important reflection of who I am	
	I feel like I belong in the field of science	
	I have a strong sense of belonging to the community of scientists	
	I am a scientist	
Belonging	I feel that I belong to the scientific community	Good et al. (2012)
1. *Membership*	I consider myself a member of the scientific community	
	I feel like I am part of the scientific community	
	I feel a connection with the scientific community	
2. *Acceptance*	I feel like an outsider	
	I feel accepted	
	I feel respected	
	I feel disregarded	
	I feel valued	
	I feel neglected	
	I feel appreciated	
	I feel excluded	
	I feel like I fit in	
	I feel insignificant	
3. *Affect*	I feel at ease	
	I feel anxious	
	I feel comfortable	
	I feel tense	
	I feel nervous	
	I feel content	
	I feel calm	
	I feel inadequate	
4. *Desire to fade*	I wish I could fade into the background and not be noticed	
	I try to say as little as possible	
	I enjoy being an active participant	
	I wish I were invisible	
Perceived identity compatibility between gender and major	I don't think that my gender will affect how others view me in my major	London et al. (2011)
	I don't think that my gender will affect how well I do in my major	
	I think my gender and my major are very compatible	
	I think I have experienced difficulties in my major because of my gender	
	I think my gender will be an important factor in the type of career I decide to pursue	
	I don't think I would pursue certain fields because of my gender	
Gender biased science majors	Women in my major experience discrimination	Ganley et al. (2018)
	Women have a hard time succeeding in my major	
	My major is more welcoming to men than it is to women	
	What percentage of students in this major do you estimate are women?	
Intention to leave science	During my degree, I have considered switching to a non-science discipline	Perez et al. (2014)
	During my degree, I have considered switching to another science discipline	
Expectancy for a science career	I would enjoy a career in science	Stake and Mares (2001)
	I have good feelings about a career in science	
	Having a science career would be interesting	
	I would like to have a career in science	

Table 3. Internal consistency of survey sub-scales measured by Cronbach's α ($n = 55$).

Measure	Cronbach's α
Academic self-efficacy	0.87
Science identity	0.76
Belonging – membership	0.87
Belonging – acceptance	0.88
Belonging – affect	0.89
Belonging – desire to fade	0.76
Perceived identity compatibility between gender and major	0.65
Gender biased science majors	0.92
Expectancy for a science career	0.91

Demographics of respondents

To control for any confounding variables, Chi-squared (χ^2) tests between genders were conducted. No statistically significant differences were found for the demographic variables of academic achievement ($\chi^2 = 5.38$, $p > 0.05$), first-generation student status ($\chi^2 = 1.95$, $p > 0.05$), ethnicity ($\chi^2 = 2.96$, $p > 0.05$) or socio-economic status ($\chi^2 = 6.91$, $p > 0.05$) between the male ($n = 22$) and female ($n = 33$) cohorts. There was a difference in age representation between male and female students ($\chi^2 = 14.27$, $p < 0.05$), with male students having older respondents in their cohort. However, the maximum age of male students was 25 and so it was assumed any mature-age student effects would be negligible in this sample.

Factors contributing to a gendered experience

Coding of the qualitative data from open-ended survey questions on experiences of gender bias revealed several major and minor themes contributing to a gendered experience for undergraduate students in the fields of biology and chemistry (Table 4). The most frequent theme to emerge in responses from male and female students was that there were no gender issues in science (57.1%):

> I don't think I've experienced gender bias in my degree. Everyone is treated equally. – Female #1

> In my experience I see no gender bias, but am aware I may be oblivious as it's not a shared experience. – Male #1

Despite this, the second most prominent theme (28.6%) was students identifying experiences of discrimination throughout their degree, with almost all examples derived from female students. Implicit forms of discrimination were most common (66.7%), with female students noting their male peers underestimate their ability and ignore their contribution in classes:

> I was in a group with 3 boys in chemistry lab in 2nd year. One of the boys never listened when I was talking and only spoke to me in a 'flirtatious' manner. The other boys were okay, although somewhat followed this guy's lead, so after the unit I felt that the labs were overall a negative experience. – Female #2

Table 4. Themes from open-ended survey responses on experiences of gender bias.

Theme	Freq. (%)	Female Quote	Male Quote
No gender issues in science	24 (57.1%)	*I believe in my major there is no gender discrimination and more or less equal [male/female] ratio.* – Female #6	*No females have been disadvantaged by their gender in my major and make up the majority of my courses.* – Male #3
Discrimination	12 (28.6%)	*I have had a couple of experiences, one particularly bad, where I was not listened to, respected etc. in my chemistry lab groups because I was a girl. Having said this, 95% of the time things have been okay.* – Female #2	*All of 3 sexist comments being heard in 2 years makes me doubt it is a big issue.* – Male #2
Gender disparities in STEM	10 (23.8%)	*I would not pursue engineering or physics due to my gender as my female friends in these areas have had bad experiences.* – Female #3	*Biology is quite a popular science field, and I do feel as if females choose to pursue a career in biology more than males.* – Male #4
Role models	10 (23.8%)	*There is a large amount of female academics that I have had the opportunity to interact with, which is inspiring.* – Female #7	*As much as I hate to admit it, in 2018 being a male seems to still be an advantage and as much as I oppose the idea and hold the belief that we should all be equal, it seems that where I have worked previously and even in government males dominate leadership positions.* – Male #5
Teaching and learning	6 (14.3%)	*There was in general also more feedback given for assignments and more personalised assistance to improve marks. In general, better support.* – Female #4	*Due to natural development characteristics between genders, education is more suited to female-style learning, logical, where active learning is encouraged.* – Male #1
Ability	5 (11.9%)	*Women need to put on more effort to prove their capability. Women tend to get more doubt from other people when making decision[s].* – Female #8	*Basically I believe most difference arises from physiological and psychological differences between men and women, for better and for worse.* – Male #6
Career goals	4 (9.5%)	*I am part of a double degree with education – if I pursue teaching, then women science teachers are sought after. I would like to pursue further science research, but I am not sure about how I would go in that field.* – Female #9	N/A
Belonging	2 (4.8%)	*It's a woman heavy degree and many female tutors/lecturers helps form a culture that we're all meant to be here.* – Female #10	N/A
Interest	1 (2.4%)	*Based on interest never based on my gender and what other people think of me that dictates what my job will be.* – Female #11	N/A

Note: frequency was calculated from valid responses ($n = 42$).

> I have had males in my course disregard my opinions, ignore me and be generally dismissive. This is followed by males suggesting the same thing and for it to be praised as an amazing idea. – Female #3

In contrast, the only male student that discussed discrimination implied that sexist comments were not a serious issue for female students. He also noted:

> Unintended offences that could be interpreted as sexist have occurred very rarely but is not a problem in my experience. – Male #2

Many students in the biology and chemistry science fields believed that issues of gender inequality were restricted to more male-dominated science disciplines. This arose from qualitative analysis when respondents discussed the theme of 'gender disparities in STEM':

> Biology tends to have a more even distribution of gender than other fields like physics or chemistry so I don't feel like my gender is particularly noteworthy in this field. – Female #4

> The genetics major is largely 50% female and 50% male, therefore neither gender is favoured. However, I believe the gendered nature of science is found in the 'hard' science majors. – Female #5

Other qualitative themes that also contributed to this gendered experience for students involved role models, teaching and learning styles, and the discussion of ability. Some themes also emerged only in female student responses, such as belonging.

To further explore what factors were contributing to a gendered experience, the survey responses to closed-ended questions were also analysed by gender using the Mann–Whitney U test with a significance level of $p < 0.05$. Of the independent variables tested, science identity had statistically significant differences between the genders with a medium effect size ($r > 0.3$; Figure 1). Female students had more positive responses to the following statements about science identity than male students: '*In general, my interest in science is an important part of my self-image*' ($U = 211$, $Z = -2.701$, $p < 0.05$, $r = 0.36$) and '*My interest in science is an important reflection of who I am*' ($U = 210$, $Z = -2.738$, $p < 0.05$, $r = 0.37$). When asked about their perceived identity compatibility between gender and major, female students also agreed more than male students that their gender and major were very compatible (Figure 2; $U = 236$, $Z = -2.274$, $p < 0.05$, $r = 0.31$). Despite a positive regard between their gender and major, female students were still more likely to agree with the statement '*I don't think I would pursue certain fields because of my gender*' than their male counterparts (Figure 2; $U = 225$, $Z = -2.464$, $p < 0.05$, $r = 0.33$).

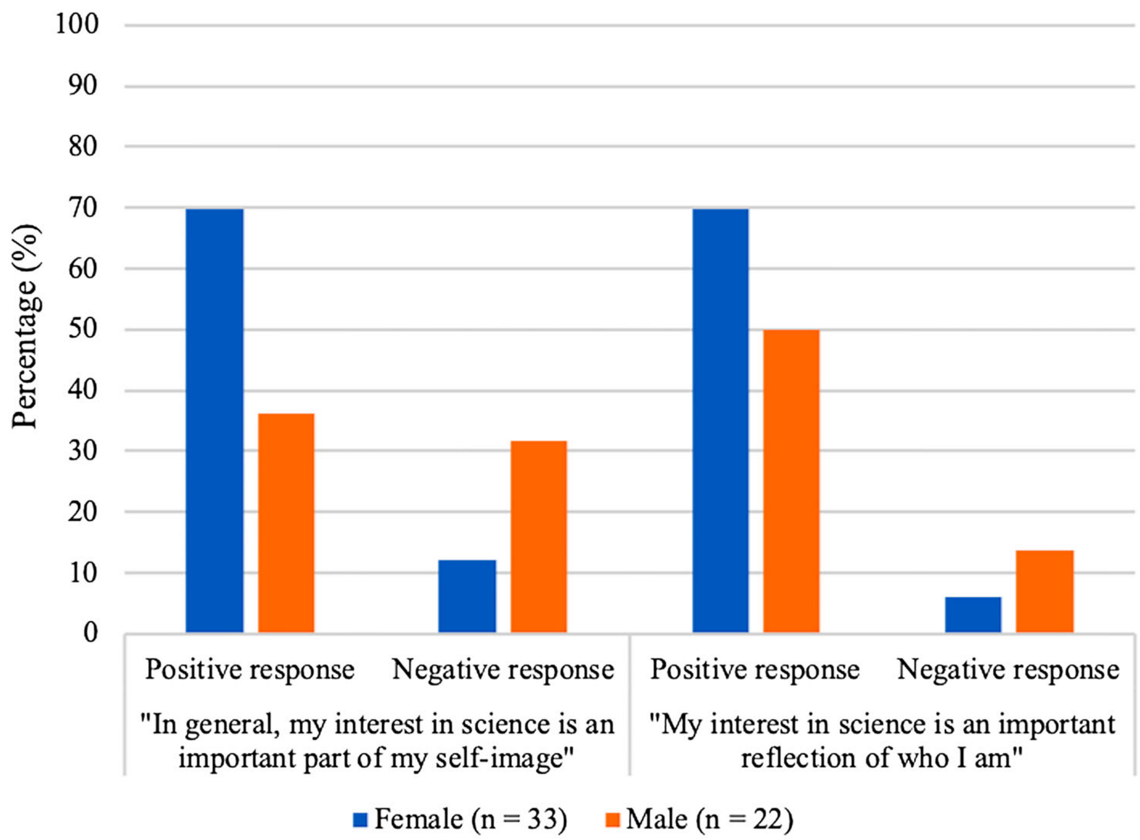

Figure 1. Science identity differences by gender.

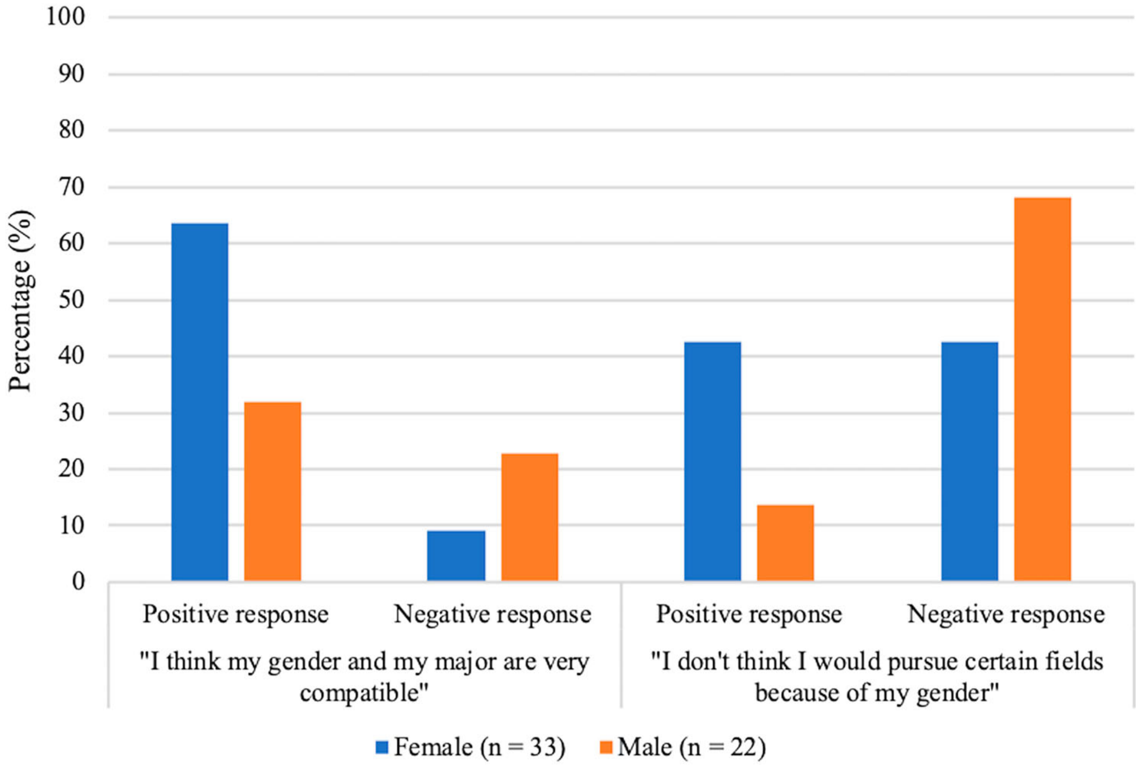

Figure 2. Perceived compatibility between gender and major.

Impact on students' persistence in the STEM pathway

Six qualitative themes arose when analysing the open-ended responses ($n = 28$) to why students had considered leaving their current science major for a non-science or another science discipline (Table 5). The most frequently reported reasons amongst both male and female students were interest ($n = 14$) and career goals ($n = 9$):

> I considered biochemistry due to my equal fascination for the subject, but have fallen in love with genetics. – Female #12

> I once considered switching to both IT and statistics as I have an interest in both and both offer stable job security. – Male #7

Table 5. Themes from open-ended survey responses to why students had considered leaving their science major.

Theme	Freq. (valid %)	Example quote
Interest	14 (50%)	*Physics – which interests me more.* – Male #7
Career goals	9 (32.1%)	*Physiology or pharmacology because may relate to science jobs other than research.* – Female #14
Belonging	4 (14.3%)	*My other degree is Arts and I found myself feeling closer to the lectures and classmates in Arts than in science.* – Female #4
Teaching and learning	4 (14.3%)	*Law – more straight forward. My style of learning is more suited to it individually.* – Male #1
Discrimination	2 (7.1%)	*I did switch from psych to genetics because I used to get teased for doing a degree that was typically for women and not 'real science'.* – Female #13
Ability	1 (3.6%)	*… lost interest as units are increasing in difficulty and I felt I was not following well and became quite hopeless.* – Male #8

Note: frequency was calculated from valid responses ($n = 28$).

However, belonging ($n = 4$) and discrimination ($n = 2$) arose as minor reasons solely for female students considering leaving their science major:

> Event management because it appears more friendly and less judgmental towards women. – Female #13

> Any 'hard' science […] as I feel like Ecology could be viewed as a 'weak' effort for a science degree and I want my degree to be respected. – Female #6

These qualitative results suggest that belonging and the remaining discrimination within these fields may be impacting female persistence in these science disciplines.

To determine how gendered experiences might impact students' intentions to remain in their science major and pursue a science career in the future, correlations between the factors tested and the dependent variables were also conducted. When analysing these correlations by gender, there were no statistically significant correlations found for male students (Supplementary Table S1). Instead, correlation analysis for female students revealed several important factors that may be preventative to females considering leaving their science degree (Supplementary Table S2). Science identity ($\rho = 0.775$, $p < 0.05$) and the belonging domains of membership ($\rho = 0.610$, $p < 0.05$) and affect ($\rho = 0.395$, $p < 0.05$) were positively correlated with science career expectations, meaning that female students with high levels of science identity and belonging were more likely to want to pursue a scientific career. Science identity ($\rho = -0.391$, $p < 0.05$), three domains of belonging (acceptance: $\rho = -0.451$, $p < 0.05$; affect: $\rho = -0.413$, $p < 0.05$; desire to fade: $\rho = -0.384$, $p < 0.05$), and self-efficacy ($\rho = -0.362$, $p < 0.05$) were negatively correlated with considering switching out of their science major for female students. Therefore, from this correlation analysis, high levels of science identity, belonging and self-efficacy could be interpreted as preventative factors for women considering leaving the science pipeline at a university level.

Discussion

This study aimed to detect whether gender issues were experienced by undergraduate students in biology and chemistry, and determine how these experiences impacted their persistence in the science career pathway. The majority of students believed that there were no gender issues for students in biology and chemistry. However, results showed that discrimination is still faced by female students, and emerged as a potential reason why female students consider leaving the sciences at university. The importance of the affective domains of science identity, belonging and self-efficacy were also highlighted, suggesting that these factors impact the persistence of female students in these undergraduate degrees.

Factors contributing to a gendered experience

Discrimination

While the most prominent theme to emerge in qualitative analysis was students believing there were no gender issues in science, discrimination, through the form of implicit biases, was the second biggest theme to emerge from female students. Female students in 'gender-balanced' STEM fields experiencing implicit discrimination has been established in the literature (Eddy et al., 2014; Grunspan et al., 2016). The examples from this study given by female students commonly related to not being respected or taken seriously by their peers. As an example, one female student noted:

> I have had a couple of experiences, one particularly bad, where I was not listened to, respected etc. in my chemistry lab groups because I was a girl. – Female #2

These examples of implicit discrimination are related to the theme of ability that arose in qualitative analysis. The male students that mentioned ability stated that there were natural biological differences between the genders:

> Basically I believe most difference arises from physiological and psychological differences between men and women, for better and for worse. – Male #6

The belief that females and males have biological differences in thinking or ability in STEM has been a focus of earlier research (Geary, 1996; Kimura, 2000), but have been discredited since (Spelke, 2005). Yet, these beliefs may still be contributing to the implicit biases of undergraduate students and to the issues that these female students are facing. Further research would be needed to confirm if these implicit biases are contributing to these forms of discrimination.

Interestingly, while female students stated that there were no gender issues in the 'gender-balanced' STEM fields, they paradoxically also provided examples of discrimination in their written responses. Students in undergraduate science disciplines have been shown to lack an awareness of the gender issues in science, especially within male students (Freedman et al., 2018). Intervention studies have attempted to increase the awareness of gender bias in science for students in these disciplines (Pietri et al., 2017). However, men have been shown to be more resistant to this concept when presented with this data (Handley et al., 2015). The results from this study suggest that both male and female students may be unaware of the gender issues in the biological and chemical sciences, which may be impacting their ability to identify experiences of discrimination as they are occurring.

Science identity and belonging

Science identity emerged as an important factor for undergraduate students in this study cohort. Quantitative data indicated a gender difference in levels of science identity, with female students reporting higher levels. This increased science identity in female students may have been related to a perceived greater visibility of female role models for these undergraduate students. Role models were a minor qualitative theme that emerged from the open-ended responses, with 10 students discussing this theme. Some students emphasised the importance of female teaching staff as valued role models:

> There is a large amount of female academics that I have had the opportunity to interact with, which is inspiring. – Female #7

> I have had lots of female teachers indicating they can succeed in this area. – Female #3

Research by Young et al. (2013) showed that female STEM students in university have higher levels of science identity when presented with positive female role models. A public presence of women in STEM is important, as female role models in STEM contribute to female student persistence in these disciplines (Cotner et al., 2011; Dennehy & Dasgupta, 2017). Having these examples of successful female scientists in the biology and chemistry fields may be helping female undergraduate students identify more strongly as a scientist.

This qualitative theme of role models was also closely linked to female students discussing their belonging in these fields. While no gender differences were found in levels of belonging within this cohort, belonging emerged as a minor qualitative theme only discussed by female students. These experiences were positive, with female students linking the greater presence of female role models as having a positive impact on their belonging in these fields:

> It's a woman heavy degree and many female tutors/lecturers helps form a culture that we're all meant to be here. – Female #10

> Within the science community, biology-based subjects (comparative to chemistry or physics based areas) have a large percentage of females practicing […] I wouldn't change my field of study due to gender and don't feel uncomfortable as a woman in this field. – Female #12

The affective domains of science identity and belonging are typically studied in the male-dominated science fields (Good et al., 2012; Hazari et al., 2010; Hazari et al., 2013). Yet, the findings from this study suggest that these factors may play an important role for women's persistence in the biology and chemistry science career pathways. Previous research has highlighted the relationship of student relatedness (e.g. belonging) and science identity in the sciences (Skinner et al., 2017). Further research is needed to explore the importance of science identity and belonging for students in biology and chemistry to support these findings.

Impact on students' persistence in the STEM pathway

Interest and career goals were the most frequently discussed reason as to why students would consider leaving their current science major. This aligns with previous theoretical frameworks that have studied gender gaps in students' intentions to persist in the sciences, such as Lent et al.'s (1994) social cognitive career theory (SCCT). Career goals and interest are both components of the SCCT model, which attempts to explain how students' career interests develop over time (Lent et al., 1994).

Belonging was a theme that emerged exclusively within female students when discussing their intentions to leave the sciences. Lower levels of belonging are a known risk factor for attrition for female students in non-traditional fields (Good et al., 2012; London et al., 2011). Qualitative results in this study highlighted that belonging may still be impacting female students' intentions to persist in the 'gender-balanced' sciences, despite an increased representation of women in these fields. As one female student noted:

> My other degree is Arts and I found myself feeling closer to the lectures and classmates in Arts than in science. – Female #4

Discrimination was another theme that emerged only in female students when discussing why students had considered leaving the sciences. It has been established that continued exposure to discrimination impacts students' motivations to remain in these fields (Leaper & Starr, 2019). With female students reporting experiences of discrimination in the 'gender-balanced' science fields, they may be at risk for attrition from the science career pipeline both at a university level and beyond.

Quantitative results showed that high levels of the affective domains (e.g. science identity, self-efficacy) were correlated with female students persisting in the science educational and career pathway. While there were no gender differences in rates of self-efficacy in this cohort, female students with higher levels of self-efficacy were still less likely to consider leaving their science major. Self-efficacy has been established as a critical factor for attrition for female students in STEM, and still affects students in the science discipline of biology (Ainscough et al., 2016). The results in this study suggest that overall these affective domains are important for women's persistence in the STEM educational and career pipeline.

Limitations

A limitation of this study is that the results have a lack of generalisability. Data were obtained from small sample sizes, and the study was based at a single institution in Australia. Nevertheless, these results have been shown to have similarity to international findings, and this study importantly adds to the dearth of studies in the Australian research space. It should also be noted that transgender students were excluded from analysis in this study as they identified additional issues regarding their identity, but further research into this sub-sample of science students is warranted.

Demographic information was collected for participants, and previous work has employed statistical methods, such as propensity score matching (PSM) to account for confounding variables in the analysis (Rosenbaum & Rubin, 1983). Due to the nature of PSM, there is usually an attrition of cases, which makes it unsuitable for analysis on small sample sizes, such as the one in this study. Instead, to control for these confounding variables, statistical tests were used to compare genders and account for any differences between groups.

Finally, analysis was restricted to biology and chemistry disciplines, which have relatively high female representation. However, the results of this study may be more meaningful if student experiences in the 'gender-unbalanced' sciences could be compared to these findings. Determining how these affective domains and experiences of discrimination differ for students in the 'gender-unbalanced' science fields will help define the experiences of female students in these more 'gender-balanced' STEM fields. A comparison of how these factors and experiences differ to those students in science disciplines with lower female representation (e.g. physics) will be needed in future studies.

Implications

Results from this study have implications for research and practice. Firstly, while the majority of undergraduate students did not believe issues of gender exist in the 'gender-balanced' science fields, female undergraduate students in these fields still reported experiences of discrimination. Continued exposure to discrimination has been known to deter women from certain career paths (Leaper & Starr, 2019). Thus, university educators need to be aware of these experiences to help develop teaching strategies to create an inclusive classroom.

Secondly, further research is warranted into the affective domains of belonging and science identity, particularly in the Australian context, as these have been relatively understudied in this research space (Fisher et al., 2020). Science identity, a relatively new analytical lens to the gender inequality debate, appears to be an important factor for female undergraduate students in the fields of biology and chemistry. These results shed light on some important factors that need to be addressed in intervention programmes for women in science at an undergraduate level. Findings suggest that science identity, aspects of belonging and self-efficacy are potential preventative factors to keeping women in science degrees, suggesting they should be the focus of future research and intervention studies.

Conclusion

When addressing the gender gap in STEM, researchers tend to overlook the science disciplines with relatively higher female student completion rates. However, female students in these fields still experience some of the same gender issues as those in the more male-dominated sciences. This study identified some important factors that may be contributing to a gendered experience for undergraduate students studying biology and chemistry. Many students believed that there were no gender issues in science. Yet, female students still provided examples of implicit biases that remain in these more 'gender-balanced' fields, suggesting that students may be unaware of this remaining discrimination. The importance of the affective domains of belonging, science identity and self-efficacy was also highlighted, with results suggesting that they may play a role in acting as preventative factors for women considering leaving science at an undergraduate level. These findings not only provide an avenue for future research in this field, but will also help in the development of more effective intervention programmes to retain more women in the STEM pipeline.

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5.2 Summary

Findings from this study highlighted some key points within the "gender-balanced" science fields of biology and chemistry:

- While the majority of students do not believe that gender bias in these fields exist at the undergraduate level, female students still reported experiences of implicit bias.
- The affective domains of self-efficacy, belonging and science identity were highlighted as potential preventative factors for women in these fields considering leaving their science major while at university.

However, as this was a small-scale study, these findings needed to be corroborated on a larger scale. Additionally, to accurately answer the second research question of this thesis, a comparison of the experience of students in the "gender-balanced" and "gender-unbalanced" science fields was needed. Therefore, to extend on this pilot study, a cross-institutional national study was conducted, which is the basis of **Chapter 6** of this thesis.

Chapter 6

A cross-institutional study on factors impacting undergraduate science student persistence

6.1 Preamble

The aim of this current chapter was to extend on the previous study and answer the second question of this thesis by comparing the experience of students in the "gender-balanced" and "gender-unbalanced" science fields. This was achieved through a cross-institutional study, which surveyed undergraduate science students across Australia at eight different institutions across six different states. An online questionnaire was used to identify factors impacting the persistence of science students and comparing this experience between the genders. This study extended on the previous chapters by utilising a larger sample size and investigating student experience throughout their undergraduate degrees by sampling students at least one year into their degree. This chapter has been accepted for publication in *Research in Science Education*, a Q1 education journal and is presented as it was submitted on the following pages. Supplementary information can be found in **Appendix A**.

'I don't study physics anymore': a cross-institutional Australian study on factors impacting the persistence of undergraduate science students

Abstract

University is a critical timepoint for students in the science, technology, engineering, and mathematics (STEM) career pathway. Gender differences in the persistence of STEM students have been established, with female students more at risk for attrition from this career pathway. While the persistence of undergraduate STEM students has been a focus in the international literature, Australian studies in this space are limited. This cross-institutional study at eight different Australian universities set out to investigate how student experiences of science identity, belonging, and discrimination, which are known to impact student attrition, were affecting the persistence of students at university and in the science career pipeline. 386 students who had experienced at least one year of university completed a questionnaire investigating these factors. Findings showed that high levels of science identity and belonging were associated with increased persistence intentions of female-identifying science students. Additionally, this same effect was found for male-identifying students in the more 'gender-balanced' science disciplines. Students also reported experiences of gender discrimination. Female students commonly reported negative experiences relating to group work, whereas male students reported initiatives to recruit more women into STEM as discriminatory against men. These results highlight potential 'at-risk' groups for attrition in the STEM fields, and provide an insight into the male student perspective on the gender equity in STEM discussion.

Keywords: gender equality, higher education, retention, science education

Introduction

Despite the number of female graduates in the science, technology, engineering, and mathematics (STEM) fields increasing in Australia, the gender gap in the STEM workforce continues to persist (Office of the Chief Scientist, 2020). This raises the question as to why more female graduates are deciding to opt-out of this pipeline post-graduation and if the university experience is adding to this effect. While research into the persistence of female university STEM students has been a focus of the international literature (Wang & Degol, 2017; Yang & Gao, 2019), Australian research on this topic is limited (for an extensive review see: Fisher, Thompson, & Brookes, 2020b). Though gender inequality research in STEM is typically set in an American context (Cheryan, Ziegler, Montoya, & Jiang, 2017; Eddy & Brownell, 2016), the generalisability of these findings in Australia are limited. For example, gender gaps in the interest and confidence in mathematics for high school students appears to be larger in Australia than in the United States (Watt et al., 2017).

Gender differences in the university experience that can impact the persistence of undergraduate STEM students have been established (Cheryan et al., 2017). The affective domains have been studied when trying to understand lower female persistence in STEM, and relate to how emotions, such as low self-esteem and interest, impact student learning (Vermunt, 1996). Some examples include science identity, belonging, and self-efficacy (Fink, Frey, & Solomon, 2020; Williams & George-Jackson, 2014). For example, Ellis, Fosdick and Rasmussen (2016) found that women who took a calculus college course were 1.5 times less likely to continue in this mathematics pathway compared to their peers who held the same career intentions and preparedness. This lower desire to persist was driven by their lower mathematics confidence.

Outside of these affective domains, additional factors, such as experiences of discrimination or perceptions of bias, have also been found to contribute to student recruitment and attrition in university STEM majors (Ganley, George, Cimpian, & Makowski, 2018). As Leaper and Starr (2019) showed, female students in introductory science courses at university who experienced discrimination from their peers or instructors had decreased motivation to persist in these fields. Experiences of bias in STEM are typically the result of stereotypic beliefs, such as the idea that men are more suited for the science disciplines than women. Discriminatory experiences driven by these stereotypes have been found to lower female students' desire to persist in these fields (Lane, Goh, & Driver-Linn, 2012).

The purpose of this current study was to investigate factors impacting students' persistence intentions in their science major and overall intentions for a science career. Specifically, science identity, belonging, and discrimination were examined. This is due to limited research on these factors within Australian undergraduate student cohorts (Fisher, Thompson, & Brookes, 2020b) as well as previous research demonstrating an interactive effect between these three domains (Kim and Sinatra, 2018; Walton and Cohen, 2007). This study examined how these experiences impacted students' intentions to persist in science. The theory of planned behaviour (TBP), developed by Ajzen (1991), states that an individual's behaviour is primarily driven by their intentions, which is impacted by three factors; subjective norms, their attitude, and perceived control over their own behaviour. TBP has recently been used to study the intentions of students pursuing a STEM major, as well as a STEM career. This previous research has demonstrated that students' intentions are the best predictor for students' choices to pursue STEM majors and careers (Moore and Burrus, 2019).

The literature has dichotomised the science fields as either 'gender-balanced' or 'gender-unbalanced' at the university level (Cheryan et al., 2017). The former refers to science fields with relatively higher enrolment rates of women, such as biology, which has 57% female students (Department of Education and Training [DET], 2018). Alternatively, 'gender-unbalanced' fields refer to the more male-dominated science fields, such as physics, which has 25% female students (DET, 2018). Though it should be noted that the term 'gender-balanced' does not reflect an equal gender ratio within these fields, and instead captures science majors that have a relatively higher female student presence compared to these more male-dominated science fields.

Previously, particular interest has been placed on the experience of female students in the 'gender-unbalanced' science fields. These studies generally focus on the female voice when discussing issues of gender in STEM and consequently may neglect the male student experience (London, Rosenthal, Levy, & Lobel, 2011; Robnett, 2016). This makes assumptions about the male student experience being the 'norm' (Miller, Taylor, & Buck, 1991), which may have negative implications for female students. For example, male science students could be *overestimating* their abilities, and so using them as the baseline for comparison could result in a bigger gender gap in the STEM fields (Bench, Lench, Liew, Miner, & Flores, 2015). Arguably, equal interest should be placed on male students in the more 'gender-balanced' science disciplines. A focus on male student experiences and their desire to pursue fields with increased female presence is beginning to emerge in the literature (Beutel, Burge, & Borden, 2019; Marulanda & Radtke, 2019). While these previous studies typically investigated nursing and humanities fields, studies investigating this effect within the STEM fields are limited. Accordingly, the research question that this study aimed to answer was:

> What factors are impacting the persistence of Australian undergraduate science students in the 'gender-balanced' and 'gender-unbalanced' science fields?

Methodology

This cross-institutional study collected data from undergraduate science students at multiple Australian universities using an embedded mixed-methods design (Creswell & Plano Clark, 2007). Quantitative data was collected through an online questionnaire, which aimed to determine what factors may be impacting the persistence of undergraduate students at university and in the science career pathway. Qualitative data was collected through a single open-ended question, which added depth to the experiences of discrimination for these students. Ethics approval was granted by the

Monash University Human Research Ethics Committee (project ID: 16341).

Participants

A voluntary, convenience sampling approach was used in this study, with educators from Australian universities being contacted to advertise an online questionnaire to their students. A total of 574 undergraduate science students attempted the questionnaire, with 411 complete responses collected. To capture how the university experience was impacting students' intentions to persist in a science career, all students had experienced at least one year of an undergraduate degree but ranged from their first to final year of study. Analysis was restricted to students who declared a major in a 'gender-balanced' or 'gender-unbalanced' science field. In Australia, 'gender-unbalanced' science majors are classed as mathematics (32% female) and physics (25% female), while 'gender-balanced' science majors are biology (57% female) and chemistry (42% female) (DET, 2018). Students who majored in the health science fields (e.g., biomedicine) were also included in the 'gender-balanced' category. This is because these fields also have higher ratios of women to men and no statistically significant differences were found in student responses of science identity or belonging between the two major classes. Any students who did not declare a major, or were majoring in a non-science field, or undertaking a double major in both a 'gender-balanced' and 'gender-unbalanced' field were excluded from analysis. This left a final analysis sample size of 386 (**Table 1**).

As this was a study investigating gender, it is important to define this term. In the context of this study, students self-reported their gender as male, female, or 'other', with the latter category capturing transgender and non-binary gender-identifying individuals. While this approach is limited in capturing the whole spectrum of gender identities (Henderson & Nicolazzo, 2018), it goes beyond the typical binary approach to addressing issues of gender in university science degrees and is a step closer to capturing the entire student experience.

Table 1. Demographics of participants (n = 386).

Variable		Frequency	(%)
Gender	Female	233	(60.4%)
	Male	148	(38.3%)
	Other/Prefer not to say	5	(1.3%)
Ethnicity	White/Caucasian	221	(57.3%)
	Asian	118	(30.6%)
	Mixed or Other	40	(10.4%)
	Black/African American	4	(1.0%)
	Aboriginal or Torres Strait Islander	3	(0.7%)
First in family to attend university?	Yes	87	(22.5%)
	No	299	(77.5%)
Previous experience in science?	Yes	375	(97.2%)
	No	11	(2.8%)
High achieving?	Yes	148	(38.3%)
	No	231	(59.8%)
	N/A	7	(1.8%)
Mature age?	Yes	38	(9.8%)
	No	346	(89.6%)
	N/A	2	(0.5%)
University classification	Go8	284	(73.6%)
	Non-Go8	23	(5.9%)
	Not specified	79	(20.5%)
Year level	First-year	86	(22.3%)
	Final year	168	(43.5%)
	Other	132	(34.2%)
Science major class	'Gender-balanced'	285	(73.8%)
	'Gender-unbalanced'	101	(26.2%)

Note: Students were classed as mature age if they were 21 or older in their first year of university, or over 25 at any other stage in their degree. High achieving students were classified as students who reported their Year 12 or equivalent mark to be 80% or higher, or if they were at least a year into their degree reported an average grade of 80% or higher. Go8 = Group of Eight.

Responses were collected from eight Australian universities across five states. Universities were a combination of Australia's Group of Eight (Go8) and non-Go8 institutions. Go8 institutions are considered Australia's leading universities in research and education, with the majority of responses from Go8 universities (n=284, 73.6%). While the majority of responses were from the main author's institution (n=194, 50.3%), other institutions across Australia were included to capture a national snapshot of the undergraduate science student experience.

Data collection

Coordinators of science courses at Australian universities in the biology, chemistry, mathematics, and physics fields advertised an online questionnaire. Data was collected at two timepoints (Semester 2, 2019 and Semester 1, 2020) to increase the sample size of the study, with a check included in the online questionnaire to prevent students accessing it more than once. The questionnaire was adapted from a previous study on the persistence of STEM undergraduates (Findley-Van Nostrand & Pollenz, 2017), which comprised of sub-scales exploring the factors of science identity (Chemers, Zurbriggen, Syed, Goza, & Bearman, 2011), belonging (Good, Rattan, & Dweck, 2012), perceived identity compatibility between gender and major (London et al., 2011), and gender biased science majors (Ganley et al., 2018).

Two outcome variable questions exploring students' career intentions ('*I would like to have a career in science*') and their intentions to persist in their science major ('*I have considered switching majors to one that is not in a science field*') were also included. These questions were based on previous sub-scales studying student persistence (Perez et al., 2014; Stake & Mares, 2001). All question items were on a 5-point Likert scale. A single open-ended question was also used to collect qualitative data on students' experiences of bias while at university ("*Gender bias occurs when people treat others unfairly due to their gender. Please describe if you have any experiences with gender bias in your discipline during your degree.*"*;* Robnett, 2016). The full questionnaire and all question items can be found in the supplementary material (Table S1).

Data analysis

Quantitative data analysis was conducted in R (version 3.6.3). To test for gender differences within the outcome variables, a Kruskal-Wallis test was used, followed by *post-hoc* Mann Whitney *U* tests using Bonferroni corrections for multiple comparisons.

To determine what factors were impacting these outcomes variables, a Spearman correlation was conducted. Only correlation analyses were conducted using a binary classification of gender (i.e., male and female), as other gender categories had sample sizes that were too small to conduct accurate statistical analysis in this instance ($n<5$; Aggarwal & Ranganathan, 2016). Statistical significance was defined at the $p<0.05$ level.

Qualitative data was analysed using Nvivo software (version 12). As this question had been used on university students in previous studies (Fisher, Thompson, & Brookes, 2020a; Robnett, 2016), a deductive approach to coding was used, using codes generated from these previous studies to generate the initial codebook (i.e., *a priori*; Crabtree and Miller, 1992). Following this, new codes were added to the codebook as they emerged from reading the text using an inductive approach (Boyatzis, 1998). To prevent bias, interrater reliability occurred with two other educational researchers who were independent to the study and experienced in education research, who coded a subset of the open-ended responses to ensure percentage agreement above 80%.

Results

Survey reliability

The internal consistency reliability of the questionnaire was validated by Cronbach's α within the overall study cohort, as well as the sub-groups of interest (i.e., male and female students) (Supplementary material: Table S2). All sub-scales were above or approximate to the acceptable cut-off of 0.70 (DeVellis, 2003), or had similar values to previous studies conducted on university cohorts (London et al., 2011).

Demographics

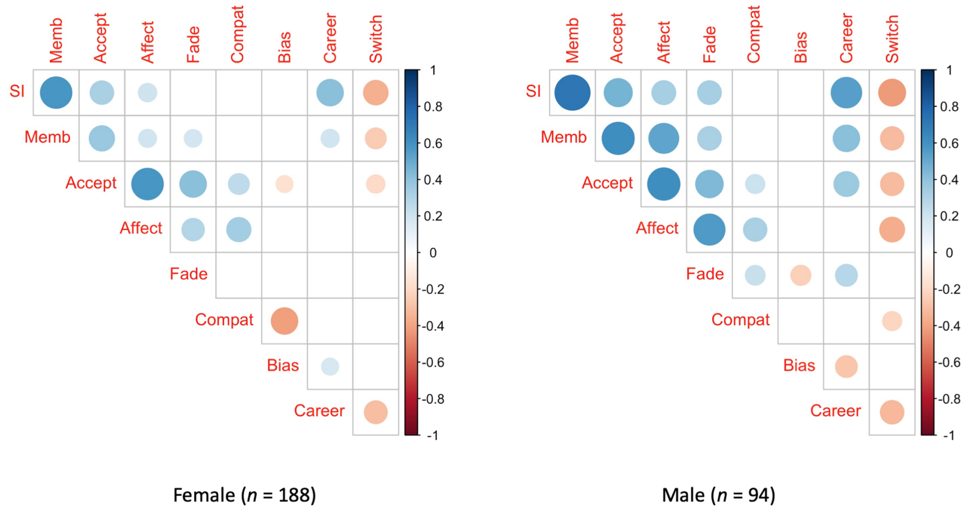
To test if any confounding variables could be impacting the outcome of this study, Fisher's exact tests of independence were conducted between the demographic variables and the gender categories, using Bonferroni corrections for multiple comparisons. No statistically significant differences ($p<0.05$) were found between male, female or non-binary gender identifying students within these background demographic variables (Supplementary material: Table S3). Therefore, it was assumed these confounding variables were not having a significant effect on the gendered persistence intentions of students.

Factors impacting the persistence of undergraduate science students

Gender differences in student persistence in the 'gender-balanced' science fields

There were no statistically significant gender differences in career or switching intentions for students in the 'gender-balanced' science fields. To determine what factors may be impacting student persistence, correlation analyses were conducted on male and female student cohorts (**Figure 1**). For female students, science identity (ρ=0.42) and membership (ρ=0.21) were both positively correlated with science career intentions, and negatively correlated with their intentions to leave their science major (science identity: ρ=-0.35, membership: ρ=-0.25, acceptance: ρ=-0.18). For male students, the same effect was found for career intentions, but with stronger correlations (science identity: ρ=0.53, membership: ρ=0.41, acceptance: ρ=0.37). Additionally, science identity (ρ=-0.46) and almost all aspects of belonging (membership: ρ=-0.39, acceptance: ρ=-0.33, affect: ρ=-0.36) were negatively correlated with their intentions to leave their science major. These correlations suggest the importance of high levels of these affective domains within both male and female student cohorts in the 'gender-balanced' science fields to ensure they persist in the science career pipeline. To aid in the interpretation of these correlations, mean values of the sub-scales for male and female students in these fields can be found in the supplementary materials (Table S4).

Figure 1. Correlation plots for female and male students in the 'gender-balanced' fields.



Note: only statistically significant ($p<0.05$) correlations are shown. Larger circles correspond to larger correlation coefficients, with blue corresponding to positive correlations and red corresponding to negative correlations. SI=science identity, memb=membership, accept=acceptance, fade=desire to fade, compat=perceived identity compatibility between gender and major, bias=gender biased science majors, career=intentions for a science career, switch=intention to switch out of a science major.

Qualitative responses were also recorded in relation to students' experiences of gender bias at university. The majority of students who responded to this open-ended question believed they had not experienced discrimination in the science fields while at university (*n*=72), with both male and female students within this subgroup (*n*=30 and 42 respectively). However, students still reported discriminatory experiences (*n*=31), with these experiences reported predominantly by female students (*n*=23). When looking at these examples, these discriminatory experiences for female students included discrimination faced by peers, teaching staff and those outside of university (**Table 2**).

Table 2. Exemplar quotes on discriminatory experiences for female students in the 'gender-balanced' science fields.

Type of discrimination	**Example quote**
By peers	*I have been in an all-male group before as the only female and my ideas were disregarded with the boys snickering when I suggested things. I felt very left out and it really decreased my confidence in the presentation we did because I felt no support from my team members.* –Female student #1
By teaching staff	*In discussion groups with a particular professor, even minor or vague contributions by male students would be met with praise. Conversely, thorough and apt responses by females tended to be dismissed. By the end of semester, almost none of the girls in the class would speak up.* –Female student #2
Outside of university	*I have not experienced gender bias during my degree, but I have experienced it before my science degree. In high school I was told that I would not get into science and that "women do not need to focus on their career as they are second home providers". I attended a school with some very sexist male teachers.* –Female student #3

Furthermore, a minority of male students (*n*=6) also reported experiences of perceived discrimination. These experiences typically mentioned diversity initiatives and programs to increase female participation in the STEM fields:

> Women only scholarships, events such as networking nights for women only, societies that are exclusively for women -- and nothing special for men. There is now an Equity, Diversity and Inclusion committee which (of course!) sets out to exclude men. –Male student #1

> I've been brushed off. Possibly because people don't want white males, they prefer diversity over merit. –Male student #2

Non-binary and transgender identifying students' experiences of discrimination at university was also found in this study (*n*=2). As one student noted:

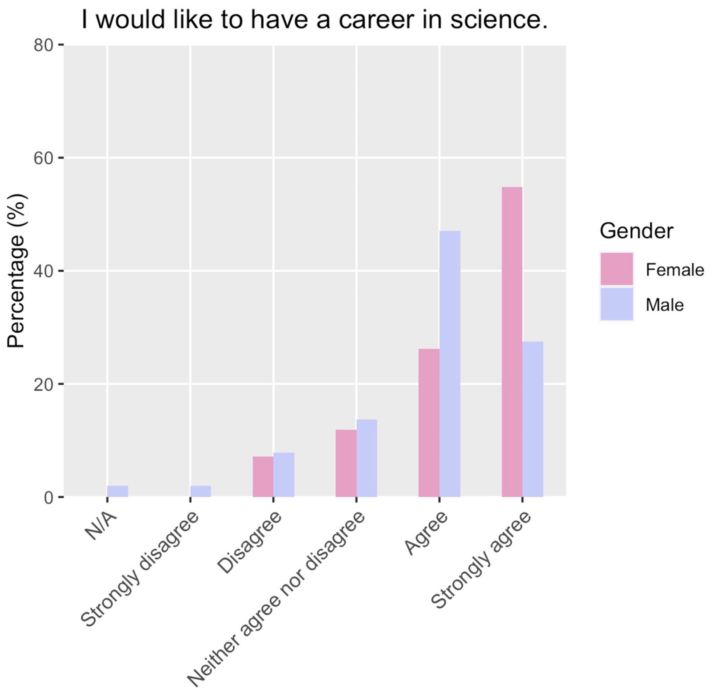
> …instances where I've experienced gender bias is when people, doesn't matter if it's for my major units or electives, are homophobic and transphobic. One instance that I can recall is biology professors using same sex couples to make crude jokes

about infertility and inability to reproduce, which was really unnecessary. –Nonbinary student #1

Gender differences in student persistence in the 'gender-unbalanced' science fields

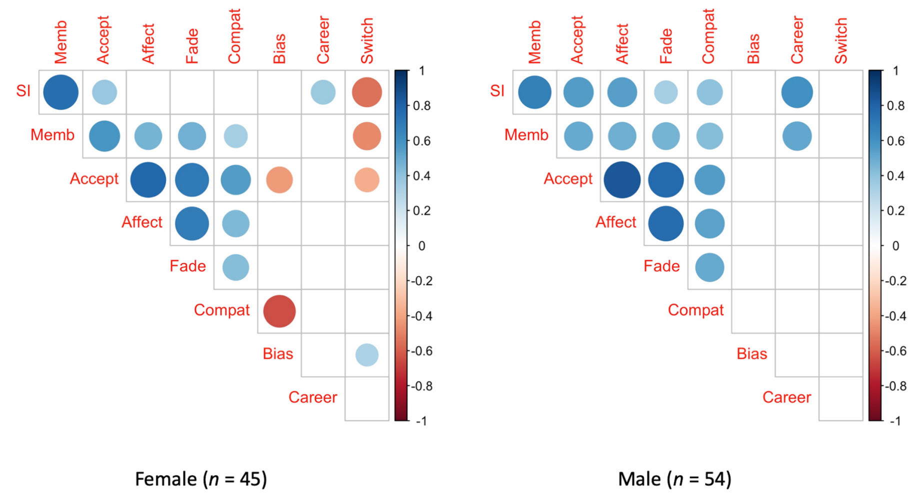
Within the 'gender-unbalanced' science fields, gender differences were observed in the career intentions of undergraduate science students but no significant effect was observed in their intentions to switch out of their science major. Using *post-hoc* pairwise comparisons, it was found that female students were more strongly inclined to pursue a science career in these fields when compared to male students (**Figure 2**; Z=-2.01, p=0.044, r=0.25). To aid in the interpretation of these correlations, mean values of the sub-scales for male and female students in these fields can be found in the supplementary materials (Table S4).

Figure 2. Gender differences in science career persistence intentions in the 'gender-unbalanced' science fields (n=93).



When looking at the more male-dominated science disciplines, there was a stark contrast in the factors correlated with male and female student persistence (**Figure 3**). For female students, aspects of belonging (membership: ρ=-0.51, acceptance: ρ=-0.36) and science identity (ρ=-0.57) were strongly negatively correlated with their intentions to switch out of their science major. Additionally, science identity (ρ=0.39) was positively correlated with their science career intentions. For male students, science identity (ρ=0.61) and membership (ρ=0.52) were strongly positively correlated with their science career intentions. However, there were no correlations with any of the affective domains tested in this study with male students' intentions to switch out of their science majors.

Figure 3. Correlation plots for female and male students in the 'gender-unbalanced' science fields.



Note: only statistically significant (p<0.05) correlations are shown. Larger circles correspond to larger correlation coefficients, with blue corresponding to positive correlations and red corresponding to negative correlations. SI=science identity, memb=membership, accept=acceptance, fade=desire to fade, compat=perceived identity compatibility between gender and major, bias=gender biased science majors, career=intentions for a science career, switch=intention to switch out of a science major.

Qualitative responses in the 'gender-unbalanced' science fields were also coded for experiences of discrimination. Similar to the 'gender-balanced' science fields, the majority of students did not report experiences of discrimination (n=26), with men being the majority of this subgroup (*n*=18). However, some students did still report experiencing bias while at university (*n*=17). Once again, the majority of these experiences were reported by female students (*n*=13), with these examples deriving from discrimination by peers and teaching staff in the classroom (**Table 3**).

Table 3. Exemplar quotes on discriminatory experiences for female students in the ‘gender-unbalanced’ science fields.

Type of discrimination	Example quote
By peers	*In my first-year studies I was assumed to be not as smart as my male peers, by my male peers. This culminated in a number of 'mansplaining' incidents, that in hindsight definitely made me avoid attending class and even compulsory class, due to not wanting to feel as stupid as they thought I was.* –Female student #4
By teaching staff	*I have had lecturers make passing comments in lectures that discriminated against females.* –Female student #5

Similar to the ‘gender-balanced’ science fields, several male students (*n*=3) reported experiences of discrimination, once again linking key initiatives to help women in STEM as discriminatory against men. As one student noted:

> Some steps that have been put in place to correct gender bias in physics (such as scholarships that are guaranteed for females, scholarships only for females, support networks only for female physics students, etc.) are themselves gender bias, given that an equivalent does not exist for the opposite gender. –Male student #3

The one non-binary student in this field also experienced discrimination at university. This discriminatory experience related back to the issues of presenting as a female student in the sciences:

> I am AMAB and non-binary, so the first example of gender discrimination I saw was towards women. This affected me because it showed me that the classroom was not going to be welcoming towards me if I presented myself the way I wanted to be seen. I don't often feel comfortable enough to share even my pronouns, and I do my best to avoid spending time in the student spaces for physics. –Nonbinary student #2

Discussion

Findings showed that female students present similar risk factors for attrition (i.e., low levels of science identity and belonging) and discrimination faced by both their peers and teaching staff, whether they are in a 'gender-balanced' or 'gender-unbalanced' science field. Interestingly, male students in the 'gender-balanced' science fields presented similar risk factors for attrition as female science students and also presented a novel insight into the discriminatory experiences of male students in the science fields. Finally, discriminatory experiences for transgender and non-binary gender identifying students were also presented in this study, adding another view on the gender equality in STEM discussion.

The importance of the affective domains

This study investigated science identity and belonging, two affective domains that have been correlated with student persistence in these fields, particularly so for female students (Fink, Frey, & Solomon, 2020; Stets, Brenner, Burke, & Serpe, 2017). The findings from this study reiterate the importance of these factors for female science students. High levels of science identity and belonging were positively correlated with their science career intentions and negatively correlated with their desire to switch out of their science major.

Qualitative responses from female students supported the impact of these affective domains. When describing experiences of discrimination at university, female students often linked this discrimination back to peers commenting on them not looking like a 'science person':

> …a group member (who was also a physics student) for another subject kept thinking I studied biology even though I told him on multiple occasions my major was physics, even after all this his latest comment was "I didn't think you were a physics person". –Female student #6

> I feel like my male colleagues constantly underestimate me, and that I have to be the best in every class to be taken seriously, whereas male students can be mediocre and are still celebrated. I think that this has a lot to do with the fact that I enjoy expressing my femininity through my clothes and make up, and am constantly told by everyone around me that "I don't look like an astrophysicist". – Female student #7

These experiences from female students suggest that the stereotypes of who is a 'science person' are still prominent, particularly in the more male-dominated science fields (e.g., physics). This is of concern as recognition by your peers is a core component of science identity (Carlone & Johnson, 2007), suggesting that over time these experiences may lower female student science identity and impact their desire to persist in these fields.

The affective domains are typically discussed when studying the female student experience in the male-dominated STEM fields. However, findings from this study suggest that these factors may also play an important role for male students in the more 'gender-balanced' science fields. Male students in these fields in this study presented similar 'risk factors' for attrition as female science students, with lower levels of science identity and belonging impacting their desire to persist in these science majors. The male student experience is often used as a benchmark for STEM students, but by disaggregating the STEM fields these findings suggest that male students in the more 'gender-balanced' science fields may be another group at risk for attrition from this science career pathway.

Experiences of discrimination for female undergraduate science students

Female students in this study, regardless of if they were in a 'gender-balanced' or 'gender-unbalanced' science field, experienced discrimination. This is of concern as female university students who experience bias can face decreased belonging and engagement in

STEM fields (Moss-Racusin, Sanzari, Caluori, & Rabasco, 2018). When giving examples of discrimination, female students often referred to issues pertaining to group work and interactions with their male peers. Previous research supports this, with recent findings highlighting that male students tend to dominate active learning classroom environments (Aguillon et al., 2020). Group work has been of particular interest when addressing the gender imbalance in STEM, as it has been suggested that female students prefer active learning and collaboration in their learning (Rainey, Dancy, Mickelson, Stearns, & Moller, 2019). However, responses from female students in this study suggest that this is not having the desired effect, with female students reporting feeling unheard by their male peers:

> I think that in class and group discussions, I find that women often get talked over, interrupted, and disregarded when trying to make a point or answer a question. –Female student #8

> My male peers sometimes ignore my ideas or don't even listen to me. I feel more comfortable working in a team that has at least one female peer besides myself. –Female student #9

This negative experience in small group work in STEM classrooms for female students has been supported by the literature (Grover, Ito, & Park, 2017; Sullivan, Ballen, & Cotner, 2018). In particular, previous research has demonstrated power imbalances in small group work in the more male-dominated science fields (Griffin et al., 2015). The findings from this current study highlight the need for educators to be more aware of these issues in small group work occurring in their classroom, which could be adversely affecting female students' desire to persist in these areas. An example of this was given by one female student:

> Many boys feel the need to speak over us girls and treat us as if our opinion is immediately wrong and that we are stupid - I have experienced this my entire course and was the reason I dropped second-semester first year chemistry. –Female student #10

Female students in the 'gender-unbalanced' science fields were still more strongly inclined to pursue a career in science when compared to their male peers, despite facing these experiences of discrimination. This effect has been supported in the literature, with students who are underrepresented in fields displaying a certain 'grittiness' when it comes to pursuing these career pathways (Flanagan & Einarson, 2017). However, this could also be a limitation of the study design, with responses being collected from students at least a year into their degree, and so findings do not capture students who have already left the science career pathway at this timepoint. As one female student who switched from a 'gender-unbalanced' to 'gender-balanced' science field noted:

> In my physics workshops the boys on my table would only talk to the other boys, about physics or not and whether they know them personally or not. I felt a bit left out and like I don't belong. I don't study physics anymore. –Female student #11

Experiences of discrimination for male undergraduate science students

While the majority of discriminatory experiences were reported by female students, male students also reported feeling discriminated against. These experiences were typically related to diversity initiatives that have recently been established to recruit more women into STEM fields. As one male student noted:

> Within my major I have occasionally [faced] some sort of disdain as if I had committed some wrongdoing on my fellow students by virtue of being there […] Other students have been given more lenient marks due to their gender, with the reasoning being "inclusivity", despite the fact I am a minority within my major (which in its own right I have no problem with). These students are doing just as well, if not better, than myself, which once again I have no problem with. As if I'm going to report this, though. It's too much trouble, I'd be chastised […] On the other hand, outside perceptions of the major offer the complete opposite, where the women are told they are doing a boy's thing. Why can't we just be normal. FFS, it's just chemistry. –Male student #4

This frustration with diversity initiatives was mainly reflected in the male student voices in the 'gender-balanced' science fields, which could be due to the larger number of female students in these fields. This frustration can then turn into aggression, as seen in an example from one male student:

> I think that women have no rights. and men are the alphas. and u should get back to the kitchen... Bitch. –Male student #5

Male students in the more 'gender-balanced' science fields appear to be developing hostile feelings towards the topic of gender equality in the STEM fields. Danbold and Huo (2017) have demonstrated that men can be threatened by these diversity initiatives through prototypicality threat, which is the notion that men are threatened by not being the dominant group in STEM. Their study showed how men who felt this threat were more resistant towards these initiatives (Danbold & Huo, 2017), and further research into male student opinions in these fields is warranted.

Experiences of discrimination for transgender and non-binary identifying undergraduate science students

Though a small percentage of this cohort, at least three of the five transgender or non-binary identifying undergraduate science students in this cohort reported experiences of discrimination. While some examples were related to "transphobic" comments by staff or peers, some experiences were related to students struggling to identify with their gender due the stereotypes around it in the sciences. As one student noted:

> As I am recognised as female, I have encountered people who are surprised that I enjoy Physics and Chemistry. This has usually come from well-meaning female medical/medical science students who seem to have fallen prey to the idea that maths intensive subjects are too difficult and have primarily seen boys excel at these subjects or have experience in attempting and not enjoying these subjects. –Transgender student #1

Recent literature has established that students from sexual minorities, such as transgender students, do have decreased retention in STEM and have issues navigating the culture of these majors (Cech and Rothwell, 2018; Miller et al., 2020). An in-depth discussion of the issues faced by this sub-group was not the focus of this study, and further research into this sub-group of students is warranted to truly capture the gendered issues occurring in STEM majors both in an Australian and international context.

Limitations

There are several limitations with the design of this study. Firstly, while several Australian universities were sampled, the majority of responses were collected from Go8 universities and so student experiences from regional and non-Go8 universities were underrepresented in this sample. Therefore, the generalisability of these findings to the experience of all Australian undergraduate science students is limited. Additionally, the science majors were dichotomised into 'gender-balanced' or 'gender-unbalanced' fields based on female participation at the university level. However, this classification varies for each science field depending on the timepoint in this career pipeline. For example, although biology was classed as a 'gender-balanced' field at an undergraduate level, women are underrepresented in senior positions in these fields within the STEM workforce (Office of the Chief Scientist, 2020).

There were also some limitations in the data collection process. Firstly, this data captured student responses at least one year into their degree and so does not capture the experience of students who have already left the STEM fields prior to this timepoint. Additionally, as the questionnaire was advertised online on a centralised learning platform or during class, determining the exact number of students who were approached could not be calculated and so is a limitation when trying to calculate the response rate of this study. The data collected in this study was also primarily quantitative, and while gender differences in persistence did arise between male and female cohorts, why these students had considered leaving was not captured directly by this data. Further qualitative data collection through student interviews would aid in understanding these student experiences in undergraduate science degrees. Finally, this study on persistence was based on correlations only, and causative effects cannot be interpreted from these results.

Implications

There are several implications from this study to aid in improving the undergraduate science student experience and addressing gender equity issues in STEM. Firstly, these experiences of discrimination reported by female students highlights the need for interventions in the classrooms and an awareness of the issue of inequitable group work for educators. Quinn et al. (2020) demonstrated that in unstructured classroom environments with little educator intervention, students adopt roles in these small groups that result in inequitable group work. Intervention studies for group work are being developed, with Lewis et al. (2019) finding that a video intervention showing counter-stereotypes in group work can lead to a more positive male-female group interaction in the classroom. Further research into intervention studies to create more gender equitable classrooms is warranted, particularly in an Australian context.

This study also highlights the need for the male voice when discussing gender equality in the STEM fields. Men in this study were found to be more resistant to initiatives to aid female student persistence in these fields, perceiving them as discriminatory against men. One way to overcome this issue could be through education. Intervention studies to raise awareness of gender bias in STEM have been developed, though they do have their limitations (Pietri et al., 2017). By educating students on the issues of gender equality for science students at university, opinions and perspectives on these issues could be changed. As one male respondent in this study noted:

> More education about gender issues and equal opportunities would be very beneficial here, for everyone, and potentially solve the problem. –Male student #6

Conclusion

This study aimed to investigate factors impacting the persistence of Australian undergraduate students in the ‘gender-balanced’ and ‘gender-unbalanced’ science fields. Belonging, science identity and discrimination were found to all play a role in undergraduate science student persistence. For female students, these factors were particularly important for their persistence in a science career and while at university. In addition, these factors were important for male students in the ‘gender-balanced’ science fields, acting as preventative factors to them considering leaving their science major at university. Findings from this study showed that Australian undergraduate science students do experience discrimination, and while these experiences are predominantly reported by women, men also feel discriminated against. While female discriminatory experiences are focused around issues with group work, male students reported initiatives to recruit more women into STEM as discriminatory against men. This study presents a novel insight into the gendered issues for Australian university science students, highlighting potential ‘at-risk’ groups for attrition while identifying discriminatory experiences that linger in a university classroom.

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6.2 Summary

The main findings from this cross-institutional study were:

- Female science undergraduate students face discrimination, regardless of what discipline they are in, and these are commonly related to negative experiences with group work in the classroom. These examples mainly related to the perception of male peers not valuing or respecting their opinions.
- Male students in the "gender-balanced" science fields present similar risk factors for attrition (i.e., low science identity) as female science students. This effect is not observed in male student cohorts in the more male-dominated science fields.
- There is a hostility towards gender diversity initiatives in the STEM fields held by some male science students, particularly so in the "gender-balanced" fields. This effect has resulted in male students feeling discriminated against due to their gender at university.

These core findings from this national study highlight some of the key messages from this overall thesis and echo similar findings from previous chapters. For example, the hostility held by male students was also presented in **Chapter 4**. Overall, these findings demonstrate that female students in the "gender-balanced" science fields have similar experiences to female students in the "gender-unbalanced" science fields, aiding in answering the second research question of this thesis. In addition, these findings highlight that male students in the "gender-balanced" science fields may have a different experience as their counterparts in the "gender-unbalanced" fields, with them presenting with similar risk factors for attrition as female students in the science fields and also their more vocal hostility towards gender diversity initiatives in STEM.

However, most of the data presented so far in this thesis has been quantitative in nature, and there is a need to examine *why* these gender differences exist. As stated in this chapter, in-depth interviews with students are needed to help understand how students define their science identity and belonging as well as providing detailed examples of bias they have faced at university. This was the focus of the following chapter.

Chapter 7

A qualitative study on the gendered experience of science students

7.1 Introduction

As previous chapters and other research have demonstrated, gender differences in the Australian undergraduate science student experience exist. In particular, lower confidence levels, decreased belonging, and experiences of gender bias for female science students are contributing to this effect and putting women at risk for attrition from undergraduate science degrees. As outlined in **Chapter 6**, women with lower levels of science identity and belonging were more likely to consider leaving their science major at university, and not pursue a future career in the science fields.

Earlier chapters of this thesis took a quantitative approach to addressing the issue of student persistence in STEM, establishing that there are gender differences in the undergraduate science student experience. However, these studies are limited as they are not examining *why* these differences exist or what was contributing to this effect. For example, while previous quantitative research has established decreased belonging within female student cohorts in the science fields, there has been a call for qualitative studies to establish what environmental factors are causing this effect (Fink, Frey, & Solomon, 2020). To capture this information, qualitative data is needed. An in-depth qualitative understanding of what factors are impacting these domains would allow for interventions to be implemented that would effectively reduce these known risk factors for attrition within science student cohorts.

Qualitative studies on the student experience in science degrees do exist. A key example of an in-depth qualitative study investigating female student persistence in the STEM fields is the Seymour and Hewitt (1997) study. From in-depth interviews with women in undergraduate STEM degrees, Seymour and Hewitt (1997) deduced that female students who leave STEM majors do so due to feeling like outsiders in these traditionally male-dominated fields. Another more recent qualitative study by Cabay, Bernstein, Rivers, and Fabert (2018), investigated similar issues for women pursuing a PhD in the more male-dominated science fields. Similar to the findings presented in this thesis, women in the Cabay et al. (2018) study reported discrimination or bias in the form of microaggressions by their peers. Though this did not deter them from finishing their post-graduate studies, Cabay et al. (2018) demonstrated that this has effects later on, with students from that cohort less likely to consider career pathways in these fields.

The purpose of this current qualitative study was to add more meaning and depth to the quantitative results presented in the first quantitative phase of this project (**Chapter 6**). Low levels of science identity and belonging, as well as experiences of bias were found to impact female students' persistence intentions in science degrees. However, quantitative data was limited in capturing the factors causing these lower levels of belonging and science identity. While examples given in the open-ended responses alluded to experiences in group work as contributing to this effect, more in-depth qualitative data was needed to elucidate this effect. To overcome this limitation, semi-structured interviews were conducted with a sub-sample of students exploring their definitions of science identity and belonging, and experiences of gender bias in the sciences at university. Therefore, the questions this study aimed to answer were:

1. How do undergraduate science students define the concepts of science identity, belonging, and gender bias in the STEM fields?
2. What are students' opinions on how these factors impact the experience of women in undergraduate science degrees?

7.2 Methodology

This current qualitative study was the second phase of a larger national study, which followed a sequential explanatory design (Creswell, 2003). The previous quantitative data collection occurred through a questionnaire that explored the themes of science identity, belonging and gender bias for undergraduate science students in Australia (**Chapter 6**). This current chapter focuses on the qualitative data collection phase that occurred via student interviews, exploring how students define these three concepts and their perceptions of how these factors impact female students in science degrees.

Participants

Participants were recruited using a purposive, convenience sampling approach (Merriam & Tisdell, 2015); participants were recruited from the first quantitative phase of this mixed-methods study. An online questionnaire was completed by 620 undergraduate science students across eight Australian universities in the first phase of this study. 64 of these students provided their email address to be contacted for interviews. Students who had reported experiences of discrimination, as well as students who self-identified as having high levels of belonging and science identity, were contacted for interviews ($n = 58$). This approach was used to capture students who had experienced bias in the STEM fields and to gather in-depth examples of this bias experienced at university. Additionally, students who self-reported high levels of science identity and belonging were targeted to capture their definitions of these concepts and identify what factors were potentially increasing these domains for these students. This approach would help direct future interventions to increase student belonging and identity in these fields.

A total of 10 students agreed to participate in an interview. Both male and female students were interviewed. Though the questionnaire had responses from non-binary and transgender identifying students, only male and female-identifying students volunteered to participate in this qualitative study. As this was a national study, participants were recruited from universities across Australia. Final participants were from four different Australian universities, which will be given pseudonyms for anonymity (Aus1 to Aus4). Aus2, Aus3 and Aus4 were Group of Eight (Go8) research-intensive universities, while Aus1 was a non-Go8 university. All participants received a $20 gift-card reimbursement for their time. A break-down of interview participants is provided in **Table 7.1**. Ethics approval for this study was approved by Monash University's Human Research Ethics Committee (project ID: 16341). Written informed consent was obtained from all participants prior to conducting an interview.

Pseudonym	**Gender**	**Science Major**	**University**
Matthew	Male	Biology	Aus1
James	Male	Biology	Aus1
Michele	Female	Biology	Aus2
Victoria	Female	Genetics	Aus2
Alan	Male	Chemistry	Aus2
Thomas	Male	Chemistry	Aus3
Cleo*	Female	Chemistry	Aus3
Sally-Ann	Female	Biology and Chemistry	Aus3
Roxanne	Female	Chemistry	Aus4
Millicent	Female	Anatomy, human biology, genetics	Aus4

Table 7.1: Demographics of interview participants ($n = 10$)

Note: *Cleo was a visiting undergraduate student from the United States.

Interview protocol

As students were located across several states in Australia, semi-structured interviews occurred virtually via Skype or Zoom software. Three themes from the previous questionnaire (**Chapter 6**) were examined in these interviews: science identity, belonging, and experiences of gender discrimination or bias while at university. These three themes were selected due to their known impact on student persistence in science degrees, as well as being understudied in an Australian context. Additionally, these three factors are known to interact and impact one other. For example, as demonstrated in the first quantitative phase of this project, female students who experienced gender bias in small group work felt less accepted in a science classroom (**Chapter 6**), which is a core component of their belonging.

Six questions were asked to every student, with follow-up probing questions used to prompt more detail within student answers. Students were also invited to share any insights they felt they had not covered towards the end of the interview. Open-ended questions were derived from previous literature as well as driven by the quantitative data collection in the first phase of this project (**Chapter 6**; Lane, 2016), with two questions for each of the three themes explored (**Table 7.2**). Interviews typically lasted 10-15 minutes, and all audio was recorded and later transcribed by the lead author for qualitative analysis.

Section	**Question**
Science identity	Have you come across any of your classmates who think have strong science identity? What characteristics do they have?
	Do you think female students struggle to identify as scientists in your field?
Belonging	Can you describe times when you felt like you “belong” in your science classes?
	Do you think female students may struggle to belong in science?
Bias in STEM	Have you ever felt like you have been discriminated against or experienced bias because of your gender in your science field?
	Do you think it’s common for female students in your field to feel discriminated against or experience bias?

Table 7.2: Questions used in interviews and corresponding section themes

Data analysis

A thematic analysis framework was used for qualitative analysis, using the six-phase approach outlined by Braun and Clarke (2006). All qualitative analysis was conducted using NVivo software (version 20). The first phase involved reading all ten interviews multiple times to gain familiarity with the data. The second phase involved generating an initial list of codes. As these questions had been asked to students in previous related studies, a combination of deductive and inductive coding was used. Deductive codes were ones that had emerged in previous studies (i.e., *a priori*), which created a thematic codebook for analysis (Crabtree & Miller, 1992). New codes were then added to this codebook from rereading the text using an inductive approach (Boyatzis, 1998). The following phases involved refining, reviewing, and defining the final list of themes. To mitigate bias, two complete interview transcripts were coded using this codebook by another educational researcher who was independent to the research project. Consensus was reached when no new themes were introduced and percentage agreement of coding was above 80%.

7.3 Results and discussion

Themes

A final list of themes that arose in these student interviews is shown in **Table 7.3**, alongside their definitions and an example quote from within the text. To determine what factors were contributing to students' definition and feelings of science identity, belonging, and bias in science, the prevalence of these themes within each section of the interview (e.g., science identity, belonging, bias in STEM) was counted (**Table 7.4**). As stated previously, the broader themes investigated are known to interact, therefore it was expected that themes would emerge in multiple sections within interviews. For example, science identity and belonging are known to interact with one another (Trujillo & Tanner, 2014), so it is expected that cross-coding might occur in multiple sections within interviews. An overall column was also added to show the total number of participants who had discussed these themes.

Theme	**Description**	**Exemplar quote**
Role models	Discussing how role models can impact science identity or belonging of students, either in a positive or negative way. Discussing bias or discrimination by role models outside or within university.	*. . . we do have a lot of like* ***role models*** *in a lot of our* ***unit coordinators*** *and a lot of like the* ***research scientists****, like it does seem pretty evenly spread.*
Capability	Discussing capability when defining a scientist or how their capability helps/hinders their ability to identify as a scientist. Discussing how their capability in science impacts their belonging.	*. . . but I think because I'm pretty* ***confident with my abilities*** *in science [. . .] I don't feel like I don't connect to the subjects material and I still really feel at home in the lab and stuff.*
'Doing' science	Stating that being a scientist is related to simply doing a science degree/course/job.	*. . . people always joke with the 'Oh, yeah. Like, we're like we're scientists,* ***simply because we're doing science.****' And that seems to be the major theme.*
Interest and passion	Discussing their passion or interest for science.	*I've been* ***passionate*** *about science since a very young age, and I've always been very inquisitive.*
Stereotypes	Discussing stereotypes when defining a scientist, or discussing how stereotypes may impact students' ability to identify as scientists.	*And you know, when people picture scientists, like especially kids when they picture scientists, they picture like the* ***male mad scientist figure****.*
Curiosity	Explicitly stating curiosity when defining a scientist or science identity.	*. . . probably a lot of like,* ***inquiry*** *as to like the world around us and what's happening and why and* ***wanting to know*** *[. . .] I feel like that's probably the essence of what makes somebody a scientist.*
A sense of belonging	Discussing positive feelings of belonging. Students relating their belonging in science to their science identity.	*Where in science, like in the classrooms and stuff like that, like I do feel, yeah, just more confident and more like that's* ***where I'm meant to be****.*
Discrimination	Experiences of being discriminated against in their science field. Students discussing how discrimination in science impacts their belonging.	*[. . .] I have experienced a bit of* ***gender bias*** *within science. I feel like lot of it comes from outside people looking into the science field.*
Gender ratios in the classroom	Discussing how gender ratios in the science classroom impacts their belonging.	*I think when, yeah, the scales kind of tip and there's like* ***more boys than girls*** *then I think it could, like some girls could possibly not feel like they belong.*
No experiences of bias at university	Discussing positive experiences and no discrimination at university.	*Like people have been* ***super helpful*** *and* ***super supportive****. And yeah, just like* ***everybody's valued*** *in the cohort.*

Table 7.3: Final themes alongside definitions and example quotes

Theme	Overall	In science identity	In belonging	In bias in STEM
Role models	9	7	3	3
Capability	7	5	3	1
No experiences of bias	7	0	0	7
Discrimination	6	0	2	6
A sense of belonging	6	1	7	0
Interest/Passion	5	5	0	0
Stereotypes	3	3	0	0
Gender ratios in the classroom	3	0	3	2
Curiosity	3	3	0	0
‘Doing’ science	2	2	0	0

Table 7.4: Prevalence of themes within each interview section

The above themes were then segregated into two broader themes to aid in analysis. Themes were categorised into either *internal* or *external* factors that can impact belonging, science identity and contribute to bias in STEM at university. Internal factors reflected the characteristics of an individual, while external factors referred to environmental factors that impact students. This distinction has been made in previous studies investigating identity and achievement (Graham, 1991; Simpson & Bouhafa, 2020). For the purposes of this study, internal factors included the following themes: capability, interest/passion, curiosity, ‘doing’ science, and a sense of belonging. External factors included: stereotypes, discrimination, role models and gender ratios in the classroom. The last theme, no experiences of bias, was the only one that was not categorised. A visual representation of these themes and their prevalence within each section of these interviews is depicted in **Figure 7.1**.

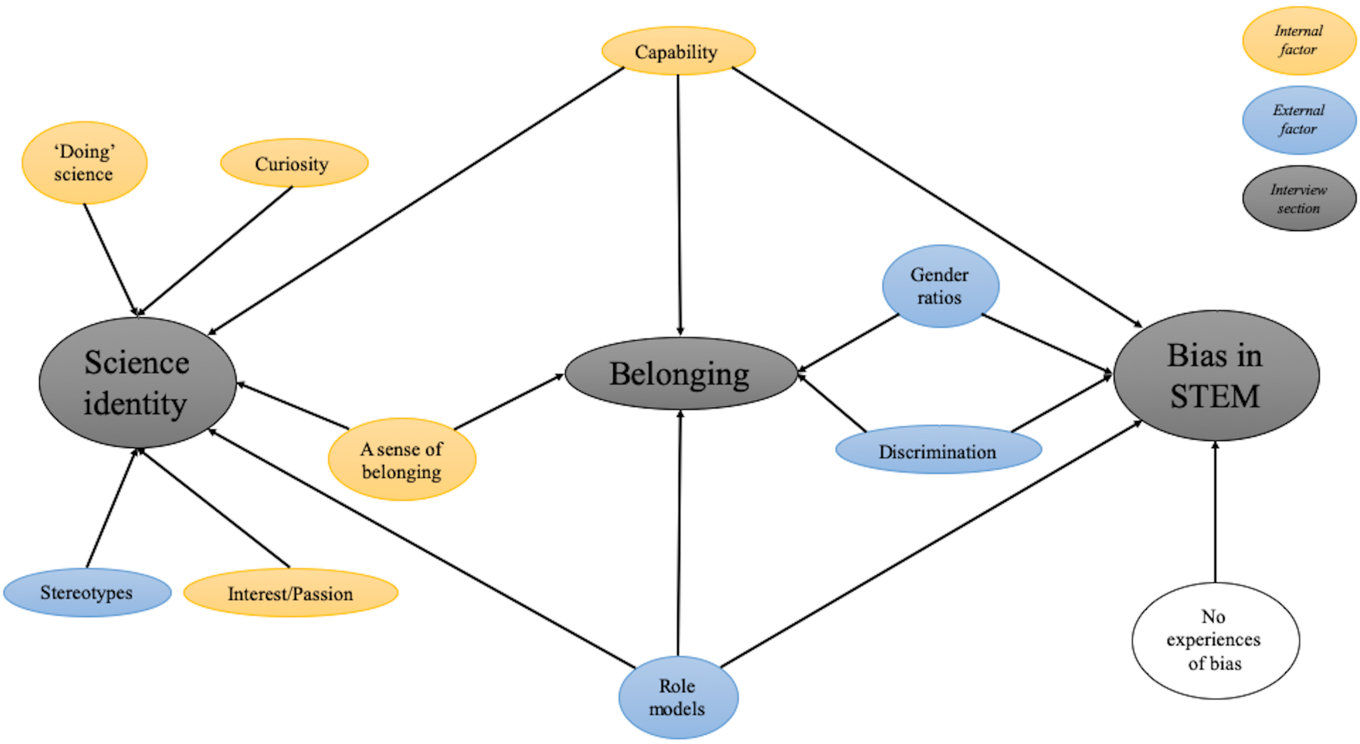

Figure 7.1: Visual representation of themes within each subsection

Note: Unclassified nodes are displayed in white

Internal factors

Internal factors were themes classified as reflecting the characteristics of an individual. The internal factors discussed by students in this study encompassed five themes, which included students discussing their capability, interest/passion, curiosity, the act of 'doing' science, as well as their sense of belonging.

Capability

Students' capability was an internal factor that was discussed across all three sections, though was most prominent when discussing science identity. Half of the participants ($n = 5$) discussed the theme of capability in science when defining science identity. For example, James indicated how a classmate who appeared to have high science identity did so because of their capability:

> I have this classmate of mine [. . .] he was definitely very well read about most things and we used to go to him for tutoring and stuff. So he was, uh, he was on the higher end [of science identity] and I think he had that quality.

Students would also occasionally link their lack of capability as a reason why they themselves do not identify strongly as a scientist, despite having an interest in this field. As Roxanne explained:

> I wouldn't necessarily call myself a scientist because I feel like I don't – I don't know enough or have enough skills to actually be a scientist. But I do love science.

Another female student, Millicent, echoed this response, stating that "it's not kind of just a given that you're a scientist" and instead felt that as a female student you do have to "prove yourself". This sub-theme of capability aligns with the theoretical framework of science identity; one of the three components of Carlone and Johnson's (2007) science identity framework is competence, which refers to one's knowledge and understanding of science. Therefore, students not feeling capable in science could be acting as a hindrance to their ability to identify as a scientist.

This discussion of capability also aligns with the concept of self-efficacy, which is a belief in one's ability to succeed in a given area (Bandura, 1997). Previous literature has highlighted the critical role that self-efficacy plays in developing one's science identity (Flowers III & Banda, 2016). The relationship between self-efficacy and science identity is problematic as it is established that female science students typically have lower self-efficacy than their male counterparts (Ainscough et al., 2016), and appears to be an effect particularly prominent in Australian university science student cohorts (**Chapter 3**; Fisher et al., 2020a). Findings from this current qualitative study reiterate that students' perceptions of their capability are contributing to their perceptions of their own science identity levels, which is problematic for students with lower self-efficacy in the science fields.

Students also linked their perceived capability with their feelings of belonging in the science fields. Some students linked their capability as a positive impact on their belonging, as Cleo stated: "I feel like I belong [...] and I feel like I know what I'm doing. And generally I feel like I am capable". However, students also gave examples of their lack of confidence in their science capability as negatively impacting their feelings of belonging in the classroom. As Alan noted:

> Alan: I think it's just like, it's more of being unsure about how smart I am in relation to other people [...] I would question whether I'm as smart as other people. Yeah.
>
> Interviewer: Right. Was that in chemistry – like, a certain discipline or...?

> Alan: I think it's across the board, but especially in chemistry, where it's like, such intense coursework [. . .] I mean, when you're surrounded by a lot of smart people - especially when you're coming out of high school and you're a bit more of a big, big fish in a small pond and then you come to university and it's a everyone smart doing really well [. . .] but even moving through, you know, there's always a bit of it in the back of your head the whole way through.

Students' perceptions of their own capability has been identified as a contributing factor to 'belonging uncertainty' in the science fields (Höhne & Zander, 2019). While this is an effect that is typically more prominent within female students in the male-dominated science fields, it is important to note that male students may also experience belonging uncertainty due to their self-belief in their science skills, as demonstrated by the previous example given by Alan. In contrast, the female students within this study self-identified as having high levels of belonging and confidence in their abilities. One male student, James, even noted that in general female students in his classes were "further ahead [. . .] performance wise [and] grades wise".

Interest and passion

Interest and passion was a sub-theme that arose when students were defining the concept of science identity. Half of the students ($n = 5$) discussed this concept in the science identity portion of the interview. This primarily arose from students claiming they were passionate or loved their science field, as Millicent noted:

> I want to say I have a fairly strong, yeah, science identity, um, in that, yeah, science is something I've always wanted to do and it's like, the only subject at school that I was like really dead set sure that like that was what I liked. And like that is what I was interested in, like the path that I wanted to go down.

All students in this study that discussed their interest or passion in the science fields mentioned that this interest started early on in their life. For some it was in a school setting, with Matthew claiming that "[biology] was [his] favourite subject in Year 12". While others mentioned it was something that began earlier than this, with Victoria and Michele both commenting that science was something they were interested and passionate about since a "very young age". This is to be expected as previous research has shown that the interest to pursue the sciences begins at the early secondary school level for many students (Maltese & Tai, 2010).

The theme of interest and passion only arose when students were discussing their science identity. As the theoretical framework of science identity continues to develop, there has been a recent call for an "interactionist approach" to this theory (Kim & Sinatra, 2018). This approach acknowledges how constructs, such as interest and belonging, contribute to an individual's science identity. While interest was only discussed in relation to science identity in this qualitative study, it has been found that personal interest is also a contributing factor to students' belonging in the science fields (Rainey, Dancy, Mickelson, Stearns, & Moller, 2018). In their interview study with college seniors, Rainey et al. (2018) reiterated that interest in science for women and students of colour contributed to students' intentions to major in the sciences, but was not the cause of their attrition from these fields. Findings from this current qualitative study reiterate the effect the internal factor of interest and passion has on the affective domains, but that it is likely a factor that is developed prior to the university experience.

Curiosity

When discussing their interest and passion in science, students often linked this theme to their inherent curiosity and inquisitiveness. Three students discussed curiosity when defining the concept of science identity. As one female participant, Victoria, noted when defining the concept of science identity:

> I think it's just a passion and curiosity for wanting to know more about the natural world around you, and always asking those questions [...] and wanting to understand why and then pushing yourself to understand more information further. I think that is one of the key characteristics. So this natural inquisitiveness [...] if you lack that curiosity about it, I don't really understand how you'd be a scientist, because part of being a scientist is, is kind of making - like - getting understanding. So everything around us and trying to explain it. So I think that's probably fundamentally, what makes a scientist.

Michele also followed this theme by noting:

> I've been passionate about science since a very young age, and I've always been very inquisitive [...] Curious about the science world, I guess. So I guess I strongly

> identify with science.

The link between curiosity and interest has been found in previous studies when investigating student engagement in science. Skinner, Saxton, Currie, and Shusterman (2017) combined the two concepts when applying self-determination theory to student engagement when conducting STEM academic work. In their study, a key part of engagement was attributed to enthusiasm, with the core components being interest and curiosity (Skinner et al., 2017). Previous studies have also highlighted curiosity as being a key component of undergraduate students' perceptions of a scientist (Li & Loverude, 2013; Schinske, Perkins, Snyder, & Wyer, 2016). For example, in a study by Schinske et al. (2016), it was found that college students commonly reported 'curious' as a key descriptor of a scientist. The current qualitative study reiterates this effect, demonstrating that curiosity is another internal factor contributing to students' definitions of science identity.

'Doing' science

A minor theme that arose when defining science identity was the concept of 'doing' science, with students commenting that "the act of doing science" made someone a scientist. This was a minor sub-theme discussed by two participants. As Sally-Ann noted:

> I guess, people always joke [...] we're scientists, simply because we're doing science. And that seems to be the major theme. I guess there is, to some extent, an idea of like, [...] you're taking a model and you're trying to find something out. But for the most part, I think it's just the act of doing science reflects on people's feelings of being scientists.

This theme was echoed in Thomas' definition of his science identity, stating that: "I would identify myself as a scientist. I do science academics and the rest of it.". The definition of a scientist as being someone who does science has mixed findings in the literature. For example, findings from a study by Archer et al. (2010) on elementary school children demonstrated a clear distinction between "doing" science and "being" a scientist. However, the concept of doing science does tie in with the performance aspect of the previously discussed science identity framework (Carlone & Johnson, 2007), which demonstrates that to have science identity students must also perform relevant scientific practices to their peers. Though a minor theme within this current study, the act of doing science appears to be another internal factor that students attribute to their ability to identify as a scientist.

A sense of belonging

The final internal factor discussed in this qualitative study was the concept of a sense of belonging, with this factor being mentioned by six participants. Most participants commented on positive feelings of belonging in the sciences while at university. Several female participants directly linked this feeling of belonging due to the higher percentage of female students in their science fields. As Millicent noted:

> ... I've never felt like I don't belong, but that could be as well just because there are more girls and so I do have more friends in those classes.

Sally-Ann reiterated this point, identifying positive feelings of belonging due to "similar proportions of men and women" in the classroom. This concept ties into one of the external factors of gender ratios in the classroom, which will be discussed in-depth in the following section. This link between a positive experience and equal gender ratios in the science classroom has been found in previous Australian studies on undergraduate science student cohorts (**Chapter 5**; Fisher, Thompson, & Brookes, 2020b).

While most students discussed belonging when explicitly asked, one female participant mentioned this concept when discussing their science identity. Millicent, who identified herself as having "fairly strong science identity", noted different experiences of belonging when in a non-science compared to a science classroom:

> ... I did a politics unit, and like those made me a lot more uncomfortable [...] I wasn't uncomfortable at all in those units. Where in science, like in the classrooms and stuff like that, like I do feel, yeah, just more confident and more like that's where I'm meant to be.

As previously mentioned, belonging and science identity are two factors that are known to interact (Kim & Sinatra, 2018). Some participants discussed belonging and science identity interchangeably when mentioning their belonging in their science field. As Victoria stated, "I feel like I belong in the community. I feel like I am a scientist". One female participant, Cleo, addressed this overlap between these two concepts when discussing her feelings of belonging in a science classroom:

> ...I wouldn't say I don't feel like I belong. I just, it's hard to feel like you identify with something when you don't see anyone who looks like you doing it.

This above example also highlights the importance of role models when discussing science identity and belonging, which was a prominent external factor discussed by participants and will be discussed in the following section. Overall, the internal themes discussed in this section identify important factors for undergraduate science students when defining their science identity and belonging in the sciences. From the above discussion it is clear that these factors do interact and the process of identifying as a scientist and developing one's belonging in the science fields are dependent on one another and impacted by a myriad of internal factors.

External factors

External factors were themes classified as environmental factors that may impact students' development of their science identity and belonging, as well as their experiences of bias in STEM. Within this study, four themes were classed as external factors. These were role models, stereotypes, experiences of discrimination, as well as gender ratios in the university classroom.

Role models

When discussing external factors that impact science identity, belonging and experiences of bias in science, role models emerged as a sub-theme that was discussed across all sections. Almost all students ($n = 7$) discussed the sub-theme of role models when discussing the concept of science identity. Within this section, some students noted the positive impact role models can have on students' science identity, with Millicent commenting that students "do have a lot of role models in a lot of [their] unit coordinators". Another male student, Matthew, highlighted the positive impact that family role models can have:

> ... my mom was a nurse for like 20 plus years. So I've always been around the hospital setting and like learning about diseases and infection and everything. So I really loved science. And I kind of knew that since a young age.

Several students ($n = 3$) also discussed the positive impact of role models on their sense of belonging in the sciences. Similar to science identity, examples of role models were derived from both parents and teaching staff. As Michele highlighted:

> I feel like I've had a good upbringing with my parents and all that and they've always encouraged me to pursue what I want to do. And I guess I'm fortunate that way because like, I was one of those kids who was allowed to have science toys, and do more stereotypically, like, male things, I guess, in the science field.

Conversely, students also discussed the negative impact role models can have on both their belonging and science identity. Most examples related to how role models at university, such as teaching staff, were hindering the ability for science students, particularly women, to identify as scientists. This observation was discussed by both male and female students. As one male student, Thomas, noted:

> [. . .] a lot of the academics, a lot of the research that is done is still male dominated. So I can definitely see females struggling, for example, to see themselves in higher positions and actually becoming those renowned kind of scientists that we see in, you know, history but even today.

Millicent, who had noted the positives of unit coordinators as role models, gave examples of how teaching staff can also negatively impact students' science identity through their teaching practices:

> . . . like some male unit coordinators that I don't, I don't think they mean to come across like, as so... Sometimes a bit like condescending in like, kind of explanations and stuff [. . .] it's kind of like more of a broad overall thing is like universities might just be like getting money and they might sometimes not look at you and see like a researcher or like a, like promising future kind of thing. Like, I think sometimes there are some that just are trying to get you through the unit and get you through this, get you through your degree and like get you out kind of thing.

This opinion was echoed by Cleo's experiences when discussing role models' teaching practices and how they impact on her feelings of belonging in a science classroom:

> I'm used to very small classes where people, the Professor knows your name and you talk to them and you go to the office hours and like have a relationship with them. But here you're in a lecture hall and your professor doesn't know you from the person next to you and I think it's, it's hard to feel like it's targeted or not targeted at any particular person just because you're all just the audience.

The effect of role models, specifically teachers and parents, on students' intentions for a STEM career has been established in the literature (Rodd, Reiss, & Mujtaba, 2013; Sjaastad, 2012). Role models have been shown to be important for the development of students' science identity. Mentoring programs, which provide students with access to role models in STEM, are a key part of initiatives to increase undergraduate students' science identity (Atkins et al., 2020). The positive impact that role models have on students' belonging has also been supported by previous research. Shin, Lee, and Ha (2016) found that role models presented to STEM students that challenged stereotypes increased their sense of belonging and self-efficacy in these fields. Findings from this current study reiterate that role models are a key external factor impacting the science identity and belonging of undergraduate science students.

The concept of role models also emerged when students were discussing bias in STEM ($n = 3$), particularly when discussing where this bias arises from. One female student, Victoria, commented that "people who are more senior, are more likely to disrespect your view... because of your gender". Cleo echoed this opinion when reflecting on her mother's experiences in the sciences:

> ...the professors who are her age are worse to each other than, like, peers with my peers are to each other. Which is interesting to see, because they don't show it to the students.

In the above examples, students were referring to senior academics, however one female student, Michele, also discussed the impact that pre-university staff can have:

> I did go to a very small school and it was rural [...] And I guess, they might be quite behind with like, their views on equality and stuff because see I had some male teachers and they were the careers coordinators as well. And they were actually saying to us girls, like, "Oh you're the second home providers, you don't need to get a good career", like "get a husband to provide for you", and they were telling some of us girls like, "Oh, you'll never get into science or biomedicine or whatever you want to study". And, it was just very off putting.

This effect of undergraduate science students facing discrimination from their professors has been found in results presented in previous chapters of this thesis. This is of concern as these experiences of discrimination and bias by teaching staff may be preventing female science students from continuing in the science career pipeline after university.

Stereotypes

The stereotypes sub-theme was very closely linked to the discussion of role models within the section of science identity, with this factor discussed by three participants. This is due to students often discussing stereotypical role models of what makes a scientist. For example, "crazy guy in a lab coat" and the "male mad scientist figure" were some of the descriptors students used to describe the stereotypes behind what society thought was a scientist. These stereotypes appear to be held by the general public and those outside of their science degrees, with Cleo stating that "when people find out that you study science, their whole attitude towards you changes a little". As another example, when Alan was discussing the stereotype of the "whole crazy guy concept which might drive females away" he mentioned that this was more prominent in the high school environment:

> Yeah, I mean, I think it's like a mix between teachers who don't understand that science is a lot more than that, because they might have just gone straight into education, but it's also like a media thing. I mean, that's like the perception of scientists in general.

Previous research has demonstrated that the stereotype of the "male mad scientist" appears to begin from an early age, and though it may be decreasing in prevalence, individuals picturing a man when describing a scientist is still engrained in society (Miller, Nolla, Eagly, & Uttal, 2018). The impact that stereotypes have on female students' feelings and persistence in STEM is an established effect in the literature (Schuster & Martiny, 2017). Cheryan, Siy, Vichayapai, Drury, and Kim (2011) demonstrated that interacting with role models who embodied the stereotypes of a computer scientist (e.g., stereotypical clothing and hobbies) negatively impacted female students' belief that they could succeed in this field. The examples provided in this qualitative study highlight that students acknowledge that these stereotypes are still present, but may be more of an issue for those outside of their university classes. Therefore, while it is an effect to be aware of, the implications for improving undergraduate student experiences in the sciences with regard to this sub-theme is limited.

Discrimination

Several students ($n = 6$) did discuss experiences of gender bias or discrimination. Some of these examples were first-hand accounts at university, while others were second-hand experiences from peers, friends or family. One female student, Sally-Ann, discussed feeling discriminated against by her peers based on her appearance:

> I guess aside from having people like, comment on "Oh, you don't dress like a scientist." – I often wear very loud makeup and have a somewhat vintage fashion and style. Yeah, like aside from those comments occasionally, but they're quite, like, they've always been rare and they've never been from, you know, people who would - like staff. They've been occasionally from, like, other students or other, like, people who sometimes weren't even in science degrees just coming from other departments. "You don't dress like a scientist." But I mean, aside from that, I'd argue that I, I haven't personally ever experienced any like, or any discrimination.

This example was highlighted in the related study of this work, with female students in the more male-dominated science fields experiencing discrimination from their male peers in regards to them looking like a scientist (**Chapter 6**). This experience of discrimination ties in closely to the concept of science identity and the stereotypes of what a scientist looks like. The effect these stereotypes have on the persistence of female students in the STEM fields has been touched on previously, with this sub-theme reiterating the stereotypes that remain in the science fields.

Other stereotypic beliefs also drove some of the discriminatory experiences in this study. For example, the implicit bias that men are more suited to science than women. This was highlighted in an example by Victoria:

> I know that I've seen examples where - um - in a group we've been - we came to the same conclusion. And then I suggested the answer to the professor. And he was like, "No, that's not correct". And then my peer, who happened to be male, suggested the same answer. And he said, "that's perfectly correct". And that was, yeah, that was annoying.

Other discussions of discrimination towards women in science were from second-hand accounts. For example, Millicent commented on her friend's experience in engineering who was "bound to cop something" in a first-year classroom. Sally-Ann also discussed her experience compared that of her friends in the more male-dominated science fields:

> Sally-Ann: I know that, that definitely changes for some of my other friends who are in different areas of science definitely have and they're, like, not very impressed by it. [...] I've very much gotten lucky in biology and chemistry where people are very much like, well no. Why, Why would we care?
>
> Interviewer: ... So what fields are your friends in? Those ones who have experienced it?
>
> Sally-Ann: Engineering and computer science. [...] The ones where I also I think people still hold on to them more is like this is a masculine field as opposed to this is a feminine field where chemistry and biology don't really care, or biology I think some people have the idea of, but there's flowers. So it's feminine. Sure. Okay..

These experiences of discrimination also arose when students discussed their feelings of belonging in the STEM fields. Michele did discuss a lack of a belonging, specifically due to experiences of sexism:

> ... when I was doing physics in first semester, there were these - in our lab groups there were mainly guys, there was two other girls in my group and about five guys or something. And the - they didn't really interact with the other girls as much but then with me they'd say comments to me like, "Oh, we can't take you seriously, because you're so pretty." and stuff like that. And it's really off putting it's like, I don't go to this class to get hit on. And it's not a compliment anyway, it's just rude.

Similarly, Victoria commented on receiving "a lot of unwanted attention" when in her science classes, which subsequently impacted her feelings of belonging in this fields:

> Victoria: With the IT portion [...] I feel like a part of the community, but I'm not treated as if I'm part of the community - if that makes sense - by the community, so...
>
> Interviewer: Right. So, in what way...?
>
> Victoria: There's been times in classes where I've been - kind of - I've received a lot of unwanted attention in IT classes because I am female, because there's not necessarily other females in the class. So I'm not necessarily treated - as it is you go to class and it is academic and all that I'm not necessarily treated with the same regard they would have for their other peers.

Experiences of discrimination or bias are known to reduce the engagement of female STEM students (Moss-Racusin, Sanzari, Caluori, & Rabasco, 2018). The findings from this qualitative study reiterate the impact these experiences have, particularly on students' feelings of belonging.

Gender ratios in the classroom

The last sub-theme to arise in external factors impacting the student experience was gender ratios in the classroom, which was discussed by three students. This was discussed in both the belonging and experiences of bias sections of interviews. Students often linked positive experiences of belonging closely to the greater presence of female students in some of these fields. Comparisons were also made between fields with fewer female students present (i.e., engineering, physics). As Millicent noted:

> ...there is like a lot of girls in the classroom. [...] I've never felt like I don't belong, but that could be as well just because there are more girls and so I do have more friends in those classes [...] I think when you do get like more of like the engineering sciences and stuff like that when they are like, more like - I think when, yeah, the scales kind of tip and there's like more boys than girls then I think it could, like some girls could possibly not feel like they belong.

Students also linked a lack of potential discrimination and more equal gender ratios in the classroom. When asked if female students would experience discrimination in their field, Matthew answered: "I would say no, because most of them are actually female". Students equating a lack of gender issues due to increased presence of female students was a common theme to arise in the previous chapters of this thesis as well.

Overall, these sub-themes highlight what external factors are impacting the science identity, belonging, and gender discrimination faced by undergraduate science students. While some of these factors, such as stereotypes of what makes a scientist, are hard to control, reiterating the importance that role models, in particular teaching staff, play in making science students feel welcome and increase their identity as a young scientist is important.

Summary

The first aim of this qualitative study was to understand how students define the concepts of science identity, belonging, and experiences of gender discrimination during a university science degree. These factors were selected to be investigated in the first phase of this mixed-methods project as they had been previously identified as known risk factors for student attrition, particularly so for female students in the science fields (**Chapter 6**). To answer the first research question of this study, students identified several themes when defining the concepts of science identity and belonging, and discussing their experiences of bias in STEM. Students' perceptions of their own and other's capability appeared to be a prominent factor when defining their science identity and belonging, suggesting that initiatives to continue to raise the self-efficacy of science students should continue to be implemented. Some of these factors identified as contributing to science identity, such as student interest, appeared to develop prior to university. This is of importance as it reiterates that interest is not driving the gender gap in university STEM degrees and beyond.

The second research question of this study was aimed at understanding how undergraduate science students perceive issues faced by female students in science. These factors were discussed predominantly in the external factors subsection. The effect of role models, both at university and outside a science classroom, was the most prominent theme, demonstrating the role that university staff play in increasing or decreasing the science identity and belonging of their female students. Stereotypes were also mentioned, highlighting the effect the view of the general public may have on women pursuing a science degree.

Implications

Findings from this qualitative study have several implications for future research. The external factors discussed have implications for intervention studies. A key part of recruiting and retaining more women in the STEM fields is to prevent any potential risk for attrition, such as low levels of belonging or science identity. As researchers and educators continue to implement initiatives to increase the belonging and science identity of their students, the external factors raised in this qualitative study suggest what domains these interventions should be focusing on. For example, one external factor that was very prominent amongst participants in this study when discussing their development of belonging and science identity was role models. Mentoring programs are typically the focus when discussing ways to expose students to role models and increase their persistence in these fields, particularly for women in STEM (Dennehy & Dasgupta, 2017; Reid et al., 2016). Yet, the findings from this qualitative study highlight the impact that teaching staff (i.e., lecturers) have as role models for their student cohorts, and how this may be impacting the affective domains of belonging and science identity. Universities also need to continue to be aware of the gender ratios in their teaching staff, with students often linking equal gender representation to a more equitable learning environment. Other external factors were identified that could be the focus of interventions for increasing belonging and science identity in student cohorts, such as how to reduce experiences of discrimination, but these will be discussed in length in **Chapter 8**.

In contrast to the external factors, the internal factors identified within this study highlight how students define these concepts of science identity and belonging. While a lot of these internal factors were interlinked, the core theme of capability and students' confidence in their capabilities was central to students' definitions and development of science identity and belonging. As stated previously, this ties in with the well-researched factor of self-efficacy. Bartimote-Aufflick, Bridgeman, Walker, Sharma, and Smith (2016) provide an extensive review of intervention studies aimed at increasing self-efficacy levels in university student populations. While these are not all aimed at science student populations, their discussion of teaching strategies to ensure high self-efficacy in students could still help in creating a more gender equitable classroom.

Overall, findings from this qualitative study highlighted factors impacting students' science identity and belonging development at the university level, while also identifying what factors may be impacting these domains prior to university. For example, the importance of interest and reducing stereotypes were factors that appeared to shape students' science identity and belonging prior to university, and so interventions and future research should instead focus on the impacts of capability, role models, and experiences of discrimination as factors at the university level.

Limitations

There were several limitations in this study. Firstly, students were mostly from the more "gender-balanced" science fields of biology and chemistry. Though some students were able to compare their experiences in some of the more male-dominated courses they had taken (i.e., physics and IT) further interviews with students in the more male-dominated science fields would help understand the complete science student experience. Additionally, participating students tended to be those with generally strong feelings of belonging and science identity. While these ten interviews revealed some interesting definitions of what belonging and science identity meant to these students, this study does not capture the experience of 'at-risk' students in the sciences and so further studies investigating the experience of students with lower levels of these affective domains is warranted.

It should also be noted that one student was an international visiting student from the United States (US) (Cleo). Therefore, their opinion does not necessarily reflect the Australian student experience. However, Cleo did contrast her experience between the US and Australia, highlighting the difference between these two Western contexts:

> . . . I feel like I've seen two very, very different experiences because my school back home is this tiny liberal arts private institution and there's only 2400 students and 60/40 women to men. And as far as gender inclusivity it's like the top of the tier. You know, like there's - we have gender inclusivity and STEM is like a club that I'm a part of [. . .] Then here, now I walk into my, my chem lab, and there's two other girls in the room. Wild to me, but yeah.

7.4 Conclusion

The aim of this qualitative study was to determine how belonging, science identity, and experiences of bias were contributing to the gendered experience of undergraduate science students and gather their perspective on how these may impact female student experiences in STEM. Findings highlighted a combination of internal and external factors occurring at the university level. Internal factors highlight how students conceptualise their science identity and belonging in the science fields, with the findings from this study suggesting that students' perceptions of their own capability could be an inhibiting factor. On the other hand, external factors highlight what interventions could be undertaken at the university level to improve the student experience with regards to belonging and science identity development. Role models and experiences of discrimination may impede students' science identity and belonging and contribute to their experienced bias in STEM. Future interventions could involve utilising female role models, promoting greater self-efficacy in their female science students, and target these experiences of discrimination faced by female students occurring in a university science classroom. Doing so will allow us to continue to improve the gender inclusiveness of the science undergraduate student experience.

Chapter 8

Integrative discussion

8.1 Summary of findings

The purpose of this final chapter is to summarise the core findings of this thesis, recommend directions for future research and outline implications for university science educators. The three primary themes of science identity, belonging, and experiences of discrimination will be discussed, alongside implications for practice and future research. Although other factors, such as self-efficacy, student persistence, and various other domains that emerged within the qualitative study of **Chapter 7**, these three factors are discussed as they are core domains across all data chapters of this thesis, and as such are the key findings of this research.

Science identity

Although an important factor impacting student persistence in the science educational and career pathway, science identity was an affective domain previously understudied in an Australian context (**Chapter 3**). Results from this thesis demonstrated that science identity levels were not different between the genders while at university within these study cohorts. This is in contrast to previous studies that have found lower levels of science identity in female science students from the very beginning of the university experience (Hazari et al., 2013; Kalender, Marshman, Schunn, Nokes-Malach, & Singh, 2019). The lack of this gender effect may be due to the large proportion of students within this study who had previous experience in the STEM fields at a secondary school level. Programs and experiences prior to university can help develop the science identity of students (Smith, Jaeger, & Thomas, 2019). It may also be due to using the term "scientist" within the science identity questionnaire, rather than discipline-specific terminology (e.g., chemist, physicist). This is particularly relevant within the physics fields, where the gender gap in identifying as a "physics person" has been found to be larger compared to other science fields (Hazari et al., 2013).

While there were no significant gender differences in levels of science identity found within this thesis, the role science identity plays in the persistence intentions of science students was highlighted. Overall, science identity played an important role for female science student persistence, whether these students were in a "gender-balanced" or "gender-unbalanced" science field. Additionally, this study highlighted a novel insight into the importance of science identity for male students in the "gender-balanced" science fields, with this sub-group of students presenting similar risk factors for attrition as female science students. Previous science identity studies have not investigated this effect for male students in these more "gender-balanced" science fields, and further research is warranted into the experience of male students in these fields.

Finally, the qualitative study within this thesis presented insights into how undergraduate science students define the concept of science identity. Students in this qualitative study discussed several internal and external factors that may impact their science identity. Notably, students' perceptions of their own competence and exposure to role models were prominent factors that contributed to their development of science identity, which is supported by the theoretical framework of science identity outlined by Carlone and Johnson (2007). Therefore, though science identity was previously understudied in an Australian context, this thesis highlighted the importance of this factor for student persistence in the science fields.

Belonging

Belonging was identified as another affective domain understudied in an Australian context at the start of this thesis (**Chapter 3**). In contrast to science identity, findings showed that significant gender differences in levels of belonging existed.

Specifically, lower levels of belonging were found in female students within the first few weeks of attending university (**Chapter 4**). This is an established effect in the literature, predominantly in the male-dominated science disciplines (Banchefsky, Lewis, & Ito, 2019; Good et al., 2012). However, findings from this study reiterate that this effect is also found in the more "gender-balanced" science fields of biology and chemistry.

In addition to these gender differences, belonging was another critical factor for the persistence intentions for undergraduate science students. Low levels of membership and acceptance, which are key domains in belonging, were found to be 'risk factors' for female students considering leaving their science major at university and the science career pathway (**Chapter 6**). Findings also highlighted that this effect was found for male students in the "gender-balanced" science disciplines. Previous studies have shown that belonging is a critical factor for persistence for students in gender-atypical majors at university (Tellhed, Bäckström, & Björklund, 2017), and findings from this current study reiterate that male students in the more "gender-balanced" science fields also present similar risk factors for attrition.

When investigating how students define the concept of belonging, students did discuss the important factor of role models, similar to when defining factors that impact their levels of science identity. Additionally, students within this qualitative study discussed how their experiences of discrimination could impact their belonging (**Chapter 7**). This also arose in the examples of discrimination given by female students in the quantitative phase of this project, with these examples involving their male peers often disregarding their contributions and making them feel less accepted in a science classroom at university (**Chapter 4** and **6**). Overall, these findings reiterate that belonging is a critical factor for student persistence in science, particularly so for women in these fields. Belonging also appears to be closely linked to the gender bias women face while at university.

Experiences of discrimination

The final factor studied in this project was experiences of gender bias and discrimination. This factor was chosen to be investigated due to the established impact it has on the domains of belonging and science identity. Throughout the studies in this thesis, experiences of bias and discrimination were reported by each of the genders investigated. The most common type of discrimination reported by female undergraduate science students was feeling like they were not respected, taken seriously or heard by their peers, particularly so by their male peers. These experiences were often linked to small group work in the classroom, with power imbalances within small groups, particularly with male peers, impacting their feelings of acceptance in their science classrooms. The implications this has for university classrooms will be discussed in the following section.

Experiences of discrimination were not solely reported by female students. Male students also reported experiences of gender bias while at university. These experiences commonly related to women only resources and opportunities that are being established to tackle gender inequality in STEM. Male resistance towards gender initiatives has been found in previous research (Handley, Brown, Moss-Racusin, & Smith, 2015). In an Australian context, research has found that Millennial males feel "excluded from measures to improve gender equality" (Evans, Haussegger, Halupka, & Rowe, 2018). Overall, findings from this thesis reiterate the need to include this sub-group in gender diversity discussions in STEM to prevent possible backlash towards these gender equity programs in the future.

Finally, transgender and non-binary students also reported experiences of discrimination while at university. While only a few transgender students shared these experiences, they did give an insight on some of the challenges this sub-group of students face at university and warrant further investigation.

8.2 Research limitations

One of the limitations with this research project is that due to the restricted size of the questionnaire, not all factors that may be contributing to this gendered experience could be investigated. For example, self-efficacy was excluded in this project, primarily due to findings from the systematic review (**Chapter 3**). Other factors that are well-known in the literature were not investigated in this project despite also being understudied in Australia. As an example, the strong altruistic beliefs in female students is a factor that has been shown to deter them from science careers (Wang & Degol, 2017; Weisgram & Bigler, 2006). Further research is warranted into these other understudied areas of the Australian literature to assess their importance in the undergraduate science student population.

Another limitation was that there are known science discipline-specific effects when investigating the factors in this study. For example, students are known to react differently when being identified as a chemist or biologist, and science discipline specific sub-scales to investigate affective factors has been identified as a gap in the literature (Trujillo & Tanner, 2014). Ideally, students in each science discipline would have been given a discipline specific questionnaire investigating their levels of identity and belonging within each of these fields. Due to the nature of how the questionnaire was delivered, this was not achievable but it is worth noting that discipline specific responses to these factors would be expected. This limitation also relates to the dichotomisation of science fields being classified as "gender-balanced" or "gender-unbalanced" during analysis. While it gives an insight into the experience of students in the more male-dominated science fields, it does assume that student experiences will be the same in the fields that are classified together (e.g., chemistry and biology).

Finally, methodological limitations within this project have already been highlighted in **Chapter 2**. For example, the non-random sampling approach to both the quantitative and qualitative data collection. To overcome this limitation in quantitative research, reporting on demographics ensured that the population studied reflected similar demographics to the population of interest. In the qualitative study, any findings were discussed in the context of the "gender-balanced" science fields, to avoid any bias in inferring results from this study to the general science student population.

8.3 Implications for practice

The findings from this study have several implications for educational practice. The first of these suggestions focuses on group work, as this was the most commonly discussed issue of discrimination reported by female science students. Previous work has proven that the active learning environment in a university setting, which typically comprises of small group work, is not gender equitable. For example, Aguillon et al. (2020) investigated gender differences in an introductory biology course, showing that despite there being a larger portion of female students, male students had a higher rate of participation in the classroom and in small group discussions. It has also been established that women in male-dominated small groups perform worse in these environments (Grover, Ito, & Park, 2017). In work by Sullivan, Ballen, and Cotner (2018), they found that increasing the percentage of female students in an introductory biology class actually improved the performance of students, regardless of gender. Overall, previous studies have shown that increasing the percentage of women in small group projects or environments has positive outcomes for others, regardless of their gender (Niler, Asencio, & DeChurch, 2020). Findings from this current study reiterate that group work in science classrooms at university present issues for female students and are something that science educators need to be addressing in their science classrooms.

One way to rectify gender issues in small group work is to prevent certain students 'dominating' a small group discussion. Consequently, intervention studies are being created focusing on how to implement more structured group work. For example, Theobald, Eddy, Grunspan, Wiggins, and Crowe (2017) showed that 'jigsaw activities' in group work, which involve more explicit turn-taking and prompts, resulted in more equitable outcomes. In their study, these activities resulted in fewer students reporting that one student dominated their discussion. While university science classrooms begin to transition to this active learning environment, utilising more structured group work environments such as this may aid in combating these issues. This is particularly relevant to female students within the studies in this thesis who commonly reported feeling unheard and unvalued in the classroom. Creating gender equitable small group work has additional benefits, such as potentially increasing students' feelings of belonging, as these experiences were found to be directly impacting their belonging in these fields.

Another way to make these classroom environments more gender equitable is to ensure that educators are also aware of these issues. In their research, Neill, Cotner, Driessen, and Ballen (2019) demonstrated that in chemistry undergraduate laboratories there were gender gaps in participation when interacting with Teaching

Associates (TAs). Overall, male students were found to participate more with teaching staff, with the authors making a call for more equitable training for TAs to help combat these gender inequitable classrooms. Further training for TAs and casual academic staff is an important factor to consider as they are often the ones running small group work activities in a university science classroom. Further gender equity training for staff would have subsequent benefits, as results from the qualitative study highlighted how teaching staff act as role models, which indirectly impact the development of students' identity and belonging in the science fields.

Students could also be educated on the gender inequality issues that remain in STEM. The majority of science students within this study did not believe that female students in science experience discrimination at university, a view that was also strongly held by male students. However, the examples of discrimination that arose in this study suggest that discriminatory experiences do exist, and as outlined in **Chapter 4**, this is occurring within the first few weeks of university for some female science students. Therefore, due to this disconnect, there is a need to educate students on these issues of bias/discrimination occurring to female students, occasionally by their peers but also by others in the university environment (e.g., teaching staff). Intervention studies that have set out to educate university students on gender issues in science do exist. A key example is the Video Interventions for Diversity in STEM (VIDS), which is an intervention developed by Pietri et al. (2017) to increase the gender bias literacy of undergraduate STEM students.

However, there are some drawbacks to this specific intervention. Firstly, it has been established that alerting female students of the bias they may face in STEM can have negative consequences. As Pietri et al. (2019) showed, when exposed to the specific VIDS intervention programme, female students had lower belonging and greater social identity threat compared to those not to exposed to it. Adjustments can be made to reduce some of these unintended consequences, such as reiterating to students that this bias can be overcome, but stereotype threat still remains a lingering negative impact of these bias literacy initiatives (Pietri et al., 2019). Secondly, it is important to note that the examples used in VIDS to increase gender bias literacy are focused around gender bias experienced at the workforce level in STEM. While this may raise awareness for students on the gender bias that remains in the STEM workforce, this may not directly translate to them being aware that this gender bias is also present in their university classrooms. Instead, there is a need to increase gender bias literacy of university STEM students in their current environments. Future intervention studies focused on increasing gender bias literacy in university populations could use the qualitative examples provided within this thesis, such as the issues surrounding small group work, to help educate students on these issues. This may be particularly beneficial to the sub-population of male students who have developed a resistance to the topic of gender inequality in STEM, as increasing their gender bias literacy may help combat this hostility that has developed towards this topic.

Findings from this thesis also highlight that intervention studies should be the focus moving forward, and are also needed in an Australian context. This study set out to capture a national snapshot of the gendered experience of undergraduate science students, and in doing so highlighted what factors educators and researchers can focus on when trying to reduce the gender gap in STEM. A key example is the well-studied domain of self-efficacy, which is a key factor for students' success and retention in the STEM fields. Gender gaps in self-efficacy within science student cohorts are well-established, yet they are still being reviewed in the literature (Henderson, Sawtelle, & Nissen, 2020). Instead of focusing on empirical studies that establish this effect, researchers should now be turning to intervention studies to rectify gender imbalances in the domains such as self-efficacy when trying to address gender inequity in STEM.

This is applicable for all the affective domains studied in this research. Interventions have been developed to raise the affective domains of belonging and science identity in university science students. For example for belonging, Marksteiner, Janke, and Dickhäuser (2019) developed an intervention involving a simple exercise that reiterated concerns or worries about belonging is common at the start of their university experience, which had positive short-term effects for these students. In the case of science identity, an intervention conducted by Schinske et al. (2016) demonstrated that showing students counter-stereotypical scientists in their homework resulted in enhanced science identity. These are just some examples of interventions being developed in a university science classroom, which could be implemented in an attempt to increase feelings of belonging and science identity within our STEM student populations. Focusing on intervention studies moving forward is particularly important in an Australian context, with findings from the systematic review (**Chapter 3**) demonstrating that intervention studies at the university level are limited.

8.4 Future research

Based on the above discussion and the findings presented in the previous chapters, there are several avenues for future research:

- Intervention studies in an Australian context on creating gender equitable active learning science university classrooms, with more equitable small group work.
- Further investigation into the opinion of male students towards diversity initiatives in STEM, particularly for male students who feel discriminated against by these programs.
- Further studies on the transgender and non-binary student experiences in university STEM degrees.
- Intervention studies in an Australian context on education initiatives on gender bias literacy, with a particular focus on the discrimination faced by students at a university level.

8.5 Conclusion

The aim of this thesis was focused on answering the question on how we can increase the persistence of female students in Australian science degrees. To answer this question, two sub-questions were posed. The first question aimed to answer what factors were associated with a "gendered experience" for Australian university science students. This was answered through the systematic review (**Chapter 3**), which identified that the lower self-efficacy in female students was the most prominent effect recorded in the Australian literature when studying a gendered effect in the university STEM student experience. Following on from this review, the factors investigated within this project (i.e., science identity, belonging, experiences of bias) all contributed to this gendered experience in the science fields. Within the qualitative study of this project, additional factors that contribute to the development of students' science identity and belonging were highlighted, such as the impact of role models. These findings demonstrate that there are more factors contributing to this effect that were not explicitly studied within the scope of this project.

The second research question of this thesis aimed to understand how experiences differ for the students in the "gender-balanced" science fields of biology and chemistry across the gender categories. Results showed that female students in the "gender-balanced" science disciplines faced similar challenges as female students in the more male-dominated science fields. In contrast, male students in "gender-balanced" science fields had different experiences regarding their belonging and science identity than their male counterparts in the more male-dominated science fields. This suggests that the experience in the "gender-balanced" science fields is not without its gender issues and should still continue to be a focus in STEM education literature moving forward.

Finally, the last section of this thesis within this current chapter highlighted implications for science educators and future research, outlining how we can work towards reducing gender inequity issues in STEM at Australian universities moving forward. Overall, this thesis highlighted the gendered experience that remains at a undergraduate level in the science fields, and how these experiences may be impacting women from becoming future scientists in Australia.

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Appendix A

Supplementary Material

Chapter 4

Theme	**Theme description**
No gender issues in science	Students reporting no direct issues of bias or discrimination while at university in the science fields so far
Discrimination	Students reporting personal experiences of discrimination while studying science at university
a. Against women	Female students reporting experiences of discrimination
b. Against men	Male students reporting experiences of discrimination
Gender imbalance in STEM	Students directly discussing gender ratios in science classrooms
Confidence	Students discussing issues of confidence or doubt in their ability in the science fields
Parents	Students discussing the influence of their parents
Transgender issues	Students discussing experiences relating to their transgender identity

Supplementary Table S1. Qualitative codes and descriptions.

Item	F1	F2	F3	F4	F5	F7	
In general, my interest in science is an important part of my self-image	0.724						
My interest in science is an important reflection of who I am	0.524						
I feel like I belong in the field of science	0.651						
I have a strong sense of belonging to the community of scientists	0.804						
I am a scientist	0.641						
I feel that I belong to the scientific community	0.867						
I consider myself a member of the scientific community	0.782						
I feel like I am part of the scientific community	0.838						
I feel a connection with the scientific community	0.793						
I feel like an outsider		0.346	0.489				
I feel accepted				0.507			
I feel respected				0.558			
I feel disregarded			0.731				
I feel valued				0.775			
I feel neglected			0.761				
I feel appreciated				0.784			
I feel excluded			0.784				
I feel like I fit in				0.606			
I feel insignificant		0.321	0.549	-0.371			
I feel at ease		-0.600		0.420			
I feel anxious		0.821					
I feel comfortable		-0.508		0.454			
I feel tense		0.779	0.326				
I feel nervous		0.758	0.304				
I feel content	0.333	-0.378		0.336			
I feel calm		-0.590		0.308			
I feel inadequate		0.484	0.403				
I wish I could fade into the background and not be noticed		0.302					0.676
I try to say as little as possible							0.698
I enjoy being an active participant							-0.607
I wish I were invisible			0.490				0.407
I don't think that my gender will affect how others view me in my major						0.642	
I don't think that my gender will affect how well I do in my major						0.723	
I think my gender and my major are very compatible							
I think I have experienced difficulties in my major because of my gender			0.371			-0.596	
I think my gender will be an important factor in the type of career I decide to pursue						-0.430	
I don't think I would pursue certain fields because of my gender							
Women in my major experience discrimination					0.826		
Women have a hard time succeeding in my major					0.849		
My major is more welcoming to men than it is to women					0.703		

Supplementary Material Table S2. EFA factor loadings.

F1 = science identity + membership, F2 = Affect, F3 = acceptance (-ve), F4 = acceptance (+ve), F5 = gender biased science majors, F6 = compatibility, F7 = desire to fade.

Demographic variable	***p*-value**
Ethnicity	0.28
First-generation student status	0.93
Previous science experience	0.13
High achieving student	0.42
Mature age status	0.22

Supplementary Table S3. Fisher's exact test (two-sided) for demographic variables.

Chapter 5

Measure	1	2	3	4	5	6	7	8	9	10	11
1. SE	-										
2. Sci Ident	0.384	-									
3. Memb	**0.500**	**0.628**	-								
4. Accept	**0.505**	**0.502**	**0.671**	-							
5. Affect	**0.634**	0.339	**0.532**	**0.801**							
6. Fade	**0.538**	0.324	0.376	**0.606**	**0.579**	-					
7. Compat	0.226	**0.498**	**0.522**	**0.678**	0.391	0.359	-				
8. Bias	0.159	0.336	0.185	0.204	0.236	-0.070	-0.098	-			
9. Sci Career	0.261	0.276	0.394	0.205	0.170	0.109	0.250	0.074	-		
10. Switch nonSTEM	0.035	-0.133	0.122	-0.026	-0.002	0.147	0.236	-0.098	**-0.228**	-	
11. Switch STEM	0.096	0.019	-0.082	0.140	0.027	0.301	0.295	0.145	0.347	**0.192**	-

Supplementary Table S1. Correlation analysis ρ values for male students (n=22).

Note: SE = academic self-efficacy, Sci Ident = science identity, Memb = membership, Accept = acceptance, Fade = desire to fade, Compat = perceived identity compatibility between gender and major, Bias = gender biased science major, Sci career = expectancy for a science career, Switch nonSTEM = considered switching to a non-science major, Switch STEM = considered switching to another science major. Correlations that are significant at the $p < 0.05$ level are bolded.

Measure	1	2	3	4	5	6	7	8	9	10	11
1. SE	-										
2. Sci Ident	0.095	-									
3. Memb	0.171	**0.529**	-								
4. Accept	**0.560**	0.319	**0.586**	-							
5. Affect	**0.477**	0.320	**0.498**	**0.577**							
6. Fade	**0.422**	**0.455**	0.203	0.297	**0.539**	-					
7. Compat	0.107	0.128	0.317	0.289	0.155	-0.321	-				
8. Bias	-0.003	0.014	-0.006	-0.154	0.143	0.234	-0.321	-			
9. Sci Career	0.018	**0.775**	**0.610**	0.336	**0.395**	0.296	0.200	-0.021	-		
10. Switch nonSTEM	**-0.362**	**-0.391**	-0.319	**-0.451**	**-0.413**	**-0.384**	-0.241	0.146	**-0.459**	-	
11. Switch STEM	**-0.388**	-0.079	-0.065	-0.244	-0.182	-0.287	-0.050	0.069	-0.089	**0.465**	-

Supplementary Table S2. Correlation analysis ρ values for female students (n=33).

Note: SE = academic self-efficacy, Sci Ident = science identity, Memb = membership, Accept = acceptance, Fade = desire to fade, Compat = perceived identity compatibility between gender and major, Bias = gender biased science major, Sci career = expectancy for a science career, Switch nonSTEM = considered switching to a non-science major, Switch STEM = considered switching to another science major. Correlations that are significant at the $p < 0.05$ level are bolded.

Chapter 6

Theme	Items	Reference
Science identity	In general, my interest in science is an important part of my self-image	(Chemers et al., 2011)
	My interest in science is an important reflection of who I am	
	I feel like I belong in the field of science	
	I have a strong sense of belonging to the community of scientists	
	I am a scientist	
Belonging	I feel that I belong to the scientific community	(Good et al., 2012)
1. Membership	I consider myself a member of the scientific community	
	I feel like I am part of the scientific community	
	I feel a connection with the scientific community	
2. Acceptance	I feel like an outsider	
	I feel accepted	
	I feel respected	
	I feel disregarded	
	I feel valued	
	I feel neglected	
	I feel appreciated	
	I feel excluded	
	I feel like I fit in	
	I feel insignificant	
3. Affect	I feel at ease	
	I feel anxious	
	I feel comfortable	
	I feel tense	
	I feel nervous	
	I feel content	
	I feel calm	
	I feel inadequate	
4. Desire to fade	I wish I could fade into the background and not be noticed	
	I try to say as little as possible	
	I enjoy being an active participant	
	I wish I were invisible	
Compatibility between	I don't think that my gender will affect how others view me in my major	(London et al., 2011)
gender and major	I don't think that my gender will affect how well I do in my major	
	I think my gender and my major are very compatible	
	I think I have experienced difficulties in my major because of my gender	
	I think my gender will be an important factor in the type of career I decide to pursue	
	I don't think I would pursue certain fields because of my gender	
Gender bias	Women in my major experience discrimination	(Ganley et al., 2018)
	Women have a hard time succeeding in my major	
	My major is more welcoming to men than it is to women	
	What percentage of students in this major do you estimate are women?	
Intent to leave STEM	I have considered switching majors to one that is not in science field.	(Perez et al., 2014)
Career intentions	I would like to have a career in science	(Stake & Mares, 2001)

Supplementary Material Table S1. Question items used in online questionnaire.

Sub-scale	**Cronach's α**
Science identity	0.81
Belonging - membership	0.89
Belonging - acceptance	0.90
Belonging - affect	0.88
Belonging - desire to fade	0.82
Perceived identity compatibility between gender and major	0.62
Gender biased science majors	0.85

Supplementary Material Table S2. Internal consistency of sub-scales (n=386).

Demographic variable	***p*-value**
Ethnicity	0.62
First-generation student status	0.25
High achieving student	0.47
Mature age status	0.08
Previous science experience*	0.03

Supplementary Material Table S3. Fisher's exact test (two-sided) testing for significant gender differences within demographic variables.

Note: *p-adjusted=0.21, using Bonferroni correction for multiple comparisons.

	"Gender-balanced" fields		"Gender-unbalanced" fields	
	Female	Male	Female	Male
Science identity	3.63	3.73	3.66	3.63
Belonging: membership	3.52	3.62	3.51	3.45
Belonging: acceptance	3.73	3.68	3.56	3.67
Belonging: affect	3.32	3.41	3.25	3.43
Belonging: desire to fade	3.61	3.57	3.42	3.38
Perceived identity compatibility between gender and major	3.74	3.80	3.53	3.81
Gender biased science majors	2.50	2.15	2.92	2.52
Intent to leave STEM	2.33	2.69	2.51	2.81
Career intentions	4.21	3.98	4.29	3.83

Supplementary Material Table S4. Mean sub-scale values for male and female students within the "gender-unbalanced" and "gender-balanced" science disciplines.