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RESEARCH ARTICLE

Factors Affecting Students' Sense of Inclusion in the Undergraduate Engineering Programme at Waipapa Taumata Rau The University of Auckland

Priyanka Dhopade[1] | James Tizard[1] | Penelope Watson[2] | Ashleigh Fox[1] | Tom Allen[1] | Hazim Namik[1] | Aryan Karan[1] | Rituparna Roy[3] | Kelly Blincoe[1]

[1]Faculty of Engineering and Design, Waipapa Taumata Rau University of Auckland, Auckland, Aotearoa New Zealand

[2]Faculty of Arts and Education, Waipapa Taumata Rau University of Auckland, Auckland, Aotearoa New Zealand

[3]Institute for Population Research, Te Whare Wānanga o Waikato University of Waikato, Waikato, Aotearoa New Zealand

Correspondence
Priyanka Dhopade
Email: priyanka.dhopade@auckland.ac.nz

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Abstract

Background: Women, ethnic minorities, and LGBTQIA+ people have historically been excluded from the engineering profession. When they do pursue engineering, they often face challenges both within education and industry. Retention is a growing issue; for example, women in industry have significantly higher turnover rates than men.
Purpose/Hypothesis: Feelings of belonging, satisfaction, and perceptions of one's future career are important for retention in engineering education. However, there is little known about the factors that impact these constructs in tertiary education, where foundational engineering experiences occur, for a range of potentially intersectional social identities, in contexts other than the United States.
Method: We designed an online questionnaire (n = 379) and a series of focus groups (n = 17) with engineering students at Waipapa Taumata Rau (The University of Auckland) in Aotearoa (New Zealand). We applied thematic analysis to extract a list of common factors that influenced students' experiences in this unique context.
Results: Students who were unsure of or did not want to disclose parts of their identity reported the lowest sense of belonging and satisfaction. The factors that specifically impacted historically excluded groups included unsupportive working environments, not being respected academically, and exclusionary course content.
Conclusion: Our findings identify factors that contributed to students' experiences which may impact retention in Aotearoa and have implications for other contexts. Finally, we make recommendations to engineering education practitioners on how to support (and retain) students from historically excluded groups, including dedicated learning and social environments, inclusive course content, and awareness education on inclusivity.

KEYWORDS
engineering education, belonging, inclusion, thematic analysis, undergraduate

1 | INTRODUCTION

Despite the recent push to increase diversity in many countries, engineering jobs remain dominated by white men. This is also the case in Aotearoa New Zealand, the setting of this study, where only 14% of engineers are women and less than 5% are Māori (the tangata whenua or Indigenous people of Aotearoa New Zealand) or Pacific Peoples (people from different Pacific Islands including Fiji, Samoa, Tonga, Niue, Tokelau, among others) according to statistics from Engineering New Zealand's Diversity Agenda (The Diversity Agenda, n.d.). Decisions to leave engineering can be made in the earliest undergraduate years and people in marginalised groups are especially at risk of such attrition (Seymour et al., 2019). The retention of people from historically excluded groups in engineering *and* engineering education is as critically important in Aotearoa New Zealand as elsewhere.

Aotearoa New Zealand has seen many recent initiatives aimed at increasing the pipeline of women, Māori, and Pacific Peoples into tertiary engineering programmes, including targeted scholarships and mentoring or networking groups (Mitchell, 2006; Richardson et al., 2017; Snell & Snell-Siddle, 2018). However, retention in these programmes is equally important for the diversity of future engineering workforces. Recent research has highlighted that the STEM learning environment in Aotearoa New Zealand is hostile and culturally unsafe for Māori and Pacific students (McAllister et al., 2022). Yet, there is little research on retention in engineering education that has been conducted in Aotearoa New Zealand.

Much of the research into attrition and retention in engineering education has been conducted in the context the United States of America. Caution has been voiced that measures to address issues of attrition and persistence in engineering could be more effective if tailored to specific groups (Navarro et al., 2019). Moreover, uncertainty as to whether interventions would be universally applicable or inclusive of all groups has been expressed (Craps et al., 2022), and researchers have called for studies that consider the intersectionality of race/ethnicity and gender (Liani et al., 2020; Marra et al., 2012; Skvoretz et al., 2020). Thus, in the current study, we examine in more detail factors that could impact engineering student retention in Aotearoa New Zealand. We study engineering students' sense of belonging, satisfaction, perceptions of their future career, and positive and negative experiences during their studies, in a novel multi-racial context. We consider multiple demographics in our analysis, including gender, ethnicity, sexual orientation, and impairment status. The study was conducted through an online questionnaire and a series of focus groups with engineering students at Waipapa Taumata Rau (The University of Auckland). Preliminary results from this work were presented at the 2024 Network Gender and STEM Conference (Dhopade et al., 2024).

We were guided by the following research questions:

RQ1: How does sense of belonging, satisfaction, and perceptions of future career of engineering students at Waipapa Taumata Rau (The University of Auckland) vary across demographic characteristics (for example, gender, ethnicity, sexual orientation)?

RQ2: What are the key factors that influence the experiences of engineering students at Waipapa Taumata Rau (The University of Auckland)?

RQ2 is intentionally general, and the resulting factors were inductively analysed and categorised into meaningful categories to reduce bias and aid in future intervention design.

1.1 | Literature Review

Researchers have sought to understand factors that affect attrition and persistence, or retention, in undergraduate science, engineering, and mathematics (SEM; later with the addition of technology, STEM) courses for over three decades (Seymour & Hewitt, 1997; Seymour et al., 2019). In a three-year qualitative seminal study of SEM undergraduates in a range of U.S. tertiary institutions, Seymour and Hewitt (1997) identified factors contributing to SEM student attrition, documenting the experiences of men students of colour and women of all races/ethnicities in comparison to white men. While overall undergraduate course attrition was lower in engineering (38% as compared to 51%-53% in SEM), men of colour and women of all racial/ethnic groups were inequitably represented (Seymour & Hewitt, 1997), and this has not changed since the 1990s (Seymour et al., 2019). Previous research concentrated on the attrition of high-ability women (Bressoud et al., 2015), but there was minimal study of the attrition of students of colour in engineering.

Seymour and Hewitt's (1997) findings suggested that it was not a lack of ability or personal inadequacy that affected students' decisions to leave STEM majors, but four key environmental 'push' factors. These were problems in course design, such as overwhelming course load, poor quality teaching, negative class climate, and difficulties in securing help with academic challenges where a lack of connectedness compromised support (Seymour & Hewitt, 1997). Seymour and Hewitt also acknowledged that 'pull' factors such as interest being superseded by attractive non-SEM alternatives were at play. Importantly, women, students who were first in family to attend university, and students of colour were those most affected and at risk in their entry year, and, at that stage, negative class climates were notably pronounced (Seymour & Hewitt, 1997). Overall, negative racial and gender class climates and institutional cultures sabotaged the opportunity for success especially for men of colour and women of all races/ethnicities (Seymour et al., 2019) and led to a lack of sense of belonging that challenged persistence (Strayhorn et al., 2013; Tate & Linn, 2005).

Student goals and expectations were a key factor. Men of colour and women of all racial/ethnic groups ranked altruistic reasons as key to their choice of SEM course. Women's goals were less materialistic than their men counterparts, and students of colour acknowledged serving their families and communities as core goals (Seymour & Hewitt, 1997). Notably, Seymour and Hewitt found that specifically in engineering, students had little idea of what professional engineers actually did. Consequently, internship experiences that were at odds with expectations could be the final straw in decisions to leave the field.

Another factor was the disconnect with student identity. Seymour and Hewitt (1997) reported that women believed they could only achieve success by losing traits associated with traditional notions of femininity. Some students perceived that they would have to develop a persona that was foreign to them (e.g., introverted, single-minded, and perfection-oriented). Stereotypical notions of masculine traits associated with engineering (e.g., brilliance and agency) have caused women to doubt whether they belonged in the field (Storage et al., 2020). Importantly, increased representation of students in historically excluded groups in STEM courses have led to more equitable outcomes for all students (Bowman et al., 2023), indicating that representation and belonging is critical in tertiary education, not just for retention but also for outcomes.

No gender difference was found in preparation to enter STEM, including engineering (Hunter, 2019). However, key among the seminal findings of Seymour and Hewitt (1997) was that loss of confidence and lowered self-esteem was a major cause for women leaving SEM fields. The culture of engineering, comprising shared values and norms, such as meritocracy and individualism found in Seron et al.'s (2018) American study, could promote an unrealistic standard of exceptionalism that women must meet. This could result in reduced confidence in an environment that prizes technical competence, while undervaluing social skills and social responsibility (Besterfield-Sacre et al., 2001). Women also reported more negative experiences during teamwork and inequality of opportunities during internships with respect to more technical engineering tasks associated with 'real' engineering (Besterfield-Sacre et al., 2001; Seron et al., 2018). Students of colour too attributed their decision to leave their SEM field of study to lack of confidence, and blamed themselves rather than institutional factors for their difficulties (Seymour & Hewitt, 1997).

Of note was a decrease in student satisfaction with the competitive class climate across all STEM fields (Hunter, 2019). This climate caused isolation and failure to develop a sense of belonging and was greater among women of all races and ethnicities and men of colour (Hunter, 2019). Women had expectations of quality teaching comprising of warm, helpful instructor-student interactions, and, where this was not enabled, the women students felt discouraged (Seymour & Hewitt, 1997). Later research noted that positive teacher-student interactions were key to engineering success for women, and especially women of colour (Johnson, 2007; Zhang & Allen, 2015). Yet, subtle threatening behaviours were found in the classroom, for example, sexist actions or exclusionary behaviours by even the teachers themselves (Seymour et al., 2019).

Three decades after Seymour and Hewitt's seminal study, there has been a slight improvement in rates of STEM student persistence in the U.S., but engineering has had the smallest increase (Weston, 2019). Attrition from undergraduate U.S. engineering courses in 2011 was 21-23% (Chen & Soldner, 2013; Eagan et al., 2014). However, students of colour and women continued to encounter multiple compounding concerns that were reported at higher rates than white men (Hunter, 2019). Engineering ranked among the top STEM disciplines where compromised belonging was a risk factor associated with attrition, and this was most notable for women and students of colour (Holland, 2019). Women comprised 19% of U.S. engineering degree completions but only 13% of that country's workforce (U.S. Congress Joint Economic Commission, 2012).

The question arises, then, as to why the attrition of men of colour and women in general is still greater than for white men in the U.S. despite evidence of progress to ameliorate this pattern (see Seymour & Fry, 2016 for a review) for almost three decades. Additionally, it could be asked whether such patterns are found in other contexts, and whether previous interventions may be universally applicable, or are indeed still relevant. Seymour and Fry (2016) gave credit for the 16% drop in STEM undergraduate attrition rates over the two decades following the study of Seymour and Hewitt (1997) to efforts in curricular and pedagogical reforms. However, as the improvement has not been equitable for all groups, it is suggested that emphasis must now shift to change at institutional and departmental levels (Fan et al., 2021; Holland, 2019). Particularly, further investigation must prioritise understanding the reward of high-quality teaching (e.g., that which fosters warm and supportive teacher-student interaction), a fine-tuned understanding of why STEM students, including those in engineering, still leave, and investigation to better understand the impact of under-preparation on attrition (Holland, 2019).

Despite the compelling nature of this comprehensive body of research, a tension exists in that the vast majority of it has been conducted in the U.S. context. Thus, internationally, interventions, changes to policy and practice, and removal of systemic barriers to equitable inclusion for students from inequitably represented ethnicities, genders, and impaired abilities must largely be based on data from one context: that of the U.S. Contemporary influences on motivation to persist (e.g., belonging) for inequitably represented engineering students in international contexts has, for the main part, been unexplored. We could find only two recent studies that addressed undergraduate STEM and specifically engineering students' motivation in cross-national contexts: Gottlieb et al. (2024) and de Souza Santos et al. (2024), and these only partly informed our specific research topic.

Based on an earlier conceptualisation of expectancy value theory (Eccles & Wigfield, 2002), Gottlieb and colleagues tracked a large sample of secondary STEM students (including engineering) through to tertiary level, across a range of national contexts. Gender equity and egalitarian notions dominated the expectancies and task values of both men and women (Gottlieb et al., 2024). However, for women, these beliefs were at odds with socio-cultural influences that affect belonging, including institutional structures, and this restricted their participation in engineering education (Gottlieb et al., 2024). Although the authors found generalisable gendered motivational tensions that mirrored prior U.S. research (e.g., Seymour et al., 2019), how those tensions might play out in terms of gender diversity, ethnicity, and impairment of ability were not explored.

Broader light was shed by de Souza Santos and colleagues (2024) on challenges to belonging encountered by software engineering students from a range of gender groups and ethnicities in 20 national contexts. Despite a small sample size (n = 89), quantitative and qualitative survey data revealed that hostile environments, limited representation, and systemic biases hindered a sense of person-environment fit and confidence for academic and professional success. Interestingly, key motivators differed by ethnicity and gender group (de Souza Santos et al., 2024). Hispanic software engineering students, for example, were motivated by the social impact of technology, the African American cohort demonstrated the most varied set of motivators, non-binary participants required a much more personalised approach to motivation, women's key motivator was self-improvement, and men's motivational focus was on technical advancement. In terms of central influencers, family members were of core importance for women, Pacific Islanders, and gay participants. Men held technical influencers in highest esteem, and friends were central influencers for Pacific Islanders (de Souza Santos et al., 2024).

Taken together, these recent cross-national findings suggest that trends in prior U.S. research into persistence and attrition in tertiary STEM education (including engineering) are reflected in other contexts. Importantly, the findings indicate that understanding specific demographic variations is key to addressing inclusion in engineering education for diverse gender groups, ethnicities, individuals with impaired abilities, and indeed intersectionality between these social identities, and require much further contextual research. Specifically, the current research aims to address this lacuna within the context of Aotearoa New Zealand, within a conceptual framework of contextual, individual, and sociocultural influences.

Important note: Early studies in this area often conflated terms of biological sex and gender identity, using the two interchangeably. We use gender terminology when referring to prior work, but note that caution is needed in the interpretation of early literature. The collective understanding of gender identity has evolved since these works have been published, so the complexities of belonging and identity in engineering may also have evolved. We, thus, interpret the research pertaining to retention of marginalised groups from our present lens of understanding, and build on it with our study to expand the understanding and applicability of these seminal works to current issues.

1.2 | Conceptual Framework

Students' psycho-social states and attitudes such as confidence, belonging, and satisfaction (e.g., with relationships with teachers and classroom climate), rather than ability or lack of it underpinned students' decisions to leave engineering majors (Hunter, 2019; Seymour & Hewitt, 1997). Recent research into attrition in engineering courses has often pursued deeper understanding of such constructs. We chose to investigate engineering students' sense of belonging, domain satisfaction, and perceptions of future career within our unique setting, as these constructs were found to influence academic success, wellbeing, and retention (Navarro et al., 2019; Seymour et al., 2019; Walton & Cohen, 2011). Explanations of the constructs follow.

1.2.1 | Belonging and Engineering Education

Belongingness comprises a person's sense of being valued and respected within the interpersonal relationships that underpin basic human social needs (Baumeister & Leary, 1995; Mahar et al., 2013). Specifically, Hausmann et al. (2007) defined belonging as a psychological sense of identifying and being affiliated with tertiary campus communities. A sense of belonging in educational settings is core to academic success and retention (Walton & Cohen, 2011), and interrelationships with peers and teachers are universally held to be key to belonging in such contexts (Chiu et al., 2016). Connectedness, care, acceptance, and respect between peers and staff are fundamental to positive academic and social interactions (Hausmann et al., 2007), greater motivation and wellbeing (Sotardi et al., 2021), and successful tertiary campus experiences (Strayhorn, 2018). Importantly, connection with peers and faculty are key to successful help seeking and gaining academic support that enables persistence and retention in engineering courses (Marra et al., 2012; Seymour et al., 2019).

Race and gender have impacted sense of belonging in tertiary STEM education (Lewis et al., 2016; Rainey et al., 2018). Further, lack of representation and negative stereotypes can undermine sense of belonging (Boon-Nanai et al., 2017; Boston & Cimpian, 2018; Good et al., 2012). Such cues are likely to pose threats to whichever aspects of one's social identity (e.g., gender, race, ethnicity, socio-economic status, and age) are made salient (Murphy et al., 2007). Notably, Marra et al. (2012), found that a lack of belonging in engineering had a stronger influence, compared to academic factors such as curriculum difficulty and teaching quality, to marginalised students' decisions to leave an engineering degree programme.

A sense of belonging in engineering courses can be uniquely compounded for inequitably represented ethnic minority students. Differences in ethnic-cultural values and socialisation, the internalisation of negative stereotypes levelled at their group, isolation due to race/ethnicity, racism against them, and numerical minority status can all compound minority student success when added to inadequate academic support (Litzler & Samuelson, 2013). Additionally, perceptions that faculty expect less from them have caused racial/ethnic minority students to feel that they do not belong in engineering (May & Chubin, 2003). For Latinx students in U.S. contexts, the experience of alienation could lead to lowered self-concept which further negatively affects academic success and persistence (Cole & Espinoza, 2008). Further, difference from the majority group per se could heighten sensitivity to factors that affect social belonging and, thus, reduce motivation and intention to persist, and notably so for women of colour (Tate & Linn, 2005). Cole and Espinoza (2008) suggested that role models, advisors, and mentorship from older students from one's own minority group and staff devoted specifically to minority relations would aid the development of belonging and, therefore, persistence for minority students.

Critique has been levelled against approaches to studying relations of belonging with attrition and persistence in engineering. Until a decade ago, little research offered significant insight into the experience of belonging of inequitably represented racial/ethnic and gender minority groups in engineering (Litzler & Samuelson, 2013). Further, quantitative studies were often limited or inconclusive as a result of low numbers characterising minorities (Besterfield-Sacre et al., 2001; French et al., 2005; Vogt, 2008). Litzler and Samuelson (2013) asserted that qualitative studies stood to provide rich insights into student belonging in engineering. Importantly, Craps et al. (2022) suggested that despite the successful introduction of interventions, these were not always tested for inclusivity and, thus, may not ameliorate factors contributing to attrition in engineering for the very groups that need to be attracted and retained.

1.2.2 | Satisfaction and Engineering Education

As well as sense of belonging, student satisfaction is key to retention and success. It was registered in lower levels for non-white, non-heterosexual, and non-Christian students (Fan et al., 2021), and further research is needed to better understand how it is experienced in engineering for racial/ethnic minorities and women (Fouad et al., 2016). Notably, satisfaction mediated the relationship between interest and persistence behaviours (Navarro et al., 2019). Specifically, higher levels of academic satisfaction were related to greater intention to persist in engineering, and the magnitude of this association was smaller for racially/ethnically diverse rather than predominantly white samples and stronger in minority-serving compared to predominantly white institutions (Flores et al., 2014; Lent et al., 2016). Environmental supports and resources were key predictors of satisfaction (Navarro et al., 2019) and were enhanced by a sense of belonging and reduced where belonging was compromised (Seymour & Hewitt, 1997), pointing to interrelations between these constructs.

1.2.3 | Perception of Future Career and Engineering Education

U.S. students' perceptions of future career were linked to peer connectedness (central to a sense of belonging), satisfaction with engineering major (strongly influenced by faculty care for student learning), and satisfaction with engineering overall in Amelink and Creamer's (2010) five-year mixed methods study. Perceptions of future career could further be influenced by visualisations of what one wished to become, in turn influenced by expectation of a particular domain, value placed on that domain, and sense of fit between one's identity and the chosen domain (Craps et al., 2022; Oyserman et al., 2012). Women and racial/ethnic minority students, for example, often attached less value to engineering than white men (Craps et al., 2022). Research has identified the need to explore professional identity and value creation in order to enhance the diversity and retention (Oyserman et al., 2012) and has emphasised the need to broaden awareness of the breadth of engineering careers to enable a better fit with individual sense of self (Faulkner, 2007). Understanding how stereotypical expectations of traits associated with masculinity (e.g., brilliance, independence, agency, and self-focus) may render women's identity at odds with engineering careers (Craps et al., 2022), and how communality is valued by women and racial/ethnic minorities is important in enhancing retention in engineering careers for marginalised groups (Diekman et al., 2010).

1.2.4 | Belonging, Satisfaction, and Perceptions of Future Career in Engineering: An Entwining of Variables

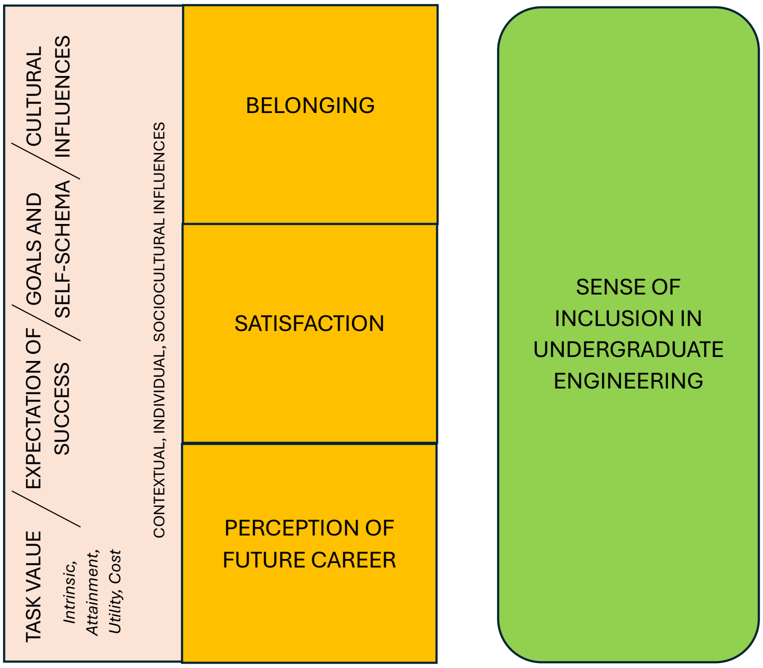
Belonging, satisfaction, and perceptions of future career were selected as key variables for investigation in the current study as they were foregrounded in previous literature as central to engineering attrition or persistence (Seymour et al., 2019). Few studies, however, have examined the relative importance of, or interrelationships between these variables in STEM attrition (Seymour et al., 2019). Although it is beyond the scope and aim of the current study to test existing models that have probed such relations, reference to two such models may further endorse and explain interrelations between belonging, satisfaction and perception of future career.

Situated expectancy task value theory (SEVT) illuminates the reciprocal processes that underpin within- and -between individuals' different expectations for success, connectedness (belonging), and satisfaction with a particular domain (Eccles & Wigfield, 2020). The SEVT model (see Eccles & Wigfield, 2020) details how individual expectancies of success, self-concept of ability, subjective task values, goals, and identities interplay with specific current situations to influence explicit or implicit choices. Further, choices available for consideration are limited by prior experience and socialisation (e.g., inculcation of stereotypical notions), cultural values, norms, and characteristics that shape individuals as they develop. Thus, SEVT is at the same time situation specific and culturally bound. Notably, the value of a task, comprising intrinsic value (interest), attainment value (importance to the individual), utility value (use as a foundation for future plans), and cost (e.g., detraction from time available for other pursuits; or the emotional cost of failure), influence motivation and engagement. Importantly, a high intrinsic value for a task or domain ensures deep engagement and perseverance, and utility value has a core influence on individuals' present and future plans (Eccles, 2005; Eccles & Wigfield, 2020). Accordingly, the value that tertiary U.S. students attached to their chosen STEM major was the key predictor of whether or not they left or changed their STEM field (Rosenzweig et al., 2021). Overall, SEVT contributes precepts that guide the current study by acknowledging links between contextual, sociocultural, and individual factors that determine individual and group differences in experiencing a sense of inclusion in undergraduate engineering at Waipapa Taumata Rau (The University of Auckland).

Social cognitive career theory (SCCT) draws on a person-environment fit and consideration of developmental career theories (Lent et al., 2013). Employing an extension of Lent and colleagues' integrative SCCT, Navarro et al. (2019) investigated environmental and personality variables influencing persistence, engagement, and satisfaction in engineering in a quantitative study with a U.S. sample. Social supports from peers and faculty, also important for a sense of belonging, were particularly important for the minority Latinx and white women students' satisfaction and that, for these students in particular, social identities and institutional contexts were important moderators of relations between satisfaction and persistence in engineering (Navarro et al., 2019). Importantly, Navarro et al. (2019) cautioned that when assessing collectivist groups' satisfaction in engineering, a review of focus in measures used would be beneficial and urged for future research to investigate expansion of the original SCCT model (Lent et al., 2013) to include intersectionality of race/ethnicity by gender. Navarro et al.'s (2019) findings suggested interrelations between satisfaction and persistence in engineering and further indicated that interventions to enhance one target variable may influence other variables because of interrelatedness. Importantly, social identity and institutional context could moderate relations between key variables (Navarro et al., 2019). Overall, both the aforementioned models add weight to Fan et al.'s (2021) assertion that belonging and satisfaction are fundamental to engineering retention and demonstrate that neither construct acts independently in shaping engineering futures.

Our conceptual framework, informed by this rich literature, is illustrated in Figure 1.

FIGURE 1 Conceptual framework for sense of inclusion in undergraduate engineering education, comprising of three main factors of belonging, satisfaction, and perception of future career.



1.3 | Positionality Statement

Our team brings together diverse cultural backgrounds, personal experiences, and academic expertise. Most of our team members have research backgrounds in technical engineering fields. Many of us teach engineering through lectures, tutorials, and student mentoring, providing insight into the challenges and opportunities facing students, particularly those from marginalised backgrounds. Two members of our team (Watson and Roy) specialise in psychology, education, and the study of systemic racism. This interdisciplinary approach enriches our understanding of how engineering and technology can be tools for both advancement and addressing societal inequities. We acknowledge that our team lacks Māori and Pasifika researchers.

2 | METHODS

To answer our research questions, we employed a multi-method research strategy (Brewer & Hunter, 2006). We used an anonymous online questionnaire to obtain perceptions of students on their sense of belonging, satisfaction, and perceptions of their future career. Quantitative data collected on these factors enabled us to look for differences in the factors across demographic variables to answer our first research question. In addition, open-ended responses related to the factors were collected in the questionnaire to provide qualitative data to potentially explain any demographic differences identified and provide richer data on perceptions of the factors. To answer our second research question, we conducted a series of focus groups for a deep understanding of student experiences. Participants were undergraduate engineering students at Waipapa Taumata Rau (The University of Auckland). The Māori name Waipapa Taumata Rau was gifted to the University of Auckland by the people of Ngāti Whātua Ōrākei in 2021, as a symbol of the ongoing partnership with tangata whenua (Waipapa Taumata Rau The University of Auckland, 2021). The study had ethics approval from the University of Auckland Human Participants Ethics Committee, Reference number UAHPEC22566.

2.1 | The Waipapa Taumata Rau Engineering Programme Context

At Waipapa Taumata Rau (The University of Auckland), the Bachelor of Engineering is a four-year, accredited honours degree (Waipapa Taumata Rau The University of Auckland, 2024a). The educational content of the degree is delivered through a mix of lectures (30-500 students at a time), tutorials (15-40 students at a time), and laboratory exercises (15-40 students at a time). After completing the first year of study, students choose one of 10 specialisations: Biomedical Engineering, Chemical and Materials Engineering, Civil Engineering, Computer Systems Engineering, Electrical and Electronic Engineering, Engineering Science, Mechanical Engineering, Mechatronics Engineering, Software Engineering, and Structural Engineering.

Students are required to take at least one general education course per semester throughout their degree, such as communication, project management, or the role of engineers in society. Students also have the option to engage in more social and environmental aspects of engineering through extra-curricular activities, such as Engineers Without Borders, Engineering for Sustainable Development, and demographic interest groups such as Rainbow Engineering (LGBTQIA+), Women in Engineering, and the South Pacific Indigenous Engineering network (SPIES).

2.2 | Questionnaire

2.2.1 | Questionnaire Design

The questionnaire contained items to assess the participants' sense of belonging, satisfaction, and perceptions of their future careers. It also contained multiple demographic questions. The questionnaire was available online through the Qualtrics platform (Qualtrics XM, 2024). All questions were optional. A complete list of questions and associated answer options is available in our online replication package (Dhopade et al., 2023).

First, at the beginning of the survey, the participants' year of study and information related to their current (or anticipated) engineering specialisation were collected. These questions were used to both ensure the participant met the inclusion criteria for the study and also to populate some of the fields in the remaining questions.

Participants next indicated their agreement using a five-point Likert-style scale from Strongly disagree (-2) to Strongly agree (2) with statements assessing their belonging, satisfaction, and perception of their future career. Items for each construct come from various sources. The items for sense of belonging came primarily from (Walton & Cohen, 2007), which studied belonging and social fit in academic environments. These items were supplemented by additional items from studies examining belonging in engineering or STEM that focused on differences in gender or other aspects of identity to ensure a broad view of belonging was captured and that aspects of belonging related to identity were included (Kissinger et al., 2009; Pietri et al., 2019; Robnett, 2013; Skvoretz et al., 2020). The items for satisfaction were selected from engineering education research on student satisfaction to cover concepts of enjoyment (Lachapelle & Brennan, 2018), satisfaction with choice of study (Creamer et al., 2010; Moosbrugger et al., 2012), persistence intentions (Lewis et al., 2017), peer recommendation intentions (Elhadary, 2016), and feelings of accomplishment (Brawner et al., 2015). The items for perception of future career came primarily from Watson et al. (2021), which studied perceptions of New Zealand adolescents on their future careers. The items were modified to apply to the study context. For example, "I want to apply for this job because I have a good chance of getting a vocational training position in this profession" was modified to "I have a good chance of getting a job when I graduate." Some additional items were added to capture additional perceptions of future careers that are relevant to University students but were not included in the study of adolescents: longer term career aspirations (Creamer et al., 2010) and perceptions of skills (Lachapelle & Brennan, 2018) and their transferability (Bannikova et al., 2018). Table 1 shows all of the items for the three constructs and their sources. As can be seen, some items either ask about the Faculty of Engineering (for students in their first year who have not yet selected a specialisation) or about the student's current specialisation.

After each set of items pertaining to belonging, satisfaction, and perception of future career, participants were given the option of supplementing their quantitative responses with an open-ended response. The question after each set of items read *"Please add anything else you would like to share about your experiences in relation to the statements above."*

Finally, demographics were collected from the participants. Participants were asked to provide their enrollment status (domestic or international), ethnicity, gender, sexual orientation, and whether they had any physical or mental impairments. In the questionnaire, a physical or mental impairment was defined as *"something that has a substantial and long-term impact on your ability to carry out day-to-day activities. It could be caused by accident, trauma, genetics, or disease. It may be temporary or permanent, total or partial, lifelong or acquired, visible or invisible."* This definition was based on the Washington Group Short Set on Functioning (WG-SS) questionnaire (Washington Group, 2022).

Following the recommendations by Spiel et al. (2019), all of the demographic questions had an explicit "Prefer not to disclose" answer option. The ethnicity, gender, and sexual orientation questions also had a "Prefer to self-describe" option, which enabled an open text box. These questions also allowed participants to select multiple options. The answer options for gender included woman, man, non-binary, prefer not to disclose, and prefer to self-describe as recommended by Spiel et al. (2019). The answer

TABLE 1 Scale items for the three main constructs: belonging, satisfaction, and future career. Response options for each item were a five-point agreement scale.

ID	Item	Source
Belonging		
B1	People in my courses/papers accept me	(Walton & Cohen, 2007)
B2	Other students understand more than I do about what is going on in my courses/papers†	(Walton & Cohen, 2007)
B3	I fit in well with others in my courses/papers	(Walton & Cohen, 2007)
B4	I get along well with people in my courses/papers	(Walton & Cohen, 2007)
B5	I feel like an outsider in [the Faculty of Engineering / my specialisation].†	(Walton & Cohen, 2007)
B6	I think in the same way as other people who do well in [the Faculty of Engineering / my specialisation].	(Walton & Cohen, 2007)
B7	I feel alienated from other students in [the Faculty of Engineering / my specialisation].†	(Walton & Cohen, 2007)
B8	I think I am similar to the kind of people who succeed in [the Faculty of Engineering / my specialisation].	(Walton & Cohen, 2007)
B9	I think I belong in [the Faculty of Engineering / my specialisation].	(Walton & Cohen, 2007)
B10	I think my lecturers treat me with respect	(Kissinger et al., 2009)
B11	I do not feel like I am part of the team during group assignments.†	(Kissinger et al., 2009)
B12	I actively participate in at least one student group/society in the Faculty of Engineering.	(Skvoretz et al., 2020)
B13	I have friends in the Faculty of Engineering	(Skvoretz et al., 2020)
B14	I think I can be myself around my friends in the Faculty of Engineering.	(Pietri et al., 2019)
B15	I have a lot in common with people in my courses/papers	(Robnett, 2013)
Satisfaction		
S1	I enjoy studying Engineering	(Lachapelle & Brennan, 2018)
S2	I am satisfied with my decision to study engineering	(Moosbrugger et al., 2012)
S3	I am satisfied with my decision to study my chosen specialisation	(Moosbrugger et al., 2012)
S4	I often think about leaving Engineering.†	(Lewis et al., 2017)
S5	I would recommend studying Engineering to others.	(Elhadary, 2016)
S6	If I had to do it over again, I would still choose to study engineering	(Creamer et al., 2010)
S7	I feel an overall sense of accomplishment in my studies	(Brawner et al., 2015)
Future career		
F1	I have a good chance of getting a job when I graduate	(Watson et al., 2021)
F2	I will be well paid as an engineer	(Watson et al., 2021)
F3	I will be respected by others	(Watson et al., 2021)
F4	I will probably not end up unemployed as an engineer	(Watson et al., 2021)
F5	I am interested in the work I would be doing, and I will enjoy doing it	(Watson et al., 2021)
F6	I will have a lot of spare time	(Watson et al., 2021)
F7	I can have a good career	(Watson et al., 2021)
F8	I will have supportive colleagues in this profession	(Watson et al., 2021)
F9	I will have enough time to take care of my family	(Watson et al., 2021)
F10	I think I will still be employed in engineering 10 years from now	(Creamer et al., 2010)
F11	I think I know what an engineer does at work	(Lachapelle & Brennan, 2018)
F12	I think the skills I learn in Engineering will be transferable to jobs in other fields	(Bannikova et al., 2018)

†negatively worded item

options for ethnicity were based on the options used in internal Waipapa Taumata Rau (The University of Auckland) teaching and learning questionnaires sent to students: NZ Māori, Samoan, Cook Islands Māori, Tongan, Niuean, Fijian, Tokelauan, Japanese, Korean, Chinese, Indian, Middle Eastern, Latin American, African, NZ European, Other European, prefer not to disclose, and prefer to self-describe. The answer options for sexual orientation were straight or heterosexual, gay or lesbian, bisexual, don't know, prefer not to disclose, and prefer to self-describe as recommended by the Australian Bureau of Statistics (2021), since the most recent New Zealand census at the time of data collection did not ask about sexual orientation.

The demographic questions were used to enable the analysis of differences in perceptions across different identity groups, to account for potential confounding variables in our analysis, and to provide context of the study setting.

2.2.2 | Recruiting Participants

The questionnaire invitation was sent to approximately 4000 undergraduate students through the Waipapa Taumata Rau (The University of Auckland) Faculty of Engineering student mailing lists. The invitation was sent in July 2021, and the questionnaire remained open for responses for three weeks until mid-August 2021. Participants were given the option to enter a random prize draw for one of three $100 vouchers upon completion of the questionnaire.

2.2.3 | Participants

We received 379 complete responses to the questionnaire. Incomplete responses were automatically deleted by Qualtrics so that only those who purposely submitted their responses were included in the analysis. Two responses were identified as unengaged (response duration: 51s and 52s, respectively) and were removed from the dataset. Next, any item or response with more than 10% missing values were excluded from further analysis, since this is beyond the standard for data imputation. The questionnaire scales had an option of 'I don't know', which were treated as missing on purpose and recorded as missing. After that, the total missing percentage was calculated for each item and response. Items and responses with more than 10% missing values were excluded from further analysis, which resulted in excluding one item (*'I am satisfied with my decision to study my chosen specialisation'*) and 45 responses. This resulted in $n = 332$ in the final dataset.

Table 2 summarizes the demographics of the participants. In terms of the demographics of the participants, the participants came from all years of study, with the greatest number of participants (38%) in their first year of study. A large majority of the students were domestic students (95%). About 11% of the participants identified as having either a physical or mental impairment. There were close to an equal number of students who identified themselves as a woman or man, and about 3% of the students identified as non-binary. Participants identified across a wide range of ethnicities, with many choosing to self-describe their ethnicity. Regarding sexual orientation, around 81% of the participants identified themselves as heterosexual and about 14%

TABLE 2 Reported demographics of questionnaire participants.

Type	Group	*n*	
Year of study	Part 1	127	(38%)
	Part 2	88	(27%)
	Part 3	41	(12%)
	Part 4	76	(23%)
Enrolment status	Domestic	316	(95%)
	International	14	(4%)
	Not disclosed	2	(1%)
Impairment	No	276	(83%)
	Yes	37	(11%)
	Not disclosed	19	(6%)
Gender	Men	161	(48%)
	Women	158	(48%)
	Non-binary	9	(3%)
	Not disclosed	4	(1%)
Ethnicity (aggregated)	Asian	139	(42%)
	European	135	(41%)
	Māori	17	(5%)
	Middle Eastern / Latin American / African (MELAA)	15	(5%)
	Pacific Peoples (PP)	12	(4%)
	Not disclosed	14	(4%)
Sexual orientation	Heterosexual	261	(79%)
	LGBTQIA+	46	(14%)
	Don't know	8	(2%)
	Not disclosed	17	(5%)

Note for some demographics, totals will add up to more than 100% since participants could select multiple responses.

identified in at least one of the LGBTQIA+ groups, including Gay or Lesbian, Bisexual, and self-described sexual orientations of Asexual, Queer, Pansexual, and Demisexual.

2.2.4 | Data Preparation

The negatively worded items as indicated by † in Table 1 were reverse scored.

Missing values for the scale items were imputed with the expectation-maximization (EM) algorithm using the missMethods R package (Rockel, 2022). The EM algorithm is an iterative method to find the maximum likelihood estimates for missing values (Dempster et al., 1977). Data was imputed based on each factor.

Given the relatively small number of participants in some of the specialisations, ethnicity groups, and sexual orientations, the low-level responses to these questions were aggregated for the statistical analysis. Ethnicity was aggregated into the five major ethnic groups used in the 2018 New Zealand census (Māori, European, Asian, Pacific Peoples, and MELAA, which includes Middle Eastern, Latin American, and African). There were many self-described ethnicity responses. These were manually checked and assigned one of the major ethnic groups (e.g., Vietnamese was assigned to the Asian group). Sexual orientation was aggregated into two groups, namely, Heterosexual/Straight and LGBTQIA+. In addition, the ethnicity, gender, and sexual orientation questions allowed for multiple selections. For the purpose of the data analysis, cases with more than one identified group were assigned to a 'prioritised' group for analysis, where marginalised groups based on population size in our sample were prioritised over the majority groups (e.g., if someone responded both Māori and European, they were included in the Māori group for the statistical analysis).

Scale scores for the latent factors (belonging, satisfaction, and perceptions of future career) were created using regression factor scores (DiStefano et al., 2009), using the lavPredict function of the lavaan R package (Rosseel, 2012).

2.2.5 | Questionnaire Validation

Confirmatory factor analysis **(CFA)** was conducted to test the validity of the item sets shown in Table 1. CFA was employed rather than alternative approaches such as Exploratory Factor Analysis (EFA) or Principal Component Analysis (PCA) because our questionnaire items were developed based on a conceptual framework. While EFA and PCA are valuable for discovering underlying factor structures when relationships between items and constructs are unknown, CFA is more appropriate when testing hypothesised factor structures derived from theory. In our case, since the questionnaire items were specifically developed to measure distinct constructs within our conceptual framework, CFA allowed us to directly test how well our data fit this hypothesised structure. Additionally, CFA provides more rigorous fit indices and modification options compared to exploratory approaches, enabling us to assess and refine the model while maintaining its theoretical foundations. This approach aligns with best practices in scale validation when working with theory-driven instrument development (Boateng et al., 2018).

The CFA was done using the lavaan R package (Rosseel, 2012). Since multiple items existed to indicate multiple latent constructs, analysis was conducted for each construct separately (sense of belonging, satisfaction, and perception of future career). Maximum likelihood estimation with oblique minimisation was used, and although the rating scales had only five options, all items were treated as continuous scales for ease of analysis (Bandalos & Finney, 2018).

Items with factor loadings lower than 0.3 were excluded from the factor (Hair et al., 2006). Once a reasonably good model fit was obtained for each factor, the three factors were put together into one correlational model. The fit of the proposed factor structure was accepted if multiple fit indices indicated non-rejection of the model. The goodness of fit values (CFI, gamma hat) $> .90$ suggest the model does not need to be rejected, with strong evidence when values $> .95$. Gamma hat was calculated as suggested by Fan and Sivo (2007). The badness of fit values (RMSEA and SRMR) $< .08$ suggest acceptable fit, and those $< .05$ indicate strong evidence of correspondence between data and model. Because chi-square tests tend to be overly sensitive with $n > 100$, the χ^2/df ratio was determined and its p-value obtained (Cohen, 2013); $p > .05$ suggests disturbance between the model and the data is due to chance.

When the model did not generate an acceptable fit, inspection of Lagrange modifiers (Modification Indices; MI) was undertaken at both the item to factor level and the item-to-item residual level. Items that had strong MI to other factors were candidates for deletion, in order to maximise a simple structure in which each item loads on only one factor. Items with strong MI for residual covariances were deleted in order to prevent correlating item residuals, which would violate the classical assumption that residuals are uncorrelated.

The items B2, B10, and F6 were excluded due to having factor loadings of < 0.3 in the individual models. Through examination of the correlational model, a series of MI deletions was carried out, with the following items deleted:

- B9 attracted to two other factors with MI> 20
- F5 attracted to one other factor with MI> 40
- F10 attracted to one other factor with MI> 20
- B8 attracted to one other item with MI> 40
- B14 attracted to one other item with MI> 40
- B7 attracted to one other item with MI> 30
- F9 attracted to one other item with MI> 20
- F8 attracted to two other factors with MI> 10

Model fit values for the three individual models and the correlational model are reported in Section 3.

For **scale reliability**, both McDonald's omega and Cronbach's alpha were checked, noting that alpha is the lowest estimator of the lower bound of reliability. McDonald's omega and Cronbach's alpha scores range from 0 to 1, with higher scores being indicative of greater consistency in the scale items (Cronbach, 1951; McDonald, 1999). A score of 0.9 or higher is excellent, 0.8 or higher is good, and 0.7 or higher is acceptable. It should be considered that Cronbach's alpha values are affected by the number of items that compose the scale. McDonald's omega and Cronbach's alpha scores were calculated using the R packages psych (Revelle, 2023) and ltm (Rizopoulos, 2006), respectively.

Given the relatively small number of items in the five scales (fewer than ten items), mean inter-item correlations are also reported following the recommendation of Piedmont (2014). Clark and Watson recommend mean inter-item correlations to fall between 0.15 and 0.50, which is high enough to indicate that the scale items are closely related but not so high that some scale items are redundant (Clark & Watson, 1995). The mean inter-item correlations were calculated using the R performance package using Pearson's correlations (Lüdecke et al., 2021).

For **scale normality**, Skewness and Kurtosis were checked. For a sample with $n = 332$, the normal threshold of Skewness < 2 and Kurtosis < 7 were used (Kim, 2013).

2.2.6 | Statistical Analysis of Demographic Differences

All analysis was conducted using RStudio (Posit Software, 2024).

One-way ANOVAs (Welch's) were conducted to establish if there were statistically significant differences across the three factors (sense of belonging, satisfaction, and perception of future career) by the demographic variables (year of study, specialisation, specialisation match, timing of specialisation decision, international status, ethnicity, gender, sexual orientation, and impairment status). All demographic variables were categorical. Welch's ANOVA was used since it is not sensitive to unequal variances. Games-Howell Post-Hoc tests were used to compare combinations of groups when significance was found through the ANOVA tests. The rstatix package in R was used for this analysis (Kassambara, 2021).

Effect sizes were calculated using Cohen's d (Cohen, 2013). With this measure, $d < 0.2$ is considered a negligible effect, $d >= 0.2$ is considered a small effect, $d >= 0.5$ is considered a medium effect, and $d >= 0.8$ is considered a large effect.

2.2.7 | Qualitative Analysis

To analyse the open-ended responses, thematic analysis was applied (Braun & Clarke, 2021). Thematic analysis is a well-known, flexible approach for identifying common themes in text data, such as open-ended questionnaire responses. It has been successfully applied in many studies, including several recent studies investigating inclusively challenges in STEM (Arthur & Guy, 2020; Liang et al., 2023; Reggiani et al., 2024).

Across the three open-ended questions, 122 responses were obtained from 64 unique participants. The initial analysis was performed independently by one of the authors (primary coder), who has experience in engineering research and the tertiary teaching environment. In line with Braun and Clarke's recommendations, the analysis followed six phases, namely:

1. Familiarisation: The primary coder read and re-read all responses to the open-ended questions to become familiar with the data. It was noticed that responses did not appear to align specifically with each construct (i.e., belonging, satisfaction, and future perceptions). This is in line with prior research as described in Section 1.2 that found that these constructs were intertwined (e.g., Fan et al., 2021). Therefore, responses from each construct were combined before further analysis.

2. Coding: Next, initial codes were added to each response, capturing relevant features. We used an inductive approach, allowing codes to emerge from the data rather than fitting responses into predetermined categories.

3. Generating initial themes: The codes were then collected into a preliminary set of higher-level themes. This process involved sorting similar codes into groups and creating preliminary thematic maps.

4. Reviewing and developing themes: Themes were refined by checking if the themes captured the initial codes and considering the themes more holistically in relation to all data. During this process, some themes were merged, others were split, and some were discarded. In this phase, the preliminary themes were iteratively reviewed through a series of meetings with four of the authors, who also have significant experience in engineering research and teaching. The primary coder reread all responses, explicitly looking for passages that contradicted emerging interpretations.

5. Refining, defining, and naming themes: Each theme was clearly defined with a detailed description of its scope and content. Names were chosen to concisely convey the essence of each theme. These were reviewed by all authors.

6. Writing up: The final phase involved selecting compelling examples to explain the theme and relating the themes back to the research questions and literature. Again, this was reviewed by all authors. The final eight themes identified are presented in Section 3.2.2, with detailed descriptions and supporting examples.

The above analysis was initially performed with no knowledge of the respondents' demographics. However, after the themes were finalised, the demographics of the respondents were analysed qualitatively to identify any trends in the responses.

2.3 | Focus Groups

A series of focus groups were conducted to provide more details and examples from students around their experiences and their sense of inclusion.

2.3.1 | Focus Group Design

Focus groups were designed to have 3-6 participants in each session. Participants were grouped based on shared demographics to minimise social identity threat. Specifically, there was one Māori group, three women groups, one LGBTQIA+ group, and one group for men. Each focus group lasted approximately 90 minutes and was conducted online using video conferencing software. The focus groups were recorded, including audio and video, after confirming participant consent. In the first 10 minutes, the focus group facilitators introduced the goal of the focus group and asked some warm up questions (*e.g., what extracurricular activities do you participate in?*) to make participants comfortable. The rest of the focus group consisted of three main sets of questions eliciting participants' positive and negative experiences in their studies, details of situations where participants felt both like they fit in and did not fit into the Faculty of Engineering, and details of situations both where participants felt confident and lacked confidence in their abilities as an engineer. The detailed set of questions is available in our replication package (Dhopade et al., 2023).

The focus groups were moderated by trained research assistants. The training covered the strengths and limitations of focus groups, how to effectively moderate focus groups to encourage discussions, how to ask probing questions, and how to pick up and record non-verbal cues. Moderators were also instructed what to do in case participants became upset or distressed.

2.3.2 | Recruiting Participants

Focus group participants were recruited from the online questionnaire participants. At completion of the anonymous online questionnaire, participants were redirected to another online questionnaire which allowed them to request an invitation to participate in a follow-up focus group if they desired to do so. We used a separate questionnaire to ensure no personal information collected would be stored with the participants' answers to data collected in the questionnaire.

We invited all 132 participants who requested invitations to the focus groups and received responses from 32 participants with their availability. Of these 32 interested participants, 17 were able to participate in the scheduled focus groups. Participants received a $50 voucher on arrival. Focus groups were conducted in February and March 2022.

2.3.3 | Participants

The 17 engineering students who participated in the focus groups consisted of 11 women, 4 men, and 2 participants who identified as both women and non-binary. Three participants were Māori, three were Chinese, one was Taiwanese, one was South African, one did not disclose their ethnicity, and the remaining eight were European. Twelve participants identified as straight or heterosexual, four as LGBTQIA+, and one did not disclose their sexual orientation. One participant had a physical or mental impairment, two did not disclose their impairment status, and the remaining 14 did not have impairments. All focus group participants were domestic students.

2.3.4 | Focus Group Analysis

The video files of the six focus groups were transcribed for analysis. The participants' responses were then analysed using thematic analysis (Braun & Clarke, 2021), using both the generated transcripts and the original video recordings. The video, in particular, was needed to help accurately attribute responses to specific participants. The analysis of the focus group transcripts also followed the six phases recommended by Braun and Clarke (i.e., familiarisation; coding; generating initial themes; reviewing themes; refining themes; and writing up) following the same process described in Section 2.2.7.

As with the survey analysis, this analysis was conducted by one author and refined through regular discussions and iterations with two other authors. The participating authors had prior experience with thematic analysis in engineering research. Through iterative discussions, the authors agreed on the nine final themes, which are presented with detailed descriptions and supporting examples in Section 3.3.

3 | RESULTS

In this section, we first report the results of the questionnaire validation. We then provide results for our two research questions.

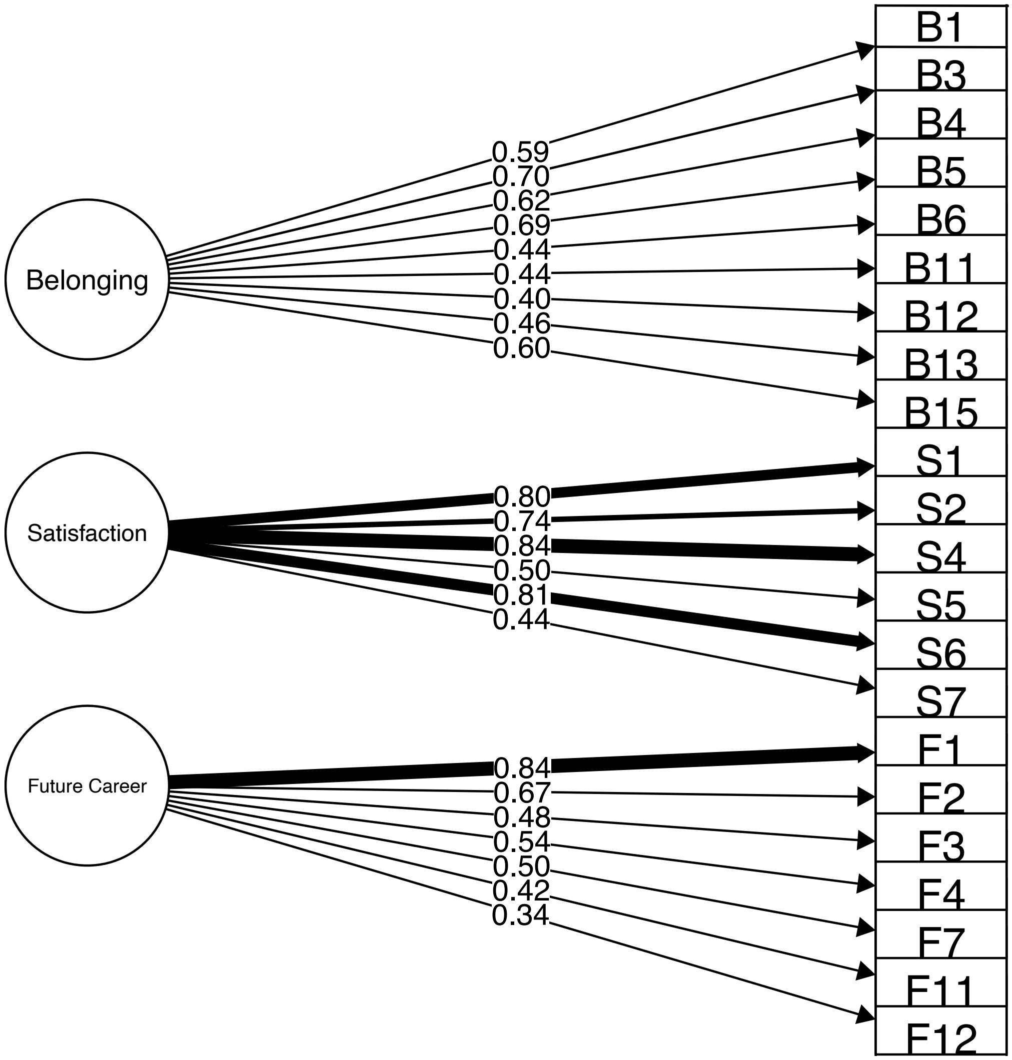


FIGURE 2 Confirmatory Factor Analysis model showing the factor structure of our final model. Rectangles represent observed variables (items from Table 1), ovals represent the latent factors, and arrows indicate factor loadings.

3.1 | Questionnaire Validation

The model fit values from the CFA for the three individual factors and the correlational model are given in Table 3, which show that all models have acceptable fit. Scale estimates of reliability and normality are shown in Table 4. The scale internal estimates of reliability indicated that most have acceptable (>0.7) to good (>0.8) reliability. The average inter-item correlations suggest acceptable reliability. All scales are normally distributed. Thus, the items appear to be measuring what they're intended to measure. The final model is shown in Figure 2.

Correlation of factors: Table 5 shows the correlation matrix of the three latent factors. All factors are significantly and positively correlated with each other at a moderate level with correlations of 0.4 or higher. All correlation coefficients are

TABLE 3 Model Fit Indices for the Confirmatory Factor Analysis (CFA), values indicate acceptable fit.

Fit measure	Belonging	Satisfaction	Future career	Correlational
χ^2	69.04	23.69	39.74	430.73
df	27	9	14	206
p	<0.001	0.005	<0.001	<0.001
χ^2/df	2.56	2.63	2.84	2.09
p	0.28	0.27	0.24	0.35
CFI	0.95	0.98	0.96	0.91
Gamma hat	0.99	0.99	0.99	0.97
SRMR	0.046	0.029	0.041	0.065
RMSEA	0.068	0.070	0.074	0.057

TABLE 4 Scale reliability and normality scores for our three latent factors, scores indicate acceptable reliability and normally distributed scales.

Measure	Belonging	Satisfaction	Future career
McDonald's ω	0.81	0.84	0.80
Cronbach's α	0.78	0.83	0.79
Mean inter-item correlation	0.32	0.47	0.36
Skewness	-0.93	-1.14	-1.12
Kurtosis	4.18	4.09	5.28

TABLE 5 Correlation Matrix showing correlations between the three latent factors. Values indicate moderate relationships between factors.

		I.	II.	III.
I.	Sense of belonging	-		
II.	Satisfaction	0.44	-	
III.	Perception of future career	0.40	0.45	-

statistically significant at p <.001 level. The scores indicate a moderate relationship between factors, which suggest related but distinct constructs, suggesting the factors belong in the same conceptual framework as hypothesised.

3.2 | Differences in Belonging, Satisfaction, and Perceptions of Future Career

RQ1: How does sense of belonging, satisfaction, and perceptions of future career of engineering students at Waipapa Taumata Rau (The University of Auckland) vary across demographic characteristics (for example, gender, ethnicity, sexual orientation)?

3.2.1 | Statistical Analysis

Table 6 shows the results of the ANOVA analysis examining the differences in sense of belonging, satisfaction, and perceptions of future career across various demographic variables. The table shows the F-values and their corresponding p-value significance level. A large F-value means the variation between the group means is more than expected by chance. For sense of belonging, significant differences were observed for ethnicity, sexual orientation, and impairment status. For satisfaction, significant differences were found for ethnicity and gender. Finally, for perceptions of future career, only ethnicity showed significance.

TABLE 6 One-way ANOVA results comparing differences in sense of belonging, satisfaction, and perceptions of future career across demographic variables. For each result, F-Values are shown and significant effects are indicated with asterisks.

	Belonging		**Satisfaction**		**Future career**	
Year of Study	1.26		2.39		1.00	
Specialisation †	1.46		1.30		0.17	
Timing of Specialisation decision†	0.49		0.76		0.34	
Got preferred specialisation†	1.67		0.53		2.93	
International Status	2.03		1.13		0.50	
Ethnicity	5.18	***	2.82	*	5.51	***
Gender	0.24		11.36	**	0.12	
Sexual Orientation	3.36	*	0.40		1.37	
Impairment Status	5.26	**	0.61		0.38	

*$p < 0.05$
**$p < 0.01$
***$p < 0.001$
†only for students in years 2-4 ($n = 205$) since specialisations selected after year 1

TABLE 7 Games-Howell Post-Hoc test results comparing differences in Sense of Belonging between ethnicity groups. Mean differences are shown. Statistically significant differences are indicated with asterisks. Negative mean differences indicate that the second group had a higher score than the first group. Means, standard deviations (sd), and standard errors (se) are also reported for each group.

	n	**mean**	**sd**	**se**	**Asian**	**Eur.**	**Māori**	**MELAA**	**Pacific Peoples**	
Asian	139	-0.071	0.990	0.084	–	0.305	0.022	-0.154	-0.632	
Eur.	135	0.234	0.768	0.066	–	–	-0.283	-0.459	-0.937	*
Māori	17	-0.048	0.868	0.210	–	–	–	-0.176	-0.654	
MELAA	15	-0.225	1.000	0.259	–	–	–	–	-0.478	
Pacific Peoples	12	-0.702	1.190	0.343	–	–	–	–	–	

*$p < 0.05$

The Games-Howell Post-Hoc test results comparing ethnicity groups for sense of belonging, seen in Table 7, shows only a statistical difference between Pacific Peoples and Europeans with a -0.937 mean difference (Cohen's $d = 0.93$, suggesting a large effect size). European participants reported the highest sense of belonging, while Pacific Peoples participants reported the lowest sense of belonging. Table 7 also shows the mean score for each ethnicity group.

For satisfaction, while there are some large mean differences between groups, none are statistically significant, which could be a result of the small group sample sizes for some of the ethnicities. Table 8 shows the differences between the groups. Pacific Peoples reported the highest levels of satisfaction and the most positive perceptions of their future careers.

For perceptions of future careers, there is a statistically significant difference between Europeans and Asians, with a mean difference of 0.427 (Cohen's $d = 0.51$, suggesting a medium effect). Table 9 shows the differences between the groups.

Although the ANOVA test showed a significant result in Satisfaction across gender groups, the Games-Howell Post-Hoc pair-wise comparisons in Table 10 showed no statistically significant differences between men, women, and non-binary participants. The only significant difference was between women and participants who chose not to disclose their gender. Those who did not disclose their gender have significantly lower satisfaction, but the sample is also very small for this group.

TABLE 8 Games-Howell Post-Hoc test results comparing differences in Satisfaction between ethnicity groups. Mean differences are shown. No statistically significant differences are found. Negative mean differences indicate that the second group had a higher score than the first group. Means, standard deviations (sd), and standard errors (se) are also reported for each group.

	n	mean	sd	se	Asian	Eur.	Māori	MELAA	PP
Asian	139	-0.060	0.918	0.078	–	0.209	0.127	-0.116	0.411
Eur.	135	0.149	0.828	0.071	–	–	-0.082	-0.326	0.202
Māori	17	0.067	0.793	0.192	–	–	–	-0.244	0.284
MELAA	15	-0.177	1.350	0.349	–	–	–	–	0.528
PP	12	0.351	0.504	0.146	–	–	–	–	–

TABLE 9 Games-Howell Post-Hoc test results comparing differences in Perceptions of Future Career between ethnicity groups. Mean differences are shown. Statistically significant differences are indicated with asterisks. Negative mean differences indicate that the second group had a higher score than the first group. Means, standard deviations (sd), and standard errors (se) are also reported for each group.

	n	mean	sd	se	Asian	Eur.	Māori	MELAA	PP
Asian	139	-0.178	0.906	0.077	–	0.427 ***	0.429	-0.565	0.606
Eur.	135	0.249	0.753	0.065	–	–	0.001	-0.992	0.179
Māori	17	0.250	0.738	0.179	–	–	–	-0.993	0.178
MELAA	15	-0.743	1.390	0.358	–	–	–	–	1.170
PP	12	0.428	0.800	0.231	–	–	–	–	–

***$p < 0.001$

TABLE 10 Games-Howell Post-Hoc test results comparing differences in Satisfaction between gender groups. Mean differences are shown. Statistically significant differences are indicated with asterisks. Negative mean differences indicate that the second group had a higher score than the first group. Means, standard deviations (sd), and standard errors (se) are also reported for each group.

	n	mean	sd	se	Men	Women	Non-binary	Not disclosed
Men	161	-0.020	0.968	0.076	–	0.050	-0.004	-0.693
Women	158	0.030	0.942	0.075	–	–	-0.054	-0.744 *
Non-binary	9	-0.024	0.799	0.266	–	–	–	-0.690
Not disclosed	4	-0.714	0.141	0.010	–	–	–	–

*$p < 0.05$

Similarly, while the ANOVA test showed a significant result in Sense of Belonging across sexual orientation groups, the pairwise comparisons in Table 11 show only a statistically significant difference between those who did not disclose their sexual orientation and those who reported not to know their sexual orientation. No statistically significant differences were seen between those who reported to be straight or heterosexual and those who reported to be LGBTQIA+.

The same is also true for the statistical significance shown for impairment status and sense of belonging. The pairwise comparisons in Table 12 show the only statistically significant difference is between those who did not disclose their impairment status and those who report not to have an impairment.

TABLE 11 Games-Howell Post-Hoc test results comparing differences in Sense of Belonging between sexual orientation groups. Mean differences are shown. Statistically significant differences are indicated with asterisks. Negative mean differences indicate that the second group had a higher score than the first group. Means, standard deviations (sd), and standard errors (se) are also reported for each group.

	n	mean	sd	se	Straight	LGBT QIA+	Don't know	Not disclosed	
Straight	261	0.036	0.889	0.055	–	-0.035	0.333	-1.190	
LGBTQIA+	46	0.001	0.867	0.128	–	–	0.368	-1.160	
Don't know	8	0.369	0.721	0.255	–	–	–	-1.530	*
Not disclosed	17	-1.160	1.380	0.398	–	–	–	–	

*$p < 0.05$

TABLE 12 Games-Howell Post-Hoc test results comparing differences in Sense of Belonging between impairment status groups. Mean differences are shown. Statistically significant differences are indicated with asterisks. Negative mean differences indicate that the second group had a higher score than the first group. Means, standard deviations (sd), and standard errors (se) are also reported for each group.

	n	mean	sd	se	No	Yes	Not disclosed	
No	276	0.050	0.913	0.055	–	-0.205	-0.559	*
Yes	37	-0.155	1.060	0.174	–	–	-0.354	
Not disclosed	19	-0.509	0.692	0.168	–	–	–	

*$p < 0.05$

3.2.2 | Thematic Analysis of Questionnaire Open-ended Responses

In the open-ended question responses, 64 unique participants provided additional text responses, which were organised, coded, and analysed to identify themes across the qualitative data set. From this data, we identified eight themes that impacted student's sense of belonging, satisfaction, and perceptions of future career:

Theme A1: Challenging content. The participants tended to describe the content they were learning as challenging. Students described engineering as, *"very gruelling, it's difficult"*, *"Engineering is a tough subject"*, *"maybe a bit too tough"*. Another wrote, *"Sometimes effort put into certain tests, exams, and assignments does not reflect my outcome"*. Some participants attributed this to the format of the courses ("*a lot of material jammed into one course*") and the conceptual components of the content ("*I struggle a lot to understand concepts and put things into the bigger picture*").

Theme A2: Intensive workload. Students described the workload as intensive and difficult to manage. One student wrote, *"There's too much content and too much information"*, while another said that *"The workload only increases from first year"*. Another student pointed out if they were *"ever to get sick or injured and fall off on [their] assignments, catching up would be extremely painful"*. This also affected their ability to socialise with their peer groups and perceptions of their future career. One student commented, *"we are stacked with endless work and assignments; we are left with no time to be social"*, while another wrote *"being female and wanting children makes me uncertain about how getting back into engineering would look like especially if I wanted to take a couple of years off at least to raise my children"*.

Theme A3: Onus on one's self. Some of the responses reflected on their own self-worth and effort, rather than external factors in the environment. The responses indicated that some students hold themselves solely responsible for their academic performance despite evidence of external factors, such as the challenging content and intensive workload. *"[These questions] are all quite dependent on one's own ability rather than the environment"*, while another student wrote "*This year has not been going as well so my expectations of myself are lowering*". Another student commented, *"...some [questions] are to do with self-esteem and worth rather than the course"*. A student also wrote *"I've built myself over the years into someone who is comfortable with herself and within this specialisation"*. No trends in ethnicity or gender were observed across these three themes.

Theme A4: Mental health and impostor syndrome. Mental health and impostor syndrome emerged as strong themes. Some students explicitly mentioned the 2020 period of COVID-19 restrictions, *"I used to actively participate in class and I felt well connected to my peers, but as my depression grew throughout 2020, I could feel them disengaging themselves from me"*. Others mentioned an overall lack of engagement with their peers and lecturers, *"If I have any problems, I choose to deal with it myself or suffer in silence because I fear people, especially my lecturers, will see me as weak"*. This also relates to the theme of holding one's self responsible for one's own success or failure, thus unable to see systemic issues or seek help from support services. Many students mentioned feeling like an impostor, indicating a lack of belonging or "fit" within their environment: *"I constantly feel like an impostor...", "Have very strong impostor syndrome...", "I'm a mentally disabled student, I don't feel like I fit in..."*. Out of the six respondents who specifically mentioned impostor syndrome and mental health, all identified as women. No trends in ethnicity were observed.

Theme A5: Lack of social skills. Students commented on a general lack of social skills among their peers as being problematic: *"It's a running joke that everyone in engineering has no social skills", "...most people seem to be quite introverted and don't chat much in lectures", "People in the industry care about people skills... Grades are important as well, but are only a part of the equation"*. Another theorised that students were *"looking down on others because they think they're superior in some way and being too socially awkward to strike up a conversation"*.

Theme A6: Emphasis on technical skills. Similarly, others also pointed out the heavy emphasis of engineering education on logical, technical skills, while not providing opportunities to develop emotional intelligence and social skills. One participant said, *"The general culture of engineering tends to be more practical, logical, and science-focused which is great but can create a bubble for a lot of people who don't seem that aware of social or emotional issues beyond their immediate interests"*.

Other participants clearly related the focus on technical skills to a reduced sense of belonging or feelings of being different. For example, one participant said, *" . . . a lot of people are extremely logically-minded, and while that in moderation is great, it is hard to find people a bit more artistically-minded like me"*. Another participant said, *"...my brain prefers to think more creatively and in high-level logic derivation than to sit down and deal with numbers and specifics"*. No trends in gender or ethnicity were observed with Themes A5 and A6.

Theme A7: Social identity. Students' social identity, particularly their minority status, affected their ability to engage and integrate into their peer community. Many students commented on their age, gender, and ethnicity as defining characteristics that affect their experiences in a negative manner. One participant said, *"I am a young Māori mother with two babies under three. My life has a different focus compared to majority of the other students"*. Similar comments were made by other participants, highlighting their identity and the difficulty and isolation this can bring: *"Quite difficult being one out of two girls in my group of 25 friends"* and *"As a Pasifika student I do feel alienated sometimes"*. All of the comments in this theme were made by students belonging to historically excluded gender and ethnicity groups.

Theme A8: Social cohesion. Many students commented on their peer friendships and the factors that can affect their ability to form such friendships, for example entering the cohort at a different time and lecture class size. One student wrote, *"A lot more difficult to get to know other people now compared to highschool, because classes are so large and it is unlikely for you to sit next to the same person each lecture unless you were already previously friends with them"*. Other students theorised that taking a break from their studies *"probably contributes to [their] feeling around fitting in being quite different to others",* and *"it's hard . . . to make friends as they already have their [cliques]"*. No trends were observed in gender or ethnicity across this theme.

3.3 | Factors Influencing Student Experiences: Focus Group Results

RQ2: What are the key factors that influence the experiences of engineering students at the Waipapa Taumata Rau (The University of Auckland)?

From the focus groups, nine themes were identified as influencing the participants' experiences at Waipapa Taumata Rau (The University of Auckland). Several themes were only cited in certain focus groups (for example, only mentioned by women's groups), these are highlighted below, and evaluated further in the Discussion (Section 4).

Theme B1: Supportive working environments, were frequently discussed by women and non-binary participants, while conversely, never being discussed by men participants. This theme comprises both negative experiences related to non-supportive social interactions and positive experiences related to having the option to work in supportive environments. Both these aspects are described in detail below.

Many participants reported inappropriate, sexist, and generally non-compassionate behaviour from their men peers, *"There were derogatory comments, boys think they are joking, but it's not good. Guys will just say anything that comes to their minds without thinking. They think they're joking, but it's not a joke if you're not a woman saying it*". Women participants also described men students creating a non-supportive environment in lectures, *"In the lectures about the Treaty [of Waitangi], half the class didn't show up. Some men were very disrespectful, making jokes. All the treaty lecturers were women, so that might have been a factor. They would have to constantly say stop talking*". Another woman participant also cited non-supportive environments being created by men students online, *"If you spend enough time in the engineering Discord [instant messaging platform], it feels like engineering is just for guys. I've spent enough time in there, that I know what I should expect from them"*.

Conversely, many women and non-binary participants praised the availability of supportive environments, away from potentially non-supportive men peers. For example, women-only spaces were seen as valuable, with one participant saying, *"Women-only tutorials show they [the University] are trying, it was actually really good. Having a woman tutor makes a difference, women can be more approachable"*. Participants also mentioned the value of supportive spaces during their (university required) internships, *"In my internship, I was lucky, I was working with a lot of women. On-site I had to deal with all guys, which was a bit intimidating*". Some participants did praise the general university working environment, compared with their previous experiences. For example, a non-binary participant said, *"I was more excluded in high school, so uni was a welcome change. A rural school wasn't very inclusive*".

Theme B2: Not being respected academically, was another theme only discussed by women and non-binary participants. This theme has an exclusively negative influence on experience, and contributes to a non-supportive environment at the university (as discussed above). One participant said, *"Being a woman, people talk down to you, even if you're at the same level. Sometimes they're just straight-up wrong*". Another participant described having issues in group work, *"Two guys in my group didn't like taking advice from girls, being a bit sexist. I said they were drilling the holes wrong, but they didn't listen, and it was wrong*". Another woman participant described not being respected in lab work, *"I had an electrical lab, and the male lab assistant asked if I wanted pink wires, it was a bit degrading. Not good for the staff to make those types of jokes. Enough little things like that, and I start avoiding asking them for help. You might not ask for help, because you want to prove something to them*".

Theme B3: Finding friends in the course, was cited by all participants (all genders) as being important. Having good opportunities to make friends, or having pre-existing friends, in the course has a positive influence on experience. However, a lack of friends, and opportunities to make them, can have a significantly negative impact.

In-person lectures, tutorials, university clubs (and groups), and halls of residence were all cited as good social opportunities. One participant said, *"First year was really good, there were really big lectures, which meant you got to meet lots of people*". Another participant said, *"It's harder to meet people online. No chance for incidental conversations. In-person labs and tutorials are a good place to meet people*". Several participants praised clubs (and groups) in particular, with one participant saying, "*I met all my close friends through SPIES and Rainbow Engineering*". SPIES and Rainbow Engineering are dedicated student networks at Waipapa Taumata Rau (The University of Auckland) for Māori and Pacific students and LGBTQIA+ students, respectively (Waipapa Taumata Rau The University of Auckland, 2024b, 2024c).

On the negative side, several participants cited the challenges of not having pre-existing friends in the course, and difficulties in making new friends. One participant said, *"When I first came into Mech [mechanical engineering], I didn't really know* *anyone, and it seemed like everyone had their own group already, it was really difficult"*, and another mentioned, "*It's a lot harder to make friends if you don't come from Auckland, and don't know anyone. People from Auckland just stick together*".

Theme B4: Support from friends in the course, was frequently cited as important (by all genders). This theme has a positive influence on experience and emphasises the importance of finding friends. Several participants cited the importance of friends when facing difficult coursework, *"I mainly go to friends that I've made. If there's a hard project, we would sit there and work through it together*", with another saying, *"Over time I got to know a few more people (in the course), and now I get support through them*". Another participant also added, "*A lot of those relationships are why I've kept going, they say you can do this. All my positive experiences come through the people.*"

Theme B5: Difficult or stressful coursework, was commonly seen by participants (all genders) as significantly influencing their experience. One participant said, *"The workload is a lot. So much more than other degrees*", with another wondering, "*Does it have to be that stressful, if it was less stressful, perhaps some people wouldn't dropout?*". When asked if they ever thought about leaving engineering, one participant said, *"Every time exams come around, when everything is full-on, and really stressful. After it's done, I feel like I can continue"*.

Theme B6: Coursework support from the university, was cited as vital by most participants. Participants discussed both good support from the university, and times when they found the support insufficient.

On the positive side, participants praised Piazza (a student support forum), office hours with the lecturers, and tutorials. One participant said, *"The tutor was really great, they made me want to go and learn more from them*". Multiple participants also praised the Women in Engineering Network (WEN), a group for students identifying as women (Waipapa Taumata Rau The University of Auckland, 2024d), *"I was feeling down because my friends were doing better than me. I talked to a mentor from WEN and got good support to keep going. Emotional support, you'll be ok, it's normal (to find the course difficult).*"

Conversely, insufficient support can significantly increase student stress. One participant said the main time they doubted their ability to be an engineer was, *"When the projects are really difficult, and there's not enough support around*". Several participants discussed insufficient support from lecturers, with one saying, *"Talking to lecturers can be good or bad. 75% of the time they're helpful. But, sometimes you get a lecturer who isn't that helpful, and it seems like they just want to get out of there*". Other participants also noted that support resources weren't always obvious, with one saying, *"Uni could do more to make students aware of what resources are available"*, and another saying, *"I didn't know details about the professor's office hours. The info was there, but I didn't know. They could promote it more. Sometimes I feel like I'm on my own*".

Theme B7: Enjoyment and perceived value of the course content, was another factor often cited as influencing experience, by all genders. This theme could be either positive or negative, with both the value/enjoyment, and non-value/non-enjoyment, of the course content being mentioned.

One participant said, *"Seeing things being built and designed from the ground up is really cool, it's something I really look forward to*". Another participant reported their experience significantly improving when they were able to focus on their specialisation, *"Once I picked Civil, I started to enjoy engineering much more, and found it really interesting*".

On the negative side, several participants cited a gap between what is taught, and what is used in industry. For example, one participant said, *"I think there's a massive gap between uni and industry. What we learn isn't always relevant to what's done in New Zealand. Uni doesn't keep up with the real world*". Other participants echoed this sentiment, saying *"I wish uni had covered more tools that are used in the industry*", and *"I feel like there's a lot of theory, and a lack of practical skills*". Some participants also mentioned not valuing the general first year of engineering, *"I feel that a lot of the first year is irrelevant to software engineering, I don't need to know Chemmat (for example)*".

Theme B8: Non-inclusive lecture content, was cited by all participants in both the Māori and LGBTQIA+ focus groups, while conversely, not being discussed in any men's or women's groups. This theme has an exclusively negative influence on experience, where participants feel marginalised by, or disconnected from, the lecture content. For example, one participant in the Māori focus group said, "*The case studies in lectures are all from overseas. I would feel I fit in more if there were more relevant case studies. They should include more content that's relevant to New Zealand*". The same participant also added, "*From my point of view as a woman, there's no emotional perspective [in the case studies]*". In the LGBTQIA+ focus group, when asked if there was anything the faculty should stop doing, one participant said, "*They should stop using heteronormative examples in class*", with another participant adding, "*They could get lecturers to use more gender neutral language, there could be more education about gendered language*".

Theme B9: Representative lecturers, was again only cited in the Māori and LGBTQIA+ focus groups. This theme comprises both positive and negative influences on experience, based on the perceived representativeness of the lecturers. For example, one participant said, "*We had a female lecturer in Mech [mechanical engineering], which was good, at least there was some diversity in the lecturers. But, it would be good to have more diversity*". Another participant described a negative experience with a man lecturer, "*Our lecturer asked how many students can drive a manual, then said not many women. It's subtle exclusion. They should hire more people who aren't old men*".

3.4 | Answers to Research Questions

We can, therefore, summarise the answers to our two research questions as:

RQ1: How does sense of belonging, satisfaction, and perceptions of future career of engineering students at Waipapa Taumata Rau (The University of Auckland) vary across demographic characteristics (for example, gender, ethnicity, sexual orientation)?

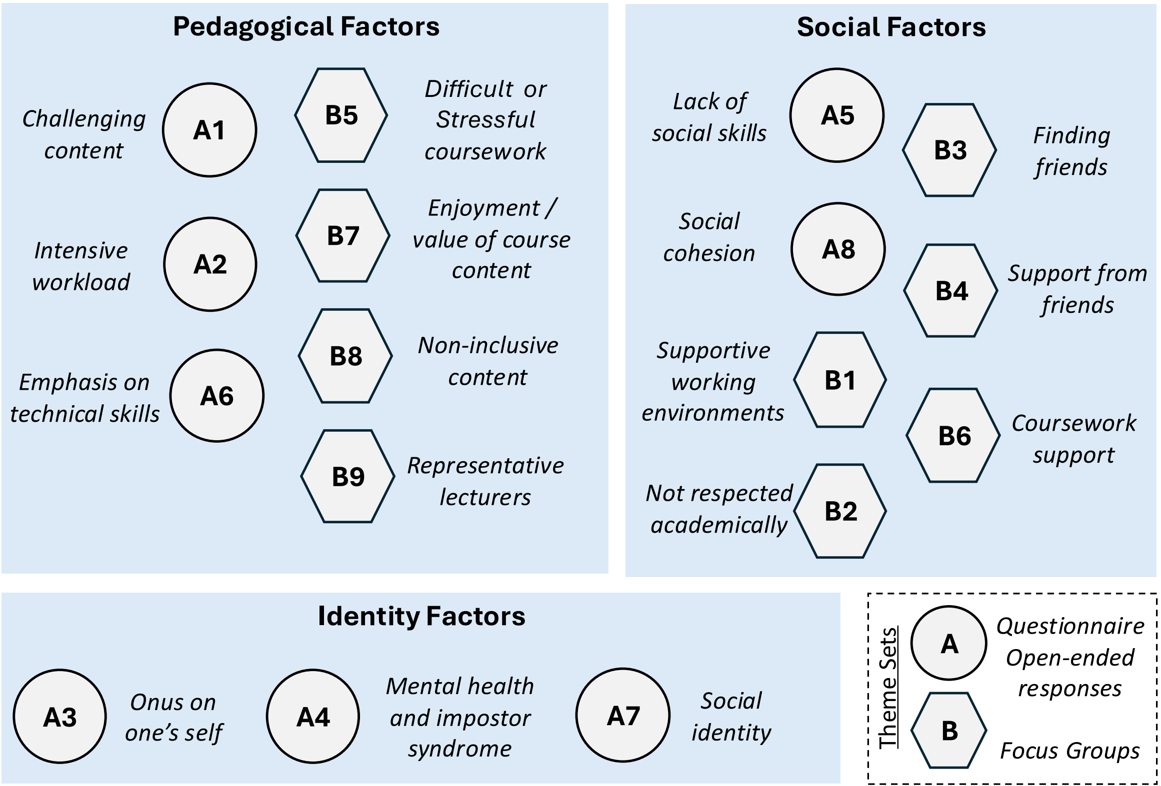
- Sense of belonging is statistically different across some demographics of ethnicity, sexual orientation and impairment status. Pacific students reported the lowest sense of belonging when compared to NZ European students, who reported the highest. Those who preferred not to disclose their sexual orientation or impairment status reported the lowest sense of belonging compared to the other demographic groups in their respective categories.
- Satisfaction is statistically different across some demographics of ethnicity and gender. Pacific students reported the highest satisfaction, while those who preferred not to disclose their ethnicity reported the lowest satisfaction. Women students reported the highest satisfaction, while those who preferred not to disclose their gender reported the lowest.
- Perception of future career is statistically different across some ethnicity demographics. Pacific students reported the most positive perceptions of their future careers, while those who preferred not to disclose their ethnicity reported the least positive perception of their future careers.

RQ2: What are the key factors that influence the experiences of engineering students at the Waipapa Taumata Rau (The University of Auckland)?

The key factors that emerged from the focus groups can be categorised as social factors and pedagogical factors. Social factors have been categorised as pertaining to the students' work environments during time spent on campus and studying off-campus, as well as their social interactions with their peers and university staff. Pedagogical factors have been categorised as pertaining to teaching content and pedagogy, as well as resources and services provided by the university to students to support their learning.

- **Social factors**: These include supportive work environments where students, particularly women students, were respected academically by their peers and teaching staff. These environments also include having peer friendships within the undergraduate programme who were supportive and accepting of their social identities, and were able to express their support using their social skills.
- **Pedagogical factors**: These include high levels of difficulty and intensity of the workload, which negatively influenced students' experiences. Support from the university, such as helpful teaching staff and asynchronous online resources positively influenced students' experiences by mitigating the effects of the challenging content and workload. Students' perceived value of the course content influenced enjoyment of their studies. Minority demographic groups in gender, ethnicity and sexual orientation were particularly influenced by the exclusivity of the content and the teaching staff, for example, engineering case studies that were less relevant to the cultural context of New Zealand and lecturers who do not belong to minority demographic groups within engineering.

FIGURE 3 Main dimensions of qualitative themes: Two sets of themes were separately identified, from the questionnaire open-ended responses (Themes A) and focus groups (Themes B), respectively. This figure illustrates three dimensions between the sets: Pedagogical, Social, and Identity.



The themes that emerged from the questionnaire open-ended questions can also mostly be categorised into social and pedagogical factors. Here, one additional dimension, identity factors, also emerged when probed more directly about belonging, satisfaction, and future career.

- **Identity factors**: These include the social identity of the participants (e.g., gender, ethnicity, and sexual orientation) as well as other aspects of identity like mental health.

Figure 3 illustrates these three main dimensions of Pedagogical, Social, and Identity factors and the themes contained within each of them.

4 | DISCUSSION

In this section, we discuss the implications of our results, discuss the limitations of the study, and provide recommendations for educators to foster more inclusive environments for historically excluded groups.

4.1 Implications

This study highlights how belonging, satisfaction, and future career perceptions interrelate and are intertwined in shaping engineering students' experiences. While quantitative data identified some demographic differences, qualitative insights highlighted the impact of inclusive or exclusive environments - particularly for women, Māori, Pacific, LGBTQIA+ students, and those who chose not to disclose aspects of their identity.

Pacific students reported lower belonging, but higher satisfaction and more positive career perceptions compared to NZ European students. While this partially aligns with research linking high satisfaction to persistence intentions (Flores et al., 2014; Lent et al., 2016), previous studies found weaker relationships for racially diverse groups — contradicting our findings where Pacific students showed the highest satisfaction and career perceptions. This contradiction may be partly understood through Naepi's (2019) work on Pacific narratives in New Zealand education, which describes historical exclusion and ongoing structural racism at universities. Despite this, Pacific Peoples connect community wellness to educational outcomes, creating intrinsic motivation to pursue and improve higher education from within (McAllister et al., 2022; Naepi, 2019). This could explain why Pacific students have contrasting belonging compared to satisfaction/career perceptions. These findings highlight the differences with respect to U.S. contexts, where most previous research occurred. The unique Aotearoa New Zealand context is entwined with the country's specific colonial injustices, and therefore more Māori and Pacific-led research is needed to understand specific factors that can improve their sense of belonging within engineering.

Quantitative findings showed no gendered differences in belonging, satisfaction, or career perceptions — unexpected given existing literature and contrasting with our qualitative findings. This discrepancy may stem from measurement invariance, differences between questionnaire and focus group samples, or subtle question variations. As Glisson (2023) notes, belonging varies depending on whether questions focus on specific engineering programs versus broader university experiences, raising questions about optimal data collection methods. Litzler and Samuelson (2013) suggests qualitative studies are more insightful for understanding historically excluded groups' belonging.

Our qualitative analyses revealed significant challenges for women and gender minorities, including sexist jokes and comments from peers and tutors. Focus group participants discussed the need for supportive environments (Theme B1) and academic respect (Theme B2), indicating challenged belonging (Tchamdjeu et al., 2018). Women-only tutorials were discussed as a valuable intervention, suggesting that women are not shying away from technical challenges, but rather finding it difficult to learn in stereotyped mixed-gender environments where their expertise and potential for success are questioned. These environments can pressure historically excluded students to work harder to prove competence (Williams & Dempsey, 2014) and can reduce confidence and self-esteem, challenging person-environment fit and leading to reduced satisfaction and persistence (Seymour & Hewitt, 1997; Seymour et al., 2019). Women-only tutorials mitigate these effects, supporting success in engineering education.

Participants emphasised social identity, social cohesion, and supportive friendships (Themes A7, A8, and B1), which SCCT identifies as crucial for historically excluded groups' belonging (Navarro et al., 2019). These findings align with Chiu et al. (2016) who found peer and teacher relationships key to belonging through connectedness, care, acceptance, and respect. Unique challenges may exist here in Aotearoa New Zealand, where students commonly attend local Universities. Students discussed difficulty developing friendships when cliques already exist (Theme B4), particularly challenging for minority students less likely to have friends joining engineering with them.

Beyond finding supportive friends, themes around lack of social skills (Theme A5) and emphasis on technical skills (Theme A6) imply that friends need appropriate skills to express their support effectively. This implies that the training environment in university engineering programmes can be unbalanced, prioritising performance and attainment over developmental experiences.

4.1.1 | Situated Expectancy Task Value Theory (SEVT) Lens

The conceptualisation of expectancies, task values, and cost and situating the research questions within SEVT (Eccles & Wigfield, 2020) afforded a greater acknowledgment of the reciprocal effects of socio-cultural, environmental, and intrapersonal factors in relation to the three key variables within an additional context. Participants discussed difficult and stressful coursework (Themes A1, A2 and B5) as effort and emotional costs. While overwhelming course load can push students from STEM majors (Seymour & Hewitt, 1997), low attrition rates (8-10% over the four year degree) suggest most students perceive the benefits as outweighing the costs. Participants noted key benefits of the coursework, including enjoyment of the content (intrinsic value) and career desires (utility value), supporting Rosenzweig et al.'s (2021) finding that task value drives STEM persistence, particularly for women socialised to perceive certain careers as poor work-life balance fits.

Non-inclusive content and non-representative lectures (Themes B8 and B9) indicate low attainment value for many participants in historically excluded groups (specifically Māori and LGBTQIA+ participants), as personal identity poorly aligns with the task (Eccles (Parsons) et al., 1983; Eccles & Wigfield, 2020). The lack of inclusive content and lack of representation signals social identity threats in the engineering industry. Prior research has found that such cues can impact sense of belonging and desire to participate (Murphy et al., 2007) and can create feelings of isolation (Boon-Nanai et al., 2017; Boston & Cimpian, 2018; Good et al., 2012).

Lecture content that is non-inclusive also signals that future engineering projects won't reflect their experience of society, demanding extraordinary resilience to succeed in an environment that does not appear to value their presence or unique identities. This may especially apply to Pacific students, who reported higher satisfaction but lower belonging. "Solo status", being the only member of a minority group, negatively impacts performance (Sekaquaptewa & Thompson, 2003). Added to this is the tendency within engineering culture on the individual self to hold themselves responsible for their performance, rather than external factors (Theme A3). This can also have important implications, such as mental health issues, for those transitioning into a workforce with little representation, and even more for those who do not feel comfortable with disclosing their gender or LGBTQIA+ identities altogether.

4.1.2 | The Study Context

Although most of the findings of the current study align with previous work related to persistence or attrition of historically excluded groups from U.S. and international contexts in general, some findings are unique to Aotearoa New Zealand. The experiences of Pacific students are specific to their motivations, perceptions, and persistence, which are likely influenced by cultural factors. More research is needed to understand these specific experiences and the three constructs in a more integrated fashion. The qualitative findings for women, LGBTQIA+, Maōri and Pacific students, and those who chose not to disclose their sexual orientation/ethnicity/impairment status indicate that some of the signals for attrition are present. Notably, as almost no research (McAllister et al., 2022 being one exception) exists that explores inclusion for inequitably represented groups in tertiary engineering education in Aotearoa New Zealand, urgency is added to the need for exploration in that arena. In particular, the culturally diverse nature of Aotearoa New Zealand highlights the pressing need to address the dearth of work that investigates how inclusion is affected in the case of intersectionality between inequitably represented minority groups (e.g., when ethnicity and gender identity intersect) in that country and in all global culturally diverse contexts.

Further, the significance of the current findings for the degree programme at Waipapa Taumata Rau (The University of Auckland) reveals the importance of conducting context-specific research on inclusion for unique groups. Importantly, the current findings also reaffirm measures that can been taken to strengthen policy, institutional structures, and inclusive pedagogies in all engineering educational contexts.

4.1.3 | Broader Implications for Engineering Education

The factors outlined in the present study could affect whether students, especially students from historically excluded groups, enter their careers with a hopeful or wary attitudes. If wary, they will be vigilant for non-belonging cues, potentially jeopardising retention (Murphy et al., 2007). Engineering job advertisements in Aotearoa New Zealand all but ignore skills related to the nation's broader societal values and bi-cultural nature, stressing instead independence and leadership (Galster et al., 2022). Moreover, Smith et al. (2022) found that Aotearoa New Zealand women engineers had a distinctly different identity-related needs than men (i.e., valuing supported authentic social identity over ambition). In the wider sector, the current ethos of policies presented by professional bodies such as Engineering New Zealand (https://www.engineeringnz.org/engineer-tools/ethics-rules-standards/policies/) does little to affirm belonging for historical inequitably represented groups.

Our findings support international research and suggest that universities need to put more effort into ensuring that students of all identities feel comfortable expressing themselves in engineering, since this has important implications for retention. In terms of institutional and pedagogical change, our participants reported increased satisfaction with support structures such as online student forums, office hours with lecturers, and women-only tutorials.

Work has been undertaken to test inclusive practices that enhance pedagogy, inclusion, intercultural understanding, and inter-personal interactions in engineering educational contexts (e.g., Jahan et al., 2022; Vaden et al., 2025), albeit again, largely in the U.S. context. Importantly, the testing of such practices has revealed that belonging can be differently affected by innovative practices for different groups (Vaden et al., 2025). Women and ethnic minority groups, for example, were less able to trust, discuss knowledge gaps, speak openly in class, and felt more judged than men and ethnic majorities (Vaden et al., 2025). Vaden and colleagues acknowledged that although research on inclusivity in general was abundant, there was a need to discretely explore the enhancement of inclusivity in engineering curricula and classrooms. Prior research mainly focused on learning style interventions and developing a sense of community in classrooms and had neglected guidance and specific resources that faculty could apply to course material. Importantly, Vaden and colleagues acknowledged that such initiatives could be even more challenging to apply in engineering because of the progressive technical complexity that accompanied advancement in that domain.

Vaden and colleagues proposed enhancing pedagogical practice in engineering contexts by faculty examining their assumptions about students, increasing their world view, integrating relevant and culturally diverse example into course material, supporting student voice in class, modelling inclusive language, behaviours, and attitudes, and overtly interrupting racist and discriminatory comments in their classrooms (Vaden et al., 2025). Further, actively reducing bias in class design, material, grading, and collaborative exercises and improving awareness to support acceptance of social identity, supporting students' connection to course content, and encouraging authenticity by understanding cultural differences were important in facilitating peer interactions (Vaden et al., 2025). Inclusive and trusting relationships with peers and teachers were foregrounded as key to belonging, but students from ethnic minorities were less likely to feel connected than their ethnic majority counterparts (Vaden et al., 2025). This work built on previous calls to enhance engineering education (e.g., Chang et al., 2014; Seymour & Hewitt, 1997; Seymour et al., 2019) by urging individual institutions to take concrete steps at systemic and faculty level. Chang et al. (2014) suggested that increased engagement via academic experience that was relevant to students' self-identity and participation in research at undergraduate level through expanded involvement in pre-professional co-curricular experiences (e.g., paid undergraduate research projects) would enhance students' sense of belonging and academic adjustment. Peer learning strategies (Lopez et al., 2013) and the development of a strong social network (Espinosa, 2011) contributed further to a positive learning climate that would promote belonging. Notably, how institutional exclusiveness or demographic nature and dynamics affected persistence would be influenced by systemic institutional practices, peer culture and the role of faculty as institutional agents for nurturing student progress (Chang et al., 2014).

Thus, research that has conceptualised and tested institutional and pedagogical changes and confirmed the need for promotion of policy aimed to enhance inclusivity, belonging, and, thus, persistence for minorities in tertiary engineering education. It is clear, however, that such changes are specific to each unique group, social identity, and context. The findings of the current study support previously mentioned changes but highlight how careful consideration of context is key to their success. Specifically, how change is implemented requires particularly focused exploration where diverse social identities intersect in novel contexts, for historically excluded groups.

4.2 | Limitations of Study

A key limitation of this study stems from using a newly developed questionnaire rather than previously validated instruments. While existing instruments measure some aspects of our research focus, none fully captured the specific constructs we aimed to investigate in engineering education. This necessitated the development of our own questionnaire, though the items used to measure our three main constructs were sourced from existing scales and prior literature (see Table 1). Still, a new questionnaire introduces potential concerns about reliability and construct validity. This limitation could impact our findings by raising questions about whether our scales truly measure the intended constructs and whether the relationships we found are reproducible. To address reliability concerns, we employed multiple measures: Cronbach's alpha (Cronbach, 1951), McDonald's omega (McDonald, 1999), and mean inter-item correlations. All measures indicate acceptable to good reliability (see Table 4), suggesting internal consistency in our measurements. To address construct validity, we conducted CFA to validate the hypothesised factor structures. The resulting model demonstrated acceptable fit values (see Table 3), providing evidence that our items measured their intended constructs. However, as this is the first application of this questionnaire, these results should be interpreted with appropriate caution. We did not establish convergent and discriminant validity, nor did we test for measurement invariance between different groups in our sample. Future work can further validate the questionnaire through replication studies and potentially refine the instrument based on additional analyses.

Social desirability bias introduces another potential limitation that could affect the validity of our findings. Despite using an anonymous questionnaire and framing questions around personal experiences rather than right or wrong answers, participants may have provided responses they believed would be viewed more favorably. This bias could lead to underreporting of negative experiences or overreporting of positive attitudes, potentially masking the true extent of belonging-related challenges in the engineering programme.

Another limitation is that all respondents who completed this questionnaire were self-selected, which introduces a self-selection bias. The target population of this study were undergraduate engineering students. We recruited participants by advertising the questionnaire through mailing lists at Waipapa Taumata Rau (The University of Auckland). However, the aim of improving inclusion in engineering education was stated in the invitation. Thus, self-selection likely resulted in overrepresentation of students who are particularly interested in or concerned about inclusive education. Consequently, our findings may not accurately represent the views of the broader student population, potentially overestimating the prevalence of inclusion-related concerns.

Beyond self-selection bias, there are other generalisability limitations that can affect the external validity of our findings. Our sample was limited to a single university, which may not be representative of the broader student population in Aotearoa New Zealand. The findings may not generalise to students at universities with different characteristics. For example, there are varying entry criteria, programme sizes, regional differences, institutional cultures, and practices across universities. Waipapa Taumata Rau (The University of Auckland) is located in Aotearoa's biggest city and is the country's largest university.

The demographic composition of our sample presents several limitations that impact the comprehensiveness and generalisability of our findings. The high proportion of first-year students (38%) means our results may disproportionately reflect the experiences of students who are still adjusting to university life and have had limited exposure to university culture. This could lead to either overestimating or underestimating belonging challenges, as first-year students may experience different integration issues compared to their senior counterparts. However, no statistically significant differences were identified between year groups. Additionally, the predominance of domestic students (95% of questionnaire respondents and all focus group participants) significantly limits our understanding of international students' experiences. This homogeneity means our findings primarily reflect the perspectives of students already familiar with the local cultural context, potentially overlooking unique challenges faced by international students in developing a sense of belonging in engineering education. Further, the absence of demographic data on participant age and enrollment type (full-time v part-time) represents another limitation. Without this information, it is impossible to know whether our sample adequately represents the age and enrollment distribution of the student body.

While the majority of participants selected a single ethnicity, 13.5% of participants reported two or more ethnicities across multiple aggregated demographic groups (e.g., Māori and NZ European). The limited number of responses and aggregation of ethnicity demographics made it difficult to understand the unique factors that influence these multi-ethnic students' sense of belonging, such as issues of colourism. Skin-shade prejudice can influence Indigenous and ethnic minorities' experience of racism in New Zealand (Simon-Kumar et al., 2022). This limitation means our findings may not fully capture the complexity of belonging experiences for students with multiple ethnic identities.

The timing of our study during the COVID19 pandemic represents a significant contextual limitation that affects the interpretation of our results. The extended period of online learning likely influenced students' reported feelings of isolation and sense of belonging. This temporal context makes it difficult to distinguish between belonging challenges inherent to engineering education and those arising from pandemic-related disruptions. These confounding factors could lead to overestimating the severity of belonging-related issues or misattributing the sources of students' experiences.

Finally, the qualitative analysis of questionnaire open-responses and focus groups introduces potential researcher bias, including interpretation and confirmation biases. To mitigate these threats, we took several steps. Both thematic analyses were conducted following Braun and Clarke's six-phase methodology (Braun and Clarke (2021)), with different authors serving as the primary coder for each data source to reduce individual bias effects. Each analysis was led by a primary coder experienced in engineering research and was subsequently reviewed by additional experienced co-authors to incorporate alternative interpretations and challenge initial coding decisions. Similar themes of pedagogical and social factors emerged independently across both data sources, demonstrating consistency in our analysis. Further, many identified themes align closely with established literature. For instance, previous studies similarly highlight how shared working environments with men can negatively impact women's confidence and self-esteem (e.g., Seymour and Hewitt (1997); Seymour et al. (2019)), consistent with Themes B1 and B2. Likewise, earlier research underscores the importance of social support from peers and faculty for cultivating a sense of belonging, aligning with our findings in Themes A7, A8, and B1. We acknowledge that member checking was not conducted, which is a limitation of the study. However, the convergence of themes across independent analyses, combined with their alignment with prior research and the involvement of multiple experienced coders help establish the credibility and trustworthiness of our findings.

While potential biases remain, this study provides meaningful insights into undergraduate engineering student experiences within the underexplored research setting of Waipapa Taumata Rau (The University of Auckland) in Aotearoa New Zealand. Future work can address the limitations of this study by replicating the study with cohorts who have not experienced pandemic-related disruptions and in different university contexts, including a more balanced representation of year levels and a larger proportion of international students, and employing regression analysis for more nuanced examination of ethnicity demographics. Such studies could also introduce new variables to account for specific intersectional experiences among engineering students, providing a more comprehensive understanding of belonging in engineering education.

4.3 | Recommendations for Educators

Based on our findings and review of the literature, here we make several recommendations to promote positive experiences and improve retention of historically excluded groups in engineering tertiary education.

Dedicated supportive learning and social environments for students from historically excluded groups are valuable and should continue to be cultivated. This study reports a number of negative experiences from students from historically excluded groups, including students identifying as women, Māori, Pacific, LGBTQIA+ and those who chose not to disclose their gender or sexual identities. This is in line with previous work, which describe a "cold" or "chilly climate" for women in engineering (Bannikova et al., 2018; Besterfield-Sacre et al., 2001; Callister, 2006; Hall et al., 2015; Longe et al., 2019; Seron et al., 2016, 2018; Weisgram & Diekman, 2015).

However, participants also reported significantly positive experiences within dedicated supportive environments. Women only tutorials, as well as student groups for women, LGBTQIA+, and ethnic minority students were frequently cited as valuable. Participants cited these resources as important for meeting like-minded friends, who can support each other through the often difficult coursework. By supporting these groups, institutions also send a clear message of support to potentially marginalised groups. Institutions can provide support in the form of finance and internal resources (e.g., meeting rooms and staff) to help cultivate supportive environments for their students.

Emphasise representation and inclusion within engineering course content. The content presented in engineering lectures was cited by many participants as having a significant impact on their experience, both positive and negative. Course content was reported as having a negative impact when perceived as non-representative or exclusionary. Additionally, LGBTQIA+ participants reported feeling excluded by the use of cisheteronormative examples as well as gendered language. For example, participants noted that course materials used "he or she" instead of "they", which contributed to their sense of exclusion.

Engineering educators should endeavor to emphasise representation and inclusion in course content, in order to cultivate a sense of belonging in their students. Content should include relevant local examples and feature the important engineering contributions of people from historically marginalised groups. There have been recent efforts developing resources that promote such contributions, including contributions of Māori, Pacific Peoples, women, LGBTQIA+ people, neurodiverse people, and those with disabilities (Bjørn & Rosner, n.d.; Cowen, 2019; Foothold, n.d.; Lysaght, n.d.; Maslen-Miller, n.d.; QueerBio, n.d.). Researchers can support educators by collecting, sharing, and promoting inclusive teaching resources that can be readily utilised to enhance existing course content.

Finally, the use of exclusionary language should be avoided in course content, with educators being mindful to practice inclusivity and avoid exclusionary behaviour, especially towards historically excluded groups.

Provide inclusivity and sensitivity education to promote awareness of exclusionary behaviour and highlight the challenges faced by historically excluded groups. As described in the results, participants from historically excluded groups often reported experiencing exclusionary behaviour from their peers and occasionally from teaching staff. Some participants also shared feelings of not being respected academically.

These reports may indicate a lack of awareness of the negative impact of exclusionary "jokes" and behaviour from some students and educators. Providing additional education on the challenges faced by students in historically excluded groups within engineering, both immediate and historic, may help to promote awareness of problematic behaviour and cultivate more compassionate communication between students. As recommended above (inclusive course content), further education on the important contributions of diverse engineers can help broaden perspectives on who belongs in engineering. Further training on inclusive language, including non-gendered language, would also be useful for many students and educators and should be tailored to the local context.

Provide sufficient social opportunities for all students to facilitate robust peer support networks. Having friends within engineering was reported as important by the majority of focus group participants for both support with difficult coursework and for social and emotional support. However, with learning increasingly moving online, natural opportunities for students to make friends within their courses can be limited. In-person gatherings should be facilitated to help build strong student peer networks. For example, in-person lectures, tutorials, and social events were all cited by participants as socially valuable. Additionally, these class-wide opportunities may help to facilitate connections between students across diverse backgrounds to help in creating more inclusive environments. Student networks that offer safe spaces for historically excluded groups such as Rainbow Engineering and the South Pacific Indigenous Engineering networks should be explicitly supported and promoted during classes. These student networks provide social activities and professional networking opportunities that can enable students to make friends within and outside their specific courses.

Universities should also investigate ways to facilitate deeper social interactions in online settings if they continue to offer online learning.

5 | CONCLUSIONS

In this study, we examined sense of belonging, domain satisfaction, and perceptions of future careers of engineering students at Waipapa Taumata Rau (The University of Auckland). We used both an online questionnaire and focus groups to understand the experiences of students that impact their sense of inclusion. We found some statistically significant differences in reported levels of belonging and satisfaction across demographic groups. From our qualitative data, we developed a set of themes that can help shed light on some of these differences. In our focus groups, when participants were probed about negative experiences, stories of continued inequities emerged. Based on our findings, we made several recommendations for educators to improve equity in the tertiary education environment to retain students from all backgrounds. Our recommendations include providing support for dedicated supportive learning and social environments for students from historically excluded groups, expanding engineering course content to emphasise representation and inclusion, and providing training to both staff and students to promote awareness of exclusionary behaviour and better understanding of inclusive language. We suggest future intervention studies where these recommendations can be validated and examined in more detail.

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Abbreviations

CFA Confirmatory factor analysis

EM Expectation-maximization

MI Modification indices

SCCT Social cognitive career theory

SDT Self-determination theory

SEVT Situated expectancy task value theory

SPIES South Pacific Indigenous engineering students

STEM Science, technology, engineering and mathematics

WEN Women in engineering network

WG – SS Washington group short set on functioning

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