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Exploring Sense of Belonging in Undergraduate Computing Students

By

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The thesis is submitted to University College Dublin in fulfilment of the requirements
for the degree of
Masters (MSc) Research

School of Computer Science

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APRIL 2024

DEDICATION

Dedicated to my bright guiding star, Aurora, my three-year-old joy and inspiration, who fills every page of my thesis with love!

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I would like to express my sincere gratitude to my supervisor, Dr. Catherine Mooney, and co-supervisor, Dr. Brett A Becker, for their unwavering support and guidance throughout my research journey. They not only mentored me but also cared for me like nurturing parent. Their patience, encouragement, and wealth of knowledge have been instrumental in my academic growth. I am truly thankful for their mentorship, which enabled me to learn the intricacies of research work from scratch. Their eagerness to help and their constant support made this journey not only educational but also enjoyable.

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Abstract

Sense of belonging or belongingness is a crucial aspect of a student's academic journey, influencing motivation, persistence, and overall well-being. Belongingness is also associated with factors such as gender, race, and socio-economic status, plays a pivotal role in shaping students' experiences and influencing their decision to remain in computing disciplines. This research examines the complex nature of belonging among undergraduate computing students, addresses the persistent representation gaps in the field.

Through a comprehensive literature review, we first establish a foundation for understanding belonging in undergraduate computing, identifying gaps in existing knowledge and highlighting the need for further exploration. We then compared the sense of belonging across diverse student populations within the College of Science, including Computer Science and other science disciplines. By examining gender identity, minoritisation, and university entry routes, we uncovered nuanced disparities in belongingness.

Contrary to some existing literature, we found no statistically significant difference in overall belongingness across genders. However, minoritised students, especially women of colour, experience significantly lower belongingness, with variations based on intersecting identities. Additionally, belongingness in Computer Science is notably lower than in other science disciplines, further contributing to the representation gap.

We expanded our focus to investigate how university entry routes impact students' sense of belonging. Findings revealed that students entering through direct-entry school leaving routes generally experience a higher sense of belonging compared to those using combined access routes. Gendered differences, particularly in Computer Science, highlight the intersectionality of entry routes and gender in shaping belonging.

Qualitative analysis revealed the multifaceted factors influencing belonging, including the impact of the COVID-19 pandemic, financial constraints, and the need for social interactions. Peer relationships, diversity in faculty, and institutional support emerge as critical contributors to a positive sense of belonging. Our research underscored the importance of creating an inclusive environment through diversity training, addressing imposter syndrome, and fostering a culture of respect.

My thesis highlights the importance of addressing gender, minoritisation, and entry routes to promote diversity and retention in computing education. We call for sustained efforts to create inclusive environments that foster a sense of belonging among all students.

PUBLICATIONS

Journal and conference papers

Shamima Nasrin Runa, Anna Markella Antoniadis, Brett A. Becker, and Catherine Mooney. 2023. **Student Sense of Belonging: The Role of Gender Identity and Minoritisation in Computing and Other Sciences.**

In Proceedings of the 25th Australasian Computing Education Conference (ACE '23). Association for Computing Machinery, New York, NY, USA, 87–96.

Shamima Nasrin Runa; Andrew McCartan; Yuhang Du; Brett A. Becker, and Catherine Mooney. **Sense of Belonging in Undergraduate Computing Students: A Scoping Review.** This manuscript has been submitted to Educational Research Review.

Shamima Nasrin Runa, Andrew McCartan, Brett A. Becker, and Catherine Mooney. **Pathways to Belonging: Understanding How University Entry Routes Shape the Sense of Belonging of Undergraduate Computing Students.** This manuscript has been submitted to ACM Transactions on Computing Education (TOCE).

Conference posters

Shamima Nasrin Runa, Andrew McCartan, Brett A. Becker, and Catherine Mooney. 2023. **Sense of Belonging of Undergraduate Computing Students: A Comparative Analysis of University Entry Routes.**

In Proceedings of the 2023 Conference on United Kingdom & Ireland Computing Education Research (UKICER '23). Association for Computing Machinery, New York, NY, USA.

Shamima Nasrin Runa, Brett A. Becker, and Catherine Mooney. 2022. **Variations in Sense of Belonging in Undergraduate Computing Students Through the COVID-19 Pandemic.**

In Proceedings of the 2022 Conference on United Kingdom & Ireland Computing Education Research (UKICER '22). Association for Computing Machinery, New York, NY, USA, Article 18, 1.

AUTHOR'S DECLARATION

I hereby certify that the submitted work is my own work, was completed while registered as a candidate for the degree stated on the Title Page, and I have not obtained a degree elsewhere on the basis of the research presented in this submitted work.

SIGNED: DATE:

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INTRODUCTION AND BACKGROUND

This chapter provides a comprehensive background of the work, including the motivations, objectives, research questions, contributions, and outline. The chapter will define the meaning of ‘sense of belonging’ and its importance. Moreover, it will delve into the concepts of minoritisation and intersectionality in relation to sense of belonging.

1.1 Motivation

My motivation for this thesis stems from the crucial impact of a sense of belonging on students’ academic progression and retention. Despite its significance, there is a noticeable gap in research on the belongingness of undergraduate computing students, and the influencing factors remain inadequately understood. The goal of my research is to enhance comprehension regarding the contributors to the sense of belongingness among undergraduate computing and science students in one of Europe’s largest universities. Additionally, I seek to investigate variations in belongingness across different Schools and student groups. Acknowledging the pivotal role of belonging in students’ engagement, motivation, and overall well-being, this work aims to identify influencing factors, address potential disparities, and contribute to the establishment of inclusive and supportive learning environments within the field of computing. Ultimately, I aspire to improve the academic journey for all students, cultivating a sense of community, diversity, and empowerment in computing.

1.2 Objectives

1. To evaluate undergraduate computing students' sense of belonging.
2. To determine the factors that affect computing students' sense of belonging, both positively and negatively.

1.3 Research questions

RQ1: How has sense of belonging been studied in undergraduate computing? (Chapter 2)

RQ2: How does sense of belonging vary by gender identity and minoritisation? (Chapter 3)

RQ3: How does sense of belonging vary by university entry routes? (Chapter 4)

1.4 Contributions

This thesis has:

- Provided a comprehensive synthesis of existing studies investigating the sense of belonging among undergraduate computing students to gain insights that can inform interventions aimed at retaining diverse student cohorts and closing representation gaps.
- Explored how the belongingness of students varies by gender identity and minoritisation.
- Compared the belongingness of Computer Science students with other Science students and examined how belongingness varies in Computer Science by gender identity and minority status compared to other Science students.
- Investigated the differences in the sense of belonging among students based on their university entry routes and compared the belongingness of Computer Science students with that of other Science students.

1.5 Sense of belonging

A ‘Sense of belonging’, or ‘belongingness’, refers to a student’s perception of acceptance, respect, inclusion, and support from others in an academic environment [34]. It encompasses the belief and perception that one is an integral and accepted member of the academic community whose presence and contribution are valued and respected [29]. Sense of belonging is closely linked to important outcomes such as academic performance, retention, self-esteem, motivation, grades, interest in a field, graduation and intentions to pursue higher education [34, 45, 64, 99]. Additionally, it plays a pivotal role in developing and sustaining inclusive and equitable learning environments [87]. Belongingness is influenced by several environmental factors, including students’ backgrounds and experiences [34], colleagues [92], and professors [28], physical [93] and virtual [52] environments, as well as contextual factors such as the discipline [29] and part-time/full-time status [44]. Furthermore, external factors such as local, regional, and global landscapes [19], as well as time [3], can also impact students’ sense of belonging.

1.6 Belonging in academia

Universities in general provide unique spatiotemporal environments in which students are encouraged to meet others and develop strong social relations to provide an ‘essential step in adulthood for improved job prospects, elevated social status, or higher income earning potential’ [15, 21, 84]. As such, sense of belonging has become a highly relevant and consistent framework for examining the experience of students as they transition into third-level education, persist in their degree programmes, and engage in campus communities [11, 42, 73, 108, 109]. Belonging at university encompasses a perception of whether students are valued and treated fairly and equally by their peers and teachers in academic and social engagements within the educational environment [5, 27, 56, 100, 103]. Students are more likely to remain in their studies if they have a healthy sense of belonging, due to how feelings of belonging can ‘help students to overcome challenges, hardships, or struggles, and mitigate or reduce non-completion of their degree’ [2, 15]. Data on sense of belonging can therefore be useful for institutions and departments looking to understand student drop-out rates, increase student retention, and address gender gaps in student populations [18, 29, 68, 74, 90]. In this way, sense of belonging may offer a useful lens for revealing the ways in which computing becomes an ‘inhospitable environment for women’ and other minorities [110].

Research in other disciplines shows disparities in belonging where a low sense of belonging is exacerbated for students from marginalised and under-represented social groups on campus [55, 77]. Students who live in an unfamiliar or foreign environment, and those who face barriers due to racism, sexism, homophobia, and/or other discriminations on campus, are known to have a lower sense of belonging on the basis of their gender, race, ethnicity, disabilities, economic background, and other factors [4, 15, 80, 98]. This may be intensified by cultures in computing that focus on ‘maintaining a competitive edge’ at the expense of ‘alienating those to whom’ coding and computing skills do ‘not come naturally’ [110]. This has raised questions about the applicability of theories of student retention based on majority students for minoritised groups and the need to synthesise culturally sensitive research into sense of belonging in order to address the representation gaps in computing [24, 42].

1.7 Measuring belonging

There is a need to better understand how sense of belonging is understood and measured in computing for diverse student populations. Tools for measuring belonging beyond anecdotal and narrative accounts have developed since the mid-1990s that can capture snapshots of student belonging. Hagerty & Patusky (1995) [33] first developed a self-reporting Sense of Belonging Instrument (SOBI) within nursing education. The SOBI contains 27 items – each being a factor describing one psychological state or antecedent of belonging – generated from focus group data, academic literature, and clinical experience, rated on a 4-point Likert scale (1 = strongly disagree to 4 = strongly agree). Construct validity was supported through factor analysis and correlation with measures of loneliness, reciprocity and social support, and was tested for contrasted groups. In mathematics, Good *et al.* (2012) [29] developed a ‘Sense of Belonging to Math Scale’. This included 30 items across five components (membership, acceptance, affect, trust, and desire to fade) rated on an 8-point Likert scale (1 = strongly disagree to 8 = strongly agree), and specifically asked participants to consider their membership in the math community, with each item preceded with the statement “when I am in a math setting...”. Their scale was found to have a ‘unique power to predict factors that are related to math achievement’ and predict student intention to remain in Math ([29, p.706-7]). However, there is no consensus on how to capture data on sense of belonging across and within disciplines, and other researchers have chosen qualitative or mixed-method approaches of analysing interview and/or focus group data on sense of belonging, for example, in

STEM (Science, Technology, Engineering and Mathematics) [78]. To measure sense of belonging is to understand belonging ‘in functional and operational terms – as something that can be fostered or fixed through interventions, policies, and strategies’ [76, p.740]. Yet, belonging is not static but is dynamic, malleable and shifting, so that it is context-dependent and felt more or less in some situations, places, and times over others [54, 57]. Therefore, it is important to assess the methods used to date to collect and analyse data on belonging in computing to be able to create interventions that recognise and respect the complexity of belongingness for diverse Computer Science cohorts.

1.8 Definitions of minoritisation and intersectionality

Minoritisation:

Gunaratnam (2003) [31] introduced the term “minoritised” in 2003 from a social constructionist perspective, emphasising that individuals are actively subjected to minoritisation by others, as opposed to belonging to a minority group by default, as implied by terms such as racial minorities and ethnic minorities. According to Chappell and Cahnmann-Taylor (2013) [13], the term “minoritised” is used to describe individuals who are part of contextually situated, non-dominant communities, taking into account various factors such as race, gender, class, sexual orientation, language, disability, and religion.

Intersectionality:

Crenshaw (1989) [16] first introduced the concept of intersectionality in 1989, emphasising the importance of considering the combined impact of gender and race within antidiscrimination laws. This recognition arose from the observation that black women’s experiences were overlooked when gender and race were treated as separate categories. Since then, intersectionality has been widely applied in various disciplines to highlight how different forms of oppression and discrimination affect individuals based on the intersections of gender, race, and class.

1.9 Outline

Chapter 2, provides a comprehensive scoping review of relevant research, encompassing various sources to understand the existing literature focusing on undergraduate computing students’ sense of belonging. Research reveals how multiple barriers to student

belonging are experienced differently across different student populations. Belongingness has significant disparities relating to gender, race, and sexuality that may explain representation gaps.

Chapter 3, presents the results and progress of one of my recently published works focused on how belongingness differs among computing and other Science students, based on gender identity and minoritisation. The result showed that belongingness is not statistically significantly different across genders overall. However, minoritised students have statistically significantly lower belongingness, which varies by gender. Additionally, the study found that the belongingness of Computer Science students is statistically significantly lower than that of other Science students and that belongingness varies across Science disciplines by gender and minoritisation.

Chapter 4, discusses how university entry routes affect computing and Science students' sense of belonging, including a detailed examination of methods, results, and implications. Results revealed a significant difference in belongingness between students entering the University through the direct-entry school leaving route, compared to those who entered via combined access routes. Specifically, within Computer Science, students entering university through the direct-entry school leaving route had significantly higher belongingness than combined access route students.

LITERATURE REVIEW

This literature review is based on an article submitted to Educational Research Review. It explores the literature on undergraduate students' Sense of belonging in Computer Science. I have presented here the contributions of these publications and their findings to provide a comprehensive understanding of the topic.

Author contribution

Conceptualisation: Catherine Mooney; Introduction: Shamima Nasrin Runa, Andrew McCartan; Methods and Results: Shamima Nasrin Runa; Discussion: Shamima Nasrin Runa, Andrew McCartan; Original Draft Preparation: Shamima Nasrin Runa and Andrew McCartan; Review and Editing: Shamima Nasrin Runa, Andrew McCartan, Catherine Mooney, Brett A. Becker, and Yuhuan Du; Supervision: Catherine Mooney. All authors have read and agreed to the submitted version of the manuscript.

Abstract

Computing faces persistent representation gaps that limit the development of the discipline, as many students who contribute to diversity leave when they do not see themselves included and feel they do not belong. Student ‘sense of belonging’ is complex and challenging to measure, so there is a need for clarity on how sense of belonging can be operationalised in computing education research aimed at improving diversity and student retention in computing. This review provides a comprehensive synthesis of existing studies investigating sense of belonging among undergraduate computing students. By consolidating community understanding of how undergraduate students develop their sense of belonging within computing, we provide a means from which insights can emerge that can inform the development of targeted interventions aimed at retaining diverse student cohorts and closing representation gaps. Most existing research follows a quantitative study design where belongingness is measured using surveys with 2 to 30 items with 5 to 8 point scales. The research reveals how multiple barriers to student belonging are experienced differently across different student populations. Belongingness has significant disparities relating to gender, race, and sexuality that may explain representation gaps, but attention needs to be paid to how these identities intersect to shape student experiences. The research also suggests various social and academic interventions that can raise sense of belonging. This paper synthesises valuable insight that can help shape the creation of future interventions and research aimed at fostering and improving sense of belonging among undergraduate computing students.

2.1 Introduction

Computing is a crucial discipline for developing students with the knowledge, skills and competencies needed to create competitive and innovative advancements for our increasingly digital world. However, representation gaps at all levels of computing, particularly around racial, gender and sexual minorities, limit the potential advancement of the field [47]. One key cause of the lack of diversity in computing is the persistent struggle to attract and retain a diverse student body at the undergraduate level [72]. The students required to have a diverse student body because of gender, race/ethnic background, socioeconomic status, learning styles, disabilities, and/or limited English proficiency (to name only a few) may have needs that are not being addressed in their current academic environments. There is an urgent requirement to better examine the experience and well-being of undergraduate students, to be able to understand these gaps and to develop interventions to strengthen the diversity of academic departments.

Existing research has explored how under-representation occurs and persists through a complex assemblage of factors across multiple scales, from individual student experiences and accessibility needs to interpersonal relations between the student and others, and the broader social-cultural norms within institutions and the discipline [60, 94]. However, researchers have called for a more enhanced, intersectional approach to understanding identity formation, or the moment when people understand themselves as computer scientists [81]. Within broader higher education research, sense of belonging (SoB), or ‘belongingness’, is a key concept for capturing how/if students feel valued and/or accepted. It is also known to be an indicator of student performance and persistence [29]. Belongingness may therefore be a key concept for revealing the complex assemblage of factors shaping student retention, particularly as it relates to intersectionality and minoritised identities.

2.2 Research objectives and questions

Despite a growing body of research that has begun to measure and assess belongingness for Computer Science cohorts at the undergraduate level, there has to date been no review to synthesise insights from this emergent literature. The primary objective of this scoping review is to identify the extent of existing literature on computing students’ sense of belonging and synthesise the key knowledge and methodological practice within it to gain insight for future research and practice.

We aim to develop a deep understanding of the complexity of belongingness in computing that will clarify how undergraduate student belonging is understood and can be used effectively in research to improve undergraduate computing students' connection to the discipline. We intend for this to reveal the best practices and future research directions, which may guide future studies in the field. To achieve this, we are guided by the following research questions (RQs):

RQ1: How is the sense of belonging conceptualised in research on undergraduate computing students?

RQ2: How is the sense of belonging measured in research on undergraduate computing students?

RQ3: How is the sense of belonging used to generate new insights into undergraduate computing student's experiences?

RQ4: What insights into undergraduate computing students have been revealed from research engaging with a sense of belonging?

RQ5: How might future research build upon this existing work?

2.3 Method

The PRISMA extension for scoping reviews (PRISMA-ScR) statement [101] was employed for this review. A scoping method was chosen to allow us to “map” the existing literature, in order to understand why, where and how research has been carried out on belongingness in computing undergraduate students. Scoping the Computer Science-specific literature in belonging also reveals the gaps in knowledge, revealing what the computing research community might still learn from other disciplines, or where Computer Science requires a nuanced approach.

2.3.1 Information sources and search strategies

This review considers institutional, national and international studies into the belongingness of computing undergraduates. The search for relevant literature took place in December 2022, with a search strategy to locate only published conference and journal articles which present methods and results of original studies with student participants. A date limit was set to cover the last ten years of studies published between 1st January 2013 and 1st December 2022.

The databases chosen for the search were Google Scholar, Web of Science, and Scopus, which are widely recognised as comprehensive academic search engines. Various title searches were conducted on all three databases using different synonyms of search terms that were selected to capture the widest range of papers. Variations of the search terms included:

1. Concept: “Sense of Belonging” or “Belonging” or “Belongingness” or “Belongs”
2. Population: “Student” or “Undergraduate” or “University” or “College”
3. Context: “Computer Science” or “Computing” or “CS” or “Science” or “STEM”

In total, 17 searches (S1-S17) were performed to produce a broad set of results from which to select relevant papers (see Table 2.1).

Table 2.1: Keywords used in database article searches

Search Number	Search Term	Search Number	Search Term
S1	“Sense of Belonging” “Students”	S10	“Sense of Belonging” “College”
S2	“Sense of Belonging” “University”	S11	“Belongs” “Computing”
S3	“Computer Science” “Sense of Belonging”	S12	“Belongs” “Computer Science”
S4	“Computing” “Sense of Belonging”	S13	“Belongingness” “Science”
S5	“CS” “Sense of Belonging”	S14	“Belongingness” “University”
S6	“Belonging” “Computing”	S15	“Belongingness” “College”
S7	“Sense of Belonging” “Science”	S16	“Sense of Belonging” “STEM”
S8	“Belonging” “Undergraduate”	S17	“Belongingness” “STEM”
S9	“Undergraduate” “Sense of Belonging”		

These searches identified a total of 2,172 possible papers: 1,319 from Google Scholar (which were retrieved using “Publish or Perish” software), 382 from Web of Science, and 471 from Scopus.

2.3.2 Study selection

As shown in Figure 2.1 initially a total of 2,172 articles were retrieved from the three databases. Following the removal of duplicates (1,148) and studies that are not available in full text (48), 976 papers remained for full-text review. Based on the examination of the title and abstract, 542 irrelevant studies were eliminated from the study in accordance with the three specified exclusion criteria:

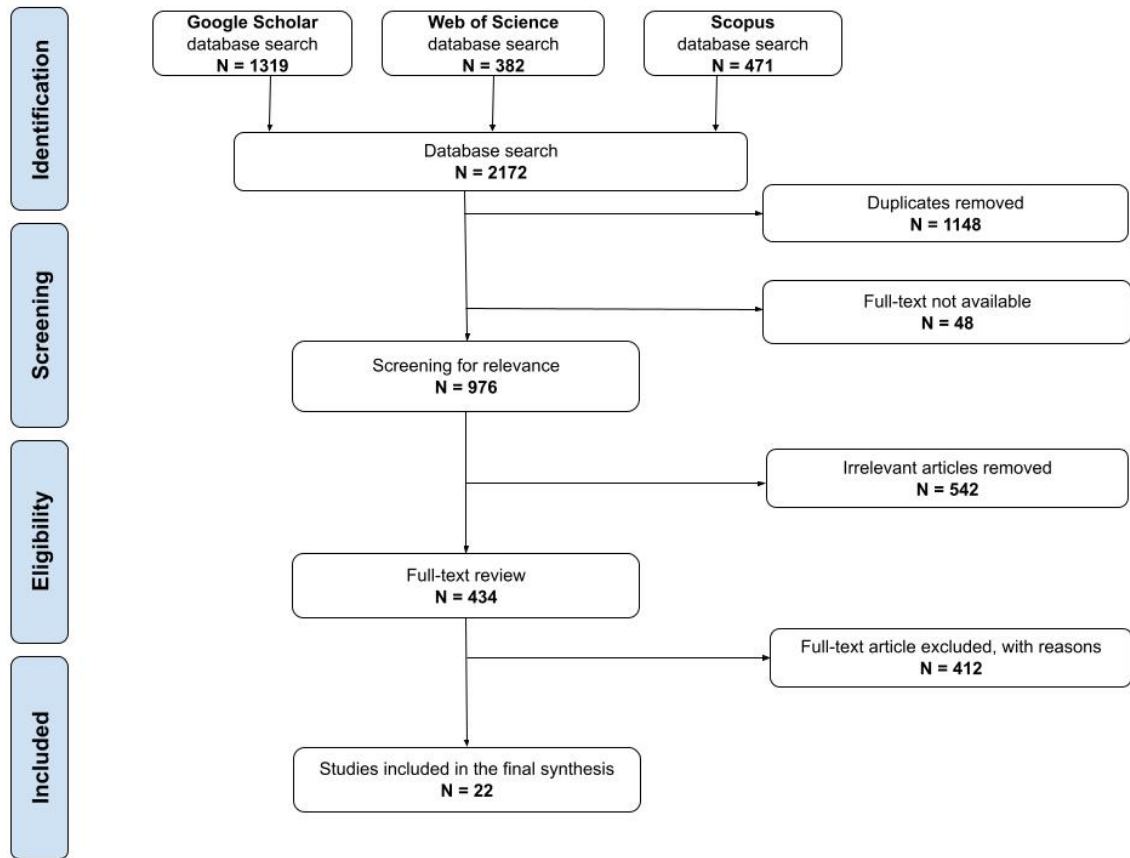


Figure 2.1: PRISMA diagram of included articles in the scoping review

1. Papers that were not written in English
2. Papers that were not peer-reviewed conference or journal papers (e.g. theses, dissertations, books, book chapters, abstracts only, work-in-progress papers, videos, preprints, posters, presentations, or other archived articles)
3. Literature reviews

The next stage involved the application of the following inclusion criteria based on full-text review:

1. Sense of belonging or belongingness or belonging is the main focus (Concept)
2. Undergraduate students are the study population (Population)
3. Studies focusing on students in computing (Context)

After applying these criteria to the remaining 434 papers, a total of 412 papers were excluded. As a result, the total number of papers included in the final review stands at 22, including 14 conference papers and 8 journal publications.

2.3.3 Data extraction

During the scoping literature review process, data extraction was carried out by selecting specific data points from the articles included in the review, based on the research questions that guide the review. Extracted data included the publication type, study location, purpose/aim of the study, the type of analysis, the survey design and scale, and the sample or population being studied. This data is organised and presented in Table 2.2. Extensive notes were additionally taken on the key findings of each study, and any limitations or gaps in the literature identified.

Table 2.2: Data extraction table

(Study) Type & Location	Purpose/Aim	Study Design & Instrument	Sample	Analysis
[97] Journal, USA	Relationship between LGBTQIA+ students' SoB & thoughts of leaving the field	Quan. (online survey by CRA's CERP)	857: LGBTQIA+ =86, heterosexual=771	SA
[95] Journal, USA	Impact of growth mindset on women's & men's SoB	Quan. (online survey by CRA's CERP & BRAID)	1631: women=440, men=1191	SA
[10] Conference, USA	Relationship between (a) introductory course experiences and (b) self-efficacy and SoB	Quan. (online survey by CRA's CERP & BRAID)	2184: women=704, men=1345	SA
[53] Conference, China	Is a digital storytelling group assignment an effective intervention for fostering SoB among 1st year students	Quan. (paper form survey)	76: women=17, men=59	SA
[87], Journal, USA	Change in SoB during intro courses for women & racially minoritised students	Quan. (online survey by CRA's CERP & BRAID)	3,814 (pre-test), 1,355 (post-test)	SA

continued..

CHAPTER 2. LITERATURE REVIEW

Table 2.2–*Data extraction continued..*

(Study) Type & Location	Purpose/Aim	Study Design & Instrument	Sample	Analysis
[48], Conference, USA	Factors behind lack of diversity	Quan. (online survey by CRA's CERP)	5,821: women=1696, men=3440	SA
[35] Journal, Germany	Belonging uncertainty as a predictor of dropout intention	Quan. (based on two item questionnaire)	217: women=49, men=168	SA
[37] Journal, Germany	Potential sources of belonging uncertainty	Quan. (Paper and pencil form two-item questionnaire)	449: women=104, men=345	SA
[66] Conference, USA & Canada	Relationships between enrolment policies & student experiences	Quan. (online survey by CRA's CERP)	1245: women=447	SA
[62] Conference, Ireland	Relationship between students' SoB, gender identity, & self-declared minoritised status	Quan. (online survey)	130: women=40, men=90	SA
[40] Conference, Brazil	Whether quota & non-quota students' SoB correlates with self-efficacy	Quan. (based on five item questionnaire)	106: women=41, men=63	SA
[25] Journal, USA	To investigate ways to improve women's SoB	Quan. (based on one item question sent out through email)	16 women	SA
[63] Conference, Ireland	Impact of the COVID-19 pandemic on students' SoB	Quan. (online survey)	198: women=62, men=136	SA
[22] Conference, USA	How Latinx students' SoB was constructed at collective & individual levels	Qual. (interviews, observation & artefacts)	19 Latinx: women=6, men=12	TA
[64] Conference, USA	How racially minoritised students' SoB relates to academic performance & interest in pursuing more CS courses	Quan. (online survey)	1165: women=460, men=690	SA

continued..

Table 2.2–*Data extraction continued..*

(Study) Type & Location	Purpose/Aim	Study Design & Instrument	Sample	Analysis
[39] Conference, Brazil	Investigate women’s SoB	Quan. (five item questionnaire)	STEM 178: women=68, men=110 Only CS 63: women=18, men=45	SA
[106] Conference, UK	Under-representation of women	Qual. (2-hr focus group)	women=13	TA
[45] Conference, USA	Correlation between students’ SoB & academic success	Quan. (weekly or bi-weekly survey)	3439	SA
[8] Journal, USA	To advance gender equity & SoB of upward transfer students	Quan. (online survey by BRAID)	1829: women=640, men=1172	SA
[1] Conference, USA	To examine the SoB among native & non-native English speakers CS students	Quan. (online survey)	954	SA
[9] Journal, USA	SoB of upward transfer students	Quan. (online survey by BRAID)	1829	SA
[26] Conference, USA	Impact of the return to in-person learning on students’ SoB	mixed-method (CASPS survey & semi-structured interview)	Qual=67, Quan=100	SA & TA

LGBTQIA+ (lesbian, gay, bisexual, transgender, queer, intersex, and asexual),
 CRA (computer research association), CERP (center of evaluation and research pipeline),
 BRAID (building recruiting and inclusion for diversity), CASPS (climate and student persistence survey),
 Qual (Qualitative), Quan (Quantitative), SA (Statistical Analysis) and TA (Thematic Analysis).

2.4 Results

The number of publications on the sense of belonging in undergraduate computing students has steadily increased from one in 2016 to seven in 2021, with a slight decrease to four in 2022 possibly due to the COVID-19 pandemic (see Figure 2.2). The majority of publications were from the United States (n=12) or joint publications from the United States and Canada (n=2). Most of the other publications came from Europe, specifically

Ireland (n=2), Germany (n=2), and the United Kingdom (n=1). The remaining publications were from Brazil (n=2), and China (n=1) (see Table 2.3). This trend highlights the growing interest in the topic and a trajectory for continued research.

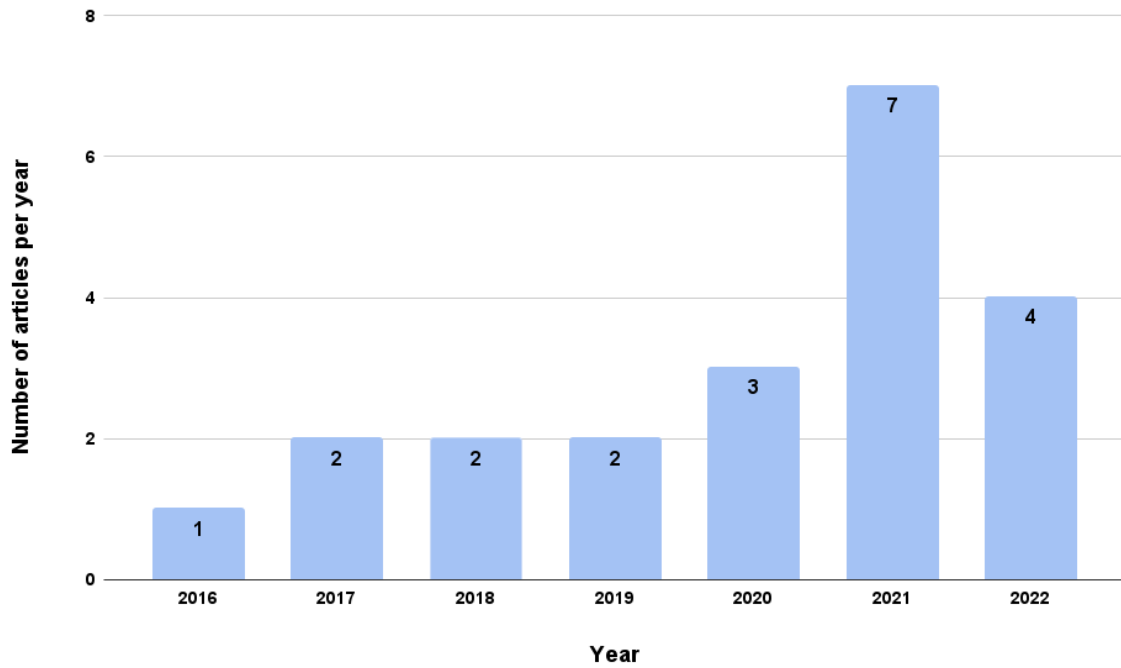


Figure 2.2: The number of articles published by year

Table 2.3: The number of articles published by country

Country of the research	Number of articles
USA	12
US and Canada	2
Brazil	2
Germany	2
Ireland	2
UK	1
China	1

Research question 1

How is the sense of belonging conceptualised in research on undergraduate computing students?

The terminology surrounding belonging in computing is varied among the papers, with some authors instead using “intellectual belonging” [39, 40, 95], or “belonging uncertainty” [37] interchangeably with the concept of sense of belonging. Most papers cite Sax *et al.* (2018) [87] and Stout & Blaney (2017) [95] when defining belonging in their own studies, and only make limited engagement with the wider literature from the humanities and social sciences. These two papers and the other papers that draw on the wider scholarship tend to take Hagerty *et al.* (1992)’s [32] and Goodnow (1993)’s [30] definitions of belonging as their theoretical framework [10, 64, 66]. The papers distinguish belongingness as related to but conceptually different from social anxieties/stresses at ‘fitting in’ [1], self-efficacy and growth mindset [10], and stereotype threat [37].

Following this, belonging is conceptualised across all of the papers as a deep ‘need’ and emotional affiliation to computing that encompasses whether students feel comfortable and supported in their computing courses [1]; feel like a legitimate ‘insider’ welcomed and accepted into the computing community [9, 10, 95]; feel their presence and contributions to computing are valued and matter [8, 22]; feel unconcerned about the quality of their academic social relationships by recognising things in common with others [8, 37]; and feel like they have an opportunity to thrive in computing [106]. A poor sense of belonging encompasses when students feel persistently ignored, under-represented, and/or devalued [37, 106], with a dissonance between their goals and what they see possible for them in computing [48]. The papers present sense of belonging as forming both individually and collectively through a relational, negotiated process between them, others, and their environments, that will be governed by structural inequities and disparities in resource allocation [22]. They understand belonging as a predictor of motivation and persistence [95], which is crucial for student retention [1]. Many stakeholders are identified as having an interest in fostering a high sense of belonging beyond the student including classmates, mentors, families, communities, professional organisations, and higher education institutions [22].

These themes and the papers that informed our discussion on them are summarised in Table 2.4

Table 2.4: The themes of the discussion of RQ1

Theme	Articles
Terminology	“Intellectual belonging” [39, 40, 95], or “belonging uncertainty” [37], or theoretical framework [10, 64, 66]
Conceptualisation	[comfortable and supported] [1], [welcomed and accepted] [9, 10, 95], or [ignored, under-represented, and/or devalued] [37, 106], and [motivation and persistence] [95]

Research question 2

How is the sense of belonging measured in research on undergraduate computing students?

Study approach

The sense of belonging in computing students has been investigated using a variety of approaches, as shown in Table 2.2. The majority of the research articles (86%) took a quantitative study design, based on online and/or paper-based surveys or questionnaires. Two articles (9%) used a qualitative approach, based on interviews and/or focus groups [22, 106], and one article (5%) used a mixed-methods approach using survey and semi-structured interview [26].

Data collection

The majority (59%) of the studies focused on examining student responses from a single institution. However, nine articles (41%) used data collected from multiple institutions. While Moudgalya *et al.* (2021) [64] collected data from 21 institutions as part of their own project, other papers analysed multi-institutional data that was collected by external organisations including CRA’s CERP (Center of Evaluation and the Research Pipeline) [48, 66, 97], and the BRAID research project [8, 9, 87], or a combination of both CERP and BRAID data [10, 95]. These studies include data from 15-104 US institutions. Multi-institutional data allows researchers to gain insights from a wider range of contexts, which could lead to a more comprehensive understanding of trends, patterns, and outcomes in the overall computing community.

Sample size

The research exhibited a range of sample sizes. Smaller studies, such as those conducted by Widdicks *et al.* (2021) [106] and Geller (2021) [25] on women, and Esquinca *et al.*

(2021) [22] on Latinx students, involved sample sizes of 13, 16, and 19 students, respectively. These smaller samples allowed for in-depth exploration of the experiences and perspectives of specific student groups, yielding a closer understanding of their unique circumstances. Medium-range sample sizes allowed for more comparison where studies were able to examine specific groups of minority students in relation to groups of majority students, such as how Agarwal *et al.* (2022) [1] compared native and non-native English speaker students. It also allowed comparisons across disciplines and year groups where Holanda *et al.* (2020) [40] compared computing with non-computing students, and Nguyen & Lewis (2020) [66] compared first-year students with other years. Studies with larger sample sizes either involved collaborative data collection efforts [48], the inclusion of multiple institutions in the study [64], or the inclusion of multiple courses for groups of students over more than one quarter in the academic year [45].

Thirteen of the 22, articles provided gender information, revealing a significant gender imbalance with a higher representation of men in study samples, sometimes more than double. This gender disparity aligns with the research focus on women’s sense of belonging in computing and their experiences of under-representation, but limits the potential to address the disparity.

Sense of belonging measure

Various quantitative techniques have been employed to assess students’ sense of belonging in computing, and the most common ones are short surveys: two-item surveys [35, 37, 97], three-item surveys [8–10, 48, 66, 87, 95], four-item surveys [1, 45], or five-item surveys [39, 40]. However, others used longer surveys, including an 11-item survey [26], or 30-item surveys adapted from the “Math Sense of Belonging Scale” developed by Good *et al.* [29] [62, 63]. In their study, Moudgalya *et al.* (2021) [64] initially employed all 30 items but subsequently removed four items due to ambiguous loading. They ultimately validated a 26-item survey to assess the sense of belonging. See appendix A.1 for survey items.

In these studies, most quantitative studies (80%) involving the measurement of sense of belonging used a survey where students rated each item on a 5-point scale ranging from 1 to 5. However, one study by Moudgalya *et al.* (2021) [64] used a 7-point scale, while two other studies by Mooney & Becker (2020, 2021) [62, 63] used an 8-point scale. The study conducted by Holanda *et al.* (2020) [40] utilised a binary response format, where participants were asked to provide a simple “yes” or “no” answer, rather than employing a quantitative scale.

Along with the items to measure sense of belonging, several studies included additional questions to capture student demographics [26, 39, 40, 45, 48, 62–64, 66, 87, 97], background [45, 62, 63, 87, 106], prior academic experiences [39, 40, 87, 106], incoming orientation (Incoming orientations are the beliefs, values, and attitudes that students bring with them when they start their studies in computing or STEM fields. These orientations include their views on leadership, creativity, family, community, and scholarly activities [99]) [87], college experience [26, 87], institutional culture [26], perceptions [48, 66, 106], GPA or grade [45, 95, 97], thoughts about leaving [97], self-efficacy [10, 66], growth mindset [95], persistence intention [95], language [1], and stress [1].

The papers taking a qualitative research design do not directly assess sense of belonging, but rather ask students about their personal experiences and opinions and analyse them based on their descriptive answers [22, 106]. Some of the quantitative/mixed studies included some qualitative questions in their surveys.

Data analysis

Each study employed different methodologies to explore specific aspects of the topic. In quantitative studies, statistical analysis was used, including descriptive analysis, analysis of variance (ANOVA), t-tests, chi-square tests, regression analyses, principal component analysis (PCA), factor analysis, correlations, etc. Qualitative studies utilised thematic analysis in their studies. See details in Table 2.2

These themes and the papers that informed our discussion on them are summarised in Table 2.5

Table 2.5: The themes of the discussion of RQ2

Theme	Articles
Study approach	Quantitative (86%), Qualitative (9%)[22, 106], and mixed-method (5%) [26]
Data collection	Single institution (59%) [1, 22, 26, 36, 38–40, 46, 53, 62, 63, 106], Multiple institution (41%) [8–10, 48, 64, 66, 87, 95, 97]
Sample size	Small (<20) [22, 25, 106], medium [26, 36, 38–40, 53, 62, 63] and large (>500) [1, 8–10, 48, 64, 66, 87, 95, 97]
Sense of belonging measure	Short surveys: [1, 8–10, 35, 37, 39, 40, 45, 48, 66, 87, 95, 97] and long surveys [26, 62–64]

Research question 3

How is the sense of belonging used to generate new insights into undergraduate computing students' experiences?

To identify barriers to belonging

Research in this area has an overarching aim of trying to identify the factors that impact student belonging in computing to develop a broad understanding of the 'belonging barriers' that are causing representation gaps and low sense of belonging [22, 25, 106]. Although papers categorise these barriers differently, we can synthesise groups together as psychological, environmental, social and socio-political barriers [22, 26].

Papers exploring psychological factors aim to understand how differences in student personalities and personal circumstances can impact belonging, by looking at their expectations, confidence levels, embarrassment levels, commitment to study hours, ability to ask for help, cultural adjustments, incoming values and orientations, and stereotypes of computing students [1, 8]. For example, Stout & Blaney (2017) [95] investigate the impact of a growth mindset on women's and men's sense of belonging and examine how having a growth mindset influences their sense of belonging. These studies explore the relationship between sense of belonging and various factors such as academic performance, interest in pursuing computing, experiences in introductory computing courses, self-efficacy, and the correlation with academic success in the field of computing [10, 45, 64]. Hohne & Zander (2019a) [35] explored belonging uncertainty as a predictor of dropout intentions and investigated the sources of belonging uncertainty and its effect on students' intentions to leave the field. Blaney & Barrett (2022) [8] also seek to understand how individual student behaviours such as social media use and video game playing, can impact belonging alongside non-college contextual factors such as finances, jobs, and work/life balance.

However, papers tend to foreground environmental factors over individual student characteristics in their analysis, by focusing their analysis on all pedagogical, curricular, informational and institutional aspects of the computing programs [9, 25, 45]. These papers aim to investigate how belonging is impacted by differences in representation within faculty and the study body [1], having to overcome masculine cultures on campus [8], and the promotion of positive culture on campus including inclusive pedagogies, the availability of identity-based groups for students, mentoring programs, and perceived instructor inclusivity [8, 10, 96]. Nguyen & Lewis (2020) [66] research departmental

policies and the potential negative impact of enrolment policies that create a competitive and cutthroat environment on students' academic and social experiences within the institution.

Papers also seek to understand the role of social factors on sense of belonging, encompassing how personal, interpersonal and professional relationships impact belongings, including relations with fellow students [1], others in shared identity-based groups [8], members of faculty [22], parental/family support [8], and how the student views their place in relation to 'the department' [8] and/or the institution [22]. Social-political factors relate to how student belonging is shaped by whether their belonging is recognised or contested within the social-political order of the university community, institution and wider society. Esquinca *et al.* (2021) [22] explore border-crossings and visa experiences as a specific example of how belonging is impacted in a unique sociopolitical context for international students and those with precarious immigration status. Finally, some of the more recent papers are beginning to address the impact of COVID-19 on belonging in computing, with Mooney & Becker (2021) [63] and Geller & Walker (2022) [26] investigating how studying at home during the COVID-19 lock-downs and the subsequent return to in-person learning changed patterns of belonging.

To understand diverse student populations in computing

Rather than viewing computing students as one homogeneous group, the papers aim to reveal how belonging is being experienced differently by distinct groups of students by examining how exposure to belonging barriers is shaped by a range of factors. While some papers developed broad investigations into specific year groups or levels of undergraduate computing students, other studies provided more in-depth analysis of specific groups within the wider cohort, such as men, women, racially minoritised students, LGBTQIA+ (lesbian, gay, bisexual, transgender, queer, intersex, and asexual) students, Latinx students, native and non-native English speakers, transfer students, and other populations (see Table 2.2). In doing so, these studies collectively contribute to understanding diverse aspects of sense of belonging experiences in relation to under-representation in computing.

Gender is the most prominent focus across the papers, where gender disparities are examined to shed light on the unique challenges and factors influencing women's sense of belonging and minoritisation in computing [8, 25, 37, 39, 106]. To a lesser extent, some papers explore other aspects of racially minoritised students [87]. Race is explored in the Esquinca *et al.* (2021) [22] paper on the intersection of cultural identity

and sense of belonging among Latinx students. Agarwal *et al.* (2022) [1] studied the experiences of native and non-native English speakers. Sexuality is also explored in papers investigating the experiences of LGBTQIA+ students and their relationship with sense of belonging [97]. Together, these papers aim to understand the gender and racial/ethnic disparities that persist in undergraduate computing [87]. Although papers tend to focus on one aspect of identity, such as gender, a small number of papers emphasised taking an intersectional approach to understanding sense of belonging, by considering the intersection of gender identity and other minoritisation status [62].

Further, papers look at the diversity of sense of belonging across year groups and students who gained entry into their computing courses through different academic pathways. Blaney & Barrett (2022) [8] and Blaney *et al.* (2022) [9] investigated the sense of belonging of upward transfer (the process of transferring from a two-year college to a four-year institution) students with the aim of diversifying pathways into STEM fields. Lui *et al.* (2018) [53] highlighted that first-year students were vulnerable during their transition from high school to university, which made them more prone to dropping out. Additionally, Hohne & Zander (2019b) [37] specifically examined the sources of belonging uncertainty between male and female students.

These themes and the papers that informed our discussion on them are summarised in Table 4.4

Table 2.6: The themes of the discussion of RQ3

Theme	Articles
Barriers to belonging	psychological factors [1, 8, 10, 35, 46, 64, 95], environmental factors [1, 8–10, 25, 45, 66, 96], and social factors [1, 8, 22, 26, 63]
Diverse student population	Gender [8, 25, 37, 39, 106], race [22], native and non-native English speakers [1], sexuality [97], intersectionality [62, 87], diverse year groups [9, 37, 53]

Research question 4

What insights into undergraduate computing students have been revealed from research engaging with the sense of belonging?

Disparities in sense of belonging across minoritised students

Gender: Gender was the most common axis through which the research examined sense of belonging, and women were found to experience a lower sense of belonging than their male counterparts in undergraduate student cohorts across all years of their degree programmes [8, 25, 48], reporting lower intellectual belonging [39, 40, 95] and higher levels of belonging uncertainty than men [35, 37]. Gender disparities were found to be significant within particular cohorts, including first-year students [66], students in introductory computing courses [45, 87] and upward transfer students, where levels of peer support were positively correlated with sense of belonging [9]. Studies also show differences in belongingness between different groups of women in the same cohorts. Mooney & Becker (2020) [62] found that although there was no significant difference between men and women overall, women who self-identified as being part of a minority group have a significantly lower sense of belonging than their majority counterparts.

Race/Ethnicity: Black students and students of colour were revealed to experience a lower sense of belonging compared to White students, although the difference was not always statistically significant and only papers from the USA examined sense of belonging through race. Lewis *et al.* (2019) [48] identified a significant effect of race on sense of belonging with Asian and Black students having a significantly lower sense of belonging than White students. Similarly, Nguyen & Lewis (2020) [66] found that Black and Lantix first-year students have a lower sense of belonging than White first-year students. However, Sax *et al.* (2018) [87] and Krause-Levy *et al.* (20221) [45] found no significant difference between the majority White or Asian students and racially minoritised subgroups (African American/Black; Hispanic/Latino; Native American/Native Hawaiian/Pacific Islander; and Arab, Middle Eastern or Persian) in their sample of students.

Sexuality: Only one study took sexuality as a central axis for comparing sense of belonging amongst students. Stout & Wright (2016) [97] indicated that LGBTQIA+ undergraduate and graduate students, especially LGBTQIA+ women, were more likely to consider leaving their program due to a low sense of belonging than heterosexual students.

Factors impacting belonging

The studies have identified various factors and predictors that contribute to a student's sense of belonging in computing.

Student-focussed factors: Studies suggest that sense of belonging in computing is impacted for first-generation students (those who are the first in their family to attend college [48]), and students with different levels of prior academic experience for themselves and in their family. Although Lewis *et al.* (2019) [48] found no significant difference in sense of belonging between first-generation and continuing-generation students, Krause-Levy *et al.* (20221) [45] found that first-generation students experience a lower incoming sense of belonging across all courses. According to Blaney & Stout (2017) [10], first-generation college women experienced the strongest impact of introductory courses on their sense of belonging and self-efficacy. Blaney & Barrett (2022) [8] show how the influence of parental computing careers varies for different cohorts, as having a parent with a career in computing positively predicts belonging for non-transfer students but negatively predicts belonging for upward transfer students as they are less likely to have parents who are computing role required a degree in computing. Nguyen & Lewis (2020) [66] found first-year students with prior experience to have a higher sense of belonging than those without. Similarly, Sax *et al.* (2018) [87] found that more prior programming experience leads to a greater sense of belonging after an introductory course.

Authors also suggest the need to consider students' incoming orientation. Sax *et al.* (2018) [87] argue that as computing departments diversify they must update their curriculum and programming practices beyond traditional scientific pedagogies to retain students who come with more artistic or creative approaches to their learning. Their research shows that women and racially minoritised students have an enhanced sense of belonging when their creative and artistic orientations are embraced in their computing programmes. As they tend to respond better to more collaborative and creative pedagogies, harnessing the more creative aspects of computing can help retain diverse groups of students [87].

Furthermore, attention should also be paid to the importance students place on communal goals (communal goals include working for others, contrasting with more self-focused agentic goals, which focus on achievement, independence, self-promotion, and personal growth [48]) in computing departments. Lewis *et al.* (2019) [48] found that students with high communal goals may have a lower sense of belonging, but this

effect can be alleviated if they perceive computing as offering opportunities to advance communal goals. Sax *et al.* (2018) [87] show how inclusivity for students with strong communal orientations can be achieved by creating opportunities for students to work with others who share their value for collaboration and community service. They suggest supporting communal goals in computing students is crucial for developing supportive campus cultures. Instructors could incorporate service opportunities to help students connect with others with similar interests and communal value [87].

Moudgalya *et al.* (2021) [64] found that a positive sense of belonging enhances interest in computing courses and improves student academic outcomes. However, sense of belonging is more strongly linked to academic outcomes in introductory computing courses compared to advanced courses [45]. However, although a lower sense of belonging among students is linked to negative course outcomes including lower pass rates and course performance, as students progress in their computing curriculum, the impact of sense of belonging on academic performance decreases.

Finally, the studies reported a range of other factors impacting belonging. Agarwal *et al.* (2022) [1] identified language barriers, where non-native English speakers reported more feelings of self-doubt and embarrassment when asking for help. Stout & Blaney (2017) [95] found that a growth mindset was associated with a stronger sense of belonging for men, but not necessarily for women. Furthermore, Esquinca *et al.* (2021) [22] identified professional relationships, pedagogical aspects, informational factors, and sociopolitical elements that affect Latinx students' sense of belonging and also highlighted that coursework is crucial but often perceived as a barrier to a sense of belonging. Blaney & Barrett (2022) [8] highlighted unique predictors of sense of belonging for upward transfer students possibly due to comparisons with traditional computing majors and related stereotypes encountered online: socialising with peers as a positive predictor and social media usage as a negative predictor.

Environment-focussed factors: The cultures of the school environment play a key role in shaping student belonging. Improved pedagogy and curriculums alone cannot achieve academic success for female computing students if the environment is not welcoming [25]. Hohne & Zander (2019b) [37] reveal that female students' belonging is significantly influenced by perceived affective and academic exclusion by peers and domain-specific academic self-efficacy belief. One way to improve the culture on campus is to avoid creating cultures of competition between students. According to Nguyen & Lewis (2020) [66], competitive cultures embedded through competitive enrollment practices

will have detrimental effects on first-year students' perception of inclusiveness, their sense of belonging, and their self-efficacy in computing. Conversely, Sax *et al.* (2018) [87] highlight the significance of creating supportive cultures embedded in peer support networks in fostering a sense of belonging in computing departments. It suggests that students' sense of belonging is enhanced when they feel like other computing students are available to help them understand the course material. Similarly, Blaney & Barrett (2022) [8] found that support from fellow students was associated with a greater feeling of belonging at the end of the course.

COVID-19-related impacts: Mooney & Becker (2021) [63] found that the shift to online classes due to COVID-19 had a greater impact on students' sense of belonging compared to the previous two years. Despite no significant difference observed in the overall sense of belonging for all students pre- and post-COVID-19 when looking at differences by gender and minoritised status, minoritised women reported an increase in their sense of belonging after the COVID-19 pandemic, while non-minoritised men and women both experienced a decline in their sense of belonging, with non-minoritised men experienced the largest and most significant drop. Geller & Walker (2022) [26] focused on returning to in-person learning after the COVID restrictions. They found that students in the second year, fourth year and above had the lowest sense of belonging, while first-year students who began their studies in person had the highest. Students reported challenges during the transition between remote and in-person learning, such as social isolation and difficulties in establishing relationships with peers and faculty [26]. These results show that the impact of COVID-19 on students' sense of belonging is a significant concern, requiring additional support and interventions to mitigate its negative effects [63].

Interventions to foster sense of belonging

The papers suggest that fostering a sense of belonging in the computing community can be achieved through various types of intervention to address the barriers and challenges that minoritised students encounter. However, the papers make clear that interventions must occur within the context of wider cultural shifts within computing departments. Widdicks *et al.* (2021) [106] show how the successful implementation of belonging interventions can be restricted when some students believe fostering sense of belonging is their individual responsibility rather than being a responsibility at an institutional or societal level. They caution that 'positive change for fostering belonging in CS is unlikely to be achieved without burdening under-represented groups until this

responsibility is fully shared’. This requires a systemic change in departmental cultures and a reorientation of how responsibility for belonging is conceived within schools, which may involve training and awareness programmes for staff and students [10, 95, 106]. Esquinca *et al.* (2021) [22]’s work also suggests a shift away from ‘competitive cultures’ is required, where women Latinx students in their research linked a low sense of belonging to gendered and racialised pressures to achieve good grades. The role of the school here is, according to Hohne & Zander (2019a) [35], to intervene with ‘alternative and nonthreatening narratives’ and provide students with the tools ‘to navigate difficult experiences in educational environments’.

To achieve this, some papers explored academic interventions to increase belonging through changes to pedagogical approaches. Lui *et al.* (2018) [53] examined the effectiveness of introducing a digital storytelling group assignment that involved asking first-year students to work together to produce a form of digital media that would tell a shared story about computer programming in their daily lives. The authors found that the storytelling assignment worked well as a catalyst for first-year students to form bonds with each other. However, in their study, only male students experienced a significant increase in sense of belonging. Providing students with structures for collaborating with each other early in their course can shape a supportive student climate that encourages the development of meaningful relationships between students in and out of class time [87]. However, Blaney & Barrett (2022) [8] argue that belonging interventions must occur in line with efforts to broaden participation in computing. They warn that as upward transfer students do not start their course with the same introductory modules, they will miss out on any interventions delivered only in those lectures, so they recommend engaging with leaders working with students entering through alternative pathways when devising belonging interventions. Together these papers show how academic interventions need to be conceived with diverse groups of students in mind by consulting with relevant experts such as community college leaders [8].

Interventions to improve belongingness cannot focus only on the classroom [106]. To this end, some papers examine social interventions to increase sense of belonging. Hohne & Zander (2019a) [35] suggest that challenging discriminatory stereotypes could help reduce the adverse effects of them on women’s dropout rates, whereas Geller (2021) [25] explored the impact of establishing a “Women in Computing Club”. They found that while the club had the potential to increase sense of belonging in women, there were limitations in reach as not all targeted women were interested in participating. They found that providing ‘tokens of belonging’ such as membership cards increased women’s

connection to computing and helped them develop a positive attitude towards club membership [25]. While tokens of belonging may work to improve belonging, Blaney *et al.* (2022) [9] stress the point that such methods to increase belonging for diverse students can require funding, for example, to fund student conference participation. Interventions do not always have to be costly, as Widdicks *et al.* (2021) [106] discuss the importance of creating mentorship programmes or spotlighting role models that can further improve gender gaps in sense of belonging. Social and academic interventions can support each other, where the academic intervention of creating manageable workloads can allow students a social intervention through more time for family and social responsibilities outside of their course, which is shown to reduce students' stress and increase belonging [1, 9].

These themes and the papers that informed our discussion on them are summarised in Table 2.7

Table 2.7: The themes of the discussion of RQ4

Theme	Articles
Disparities accross minoritised	Gender [8, 9, 25, 46, 48, 62], race/ethnicity [46, 48, 87], sexuality [97]
Factors impacting belonging	Student-focused [1, 8, 10, 22, 46, 48, 64, 66, 87], environment-focused [8, 25, 37, 66], Covid-19 impacts [26, 63]
Intervention to foster belonging	[1, 8, 10, 22, 35, 53, 95, 106]

Research question 5

How might future research build upon this existing work?

Recognising complex, intersectional identities

Researchers have highlighted the importance of examining intersectionality in future research. This involves exploring how various intersecting identities such as race, ethnicity, sexual orientation [1, 10, 48], socioeconomic status, religion [10], first-generation status [48], language proficiency [1] and how these factors influence individuals' sense of belonging in computing classrooms, as well as students' sense of belonging.

However, a recurring challenge in the research is how to deal with intersectional and complex identity categories that are not easily defined. Our review reveals that

there are various limitations to exploring intersectionality. Papers tend to focus only on one aspect of identity and avoid collecting data on additional identity markers, thus restricting the analysis of the data [66, 106]. For example, Stout & Wright (2016) [97] solely focused on LGBTQIA+ students, while Stout & Blaney (2017) [95] specifically focused only on gender differences. Other papers examine more than one axis of identity but usually no more than two. For example, while Blaney & Stout (2017) [10] explored the intersection of gender and generation status in understanding first-generation women's experience, they overlooked other intersectional identities such as race/ethnicity, sexual orientation, socioeconomic status, and religion. When more than two factors of identity are analysed the approach taken is not always intersectional. Although Lewis *et al.* (2019) [48] examined four racial groups alongside gender and first-generation status, they analysed these categories separately, without considering their interactions. Agarwal *et al.* (2022) [1] chose to categorise students based on self-reported language proficiency rather than race, nationality, or gender. Other authors avoid identity categories in their analysis and instead group students by behaviour or traits.

Authors commonly cite small sample sizes as restricting their ability to analyse results across intersecting identities [8]. Mooney & Becker (2020) [62] noted how a particularly small number of non-minoritised women in their sample limited the potential comparisons to be made with women in majority groups. Their study, along with Nguyen & Lewis (2020) [66], only used binary gender classifications of “men” or “women” and was unable to include non-binary genders in their discussion due to anonymity concerns arising from the low number of non-binary students. Lewis *et al.* (2019) [48] also excluded certain racial groups (e.g., Native American, Native Hawaiian/Pacific Islander, Middle Eastern) and multiracial individuals from their analysis due to insufficient responses. As a result, these study's outcomes may have overlooked the complexities of intersectional gendered and racialised identity. Unsurprisingly, the main approach suggested to address this is to increase the size of the sample.

Addressing issues with how to measure belonging

The papers acknowledge that their results are based on self-reported measures of belonging that may be subject to biases or inaccuracies [35, 37, 95]. The studies capture students' sense of belonging through their own perceptions of their social and academic inclusion, without collecting information from external sources that could corroborate the claims, such as data on students' attendance, grades, or other measures of academic and social performance [35]. Self-reporting against statements of belonging creates

challenges around how best to elicit accurate information from students in the survey responses. Agarwal *et al.* (2022) [1] argue that in asking students to score items such as ‘I feel supported in this class’ without specifying what they meant by support, means that different students could interpret the items differently and thus not respond in the same way.

Future quantitative surveys could improve item design to provide more detailed and specified statements with less room for divergent interpretations for students. It is suggested that future research might also collect reported data from peers, lecturers, and/or other people who interact with the students on campus, or through observational data that could be gathered from researchers observing student behaviour in computing classes [35]. Blaney & Stout (2017) [10] argue that taking a qualitative or mixed-method approach to study design is necessary to create a deeper understanding of the intersectional nature of student experiences in computing by allowing students more time to think about and explain their self-reporting. Allowing participants to be involved in the writing of the research as authors might also deepen this understanding and the overall reliability of the data, although the possible bias of participant authors would need to be acknowledged [106].

Establishing stronger causality

Multiple studies highlight the challenge of establishing causality in their research due to their reliance on cross-sectional data, preventing them from establishing causal effects in their analyses [10, 39, 48, 66, 95]. Consequently, studies are limited to demonstrating correlations rather than causation, so they are unable to establish causal relationships between sense of belonging and dropout intentions, academic self-efficacy and social exclusion [35, 37, 45]. Future research could include experimental studies, following the suggestions of Hohne & Zander (2019a) [35] and Lewis *et al.* (2019) [48], to establish causal relationships between predictors and dropout intentions, as well as between communal goals, perceived communal goal affordances, and the sense of belonging in computing. Stout & Blaney (2017) [95] also suggest that controlled studies could take place in which factors of belonging are manipulated to help build causality.

Evaluating students’ sense of belonging in individual courses may not provide a complete understanding of their overall sense of belonging within computing programs as other external factors, like peer networks, should also be taken into consideration in study design [1, 45]. Moudgalya *et al.* (2021) [64] highlight that for minoritised students it is also important to understand factors contributing to their sense of belonging and

how they relate to learning assessments. Future research could explore in more depth the socio-economic background and support systems that impact belonging [35].

Increasing generalisability and applicability

The generalisability of the research reviewed here is constrained in several ways. Most studies are confined to a specific undergraduate computing program, possibly limiting their relevance to other academic disciplines or institutions beyond the specific context and population studied as results might not translate into other settings [45, 63]. For example, as the studies only encompass students at research universities, the relevance to students, particularly upward transfer students, at different types of institutions is uncertain [8]. Generalisability within computing is also limited by relatively small sample sizes and single time point data collection that affect the statistical power of the data and make generalisation to different academic stages or fields challenging [35, 39, 53]. Mooney & Becker (2020, 2021) [62, 63] emphasise the need for a multi-institutional study to provide more robust results and overcome the limitations of the small sample size.

To ensure a comprehensive understanding of factors affecting students' sense of belonging in computing, future research needs to be inclusive, diverse and broadened to cover under-represented groups such as students from racial and ethnic backgrounds, LGBTQIA+ students, and students with disabilities [10]. Including more diverse samples and STEM fields would improve generalisability when the diversity of the sample closely matches the diversity of the student population [35]. Inclusive sampling strategies can be employed to overcome sample size constraints and racial exclusion and to ensure comprehensive analysis across various demographics [48].

Longitudinal approach

To capture trends in belonging and gain a better understanding of how sense of belonging changes over time in response to interventions, future research should engage in creating longitudinal data [10, 37]. Authors suggest that further research projects should collect data at multiple time points to track changes in students' experiences as they progress through their course, especially at 'critical time points' following interventions and changes to relevant policies impacting student belonging [10, 66]. By doing so, researchers can gain insights into any positive or negative effects of these policies to check if interventions have the intended result [1]. This will help identify challenges and barriers to interventions [45]. This can also capture the long-term impacts

of interventions where impacts in the short-term may be delayed or overemphasised [53]. Long-term studies and assessments can also be useful for monitoring the relationship between efforts to increase belonging and representation gaps, to track the impact on, for example, women's progression in computing over extended periods [35].

Yet, the papers acknowledge additional difficulty in how to best capture shifts in belonging over time if there are multiple changes in the academic environment over the study duration that could alter and influence how students measure their belonging. For example, Krause-Levy *et al.* (20221) [45] recognise that there can be variations in different offerings of the same computing course due to factors such as changes in instructor and pedagogical differences and that this can alter experiences of belonging. Longitudinal studies must control for these changes [48].

2.5 Discussion

This review has covered 22 studies and while each takes a different approach, there are theoretical and methodological similarities between them. Research in this field is growing but notably limited, emphasising a need for continued research efforts and the contribution of insights from more geographically diverse locations. Although there is no universally accepted definition of a sense of belonging across all articles, consistent emphasis is put on acceptance, inclusion, value, and connection within academic or social contexts. Belonging is dynamic and malleable, something that can be transformed positively through targeted interventions. The potential of such interventions creates an opportunity for proactive efforts that can positively influence students' belonging and engagement in computing programs. This may offer pathways towards closing representation gaps in the discipline if care is taken to create interventions that are context-driven and intersectional, and where the responsibility for improving belonging is understood as collective within institutions.

Sense of belonging is subjective with embodied with material impacts, and as it is prone to change and open to reinterpretation it is challenging to measure. The articles included in the review utilised various methodologies, with 86% using quantitative research designs [1, 8–10, 25, 35, 37, 39, 40, 45, 48, 53, 62–64, 66, 87, 95, 97], while 9% used qualitative approaches [22, 106], and 5% used mixed-methods [26]. Although the quantitative analysis was primarily used across the papers, the incorporation of qualitative and mixed-methods approaches indicates the acknowledgement of the importance of diverse study designs in investigating student sense of belonging. The scoping review

encourages further emphasis on qualitative analysis in addition to quantitative analysis, enabling valuable insights to be gained.

Qualitative and mixed-methods approaches are one way of potentially addressing a key limitation of the existing literature in establishing causality. The existing research can tell us which groups of students are more or less likely to experience high or low belonging, using various factors to predict belonging. However, it does not yet provide the tools for understanding why and is therefore limited in being able to inform successful interventions. More attention could be paid to revealing the pedagogies and social relations creating campus academic and social cultures that are inhibiting student belonging in computing. As Agarwal *et al.* (2022) [1] argues, ‘it is imperative to build a supportive and inclusive learning environment that values sense of belonging and mental health for everyone’. This requires refocusing the questions we are asking when researching belonging: for example, if non-native English speakers feel more embarrassed asking for help, how are computing spaces facilitating those moments of embarrassment for non-native English speakers and how can this be changed at the school level?

The research underscores that students’ experiences of belonging are not uniform. It varies among different student groups, including gender, sexuality, racially minoritised groups, and those with varying academic pathways. Gender disparities in computing are examined to understand the unique challenges and factors influencing women’s sense of belonging and minoritisation [9, 25, 37, 39, 106]. Some papers explore other aspects of minoritised students, such as race and sexuality [22, 87]. An intersectional approach is also emphasised, considering the intersection of gender identity and other minoritisation [62]. This diversity highlights the importance of tailoring interventions and support to the specific needs of these groups. Interventions for fostering a sense of belonging are suggested to address these disparities.

Intersectionality is the most prominent key conceptual framework in this area that has the potential to address representational gaps but is not widely understood. Blaney *et al.* (2022) [9] argue that ‘practitioners should use an intersectional lens when creating spaces where students can develop a STEM identity that is inclusive of their gender, race, ethnicity and other salient identities.’ Solomon *et al.* (2018) [89] acknowledge that ‘an intersectional lens may not always be feasible’, but argue that intersectionality like belonging ‘could be useful for understanding retention, persistence, and, more broadly, broadening participation’. As Agarwal *et al.* (2022) [1] invites future research to focus also on the ‘coping mechanisms’ students create when they experience low belonging, we are also reminded to recognise student agency and their ability to transform their own

situations. Future research and the development of interventions must be a collective effort and student-focused, to include the widest range of diverse stakeholders [106].

2.6 Limitations

Our scoping review is focused on undergraduate computing students, and our aim is to provide a comprehensive synthesis of studies on their sense of belonging. However, it is important to note that there are several limitations to our study. Firstly, our review only covers three widely recognised databases, which means that we may have missed relevant papers that were not adequately indexed or indexed elsewhere. Additionally, our search strategy may have excluded pertinent articles due to specific search terms, and a second researcher does not validate the methodology. Furthermore, we have excluded papers written in languages other than English, which may have resulted in the exclusion of relevant studies. Moreover, we have only relied on peer-reviewed journals and conferences, ignoring non-peer-reviewed sources such as book chapters and books. Finally, we have also excluded literature reviews conducted by other studies, as they may not provide reliable information for our research objectives.

THE ROLE OF GENDER IDENTITY AND MINORITISATION

This chapter is based on a paper which was presented at the 25th Australasian Computing Education Conference (ACE 2023), which took place at Monash University in Melbourne, Australia, from January 30 to February 3 [82].

Author contributions

Conceptualisation: Catherine Mooney; Methods and Results: Shamima Nasrin Runa; Discussion: Catherine Mooney and Brett A. Becker; Original Draft Preparation: Shamima Nasrin Runa, Catherine Mooney, and Brett A. Becker; Review and Editing: Shamima Nasrin Runa, Catherine Mooney, Brett A. Becker, and Anna Markella Antoniadi; Supervision: Catherine Mooney. All authors have read and agreed to the published version of the manuscript.

Abstract

Sense of belonging, or belongingness, is an important factor in a student's academic life as it is associated with factors such as motivation and persistence, in addition to mental health and well-being. Belongingness has been shown to be correlated with factors such as gender, race, nationality, socio-economic status, religion and disability. Previous work has shown lower belongingness of minoritised women in Computer Science compared to other Computer Science students. However, it is not well known how belongingness in Computer Science compares to other disciplines. This is a difficult comparison to draw as belongingness is closely related to specific contexts including learning environment, and therefore one's discipline.

We utilised a survey adapted from the validated "Math Sense of Belonging Scale" to examine the belongingness of undergraduate Science – including Computer Science – students. We examined how the belongingness of students varies by gender identity and minoritisation, how the belongingness of Computer Science students compares to that of other Science students, and how the belongingness of students in Computer Science varies by gender identity and minoritisation compared to other Science students.

In this specific study, we found that belongingness is not statistically significantly different across genders overall. However, minoritised students have statistically significantly lower belongingness, which varies by gender. We also found that the belongingness of Computer Science students is statistically significantly lower than that of other Science students and that belongingness varies across Science disciplines by gender and minoritisation.

Our results provide insight that may help us as well as others improve the belongingness of undergraduate Computer Science students, with a particular focus on the intersection of identities. We will explore the impact of interventions to increase belongingness in future work.

3.1 Introduction

There is an acknowledged lack of diversity in computing [105], and not unlike many other STEM disciplines [20] there is evidence of racist and misogynistic issues throughout the pipeline [65, 79, 102]. This is particularly problematic for Black women and girls where the intersection of racialisation and gender has led to further marginalisation and discrimination [79, 102]. This lack of diversity and cultural competence creates a culture that excludes those who do not fit the White and Asian male stereotype of

computing [104]. Those who do study/work in Computer Science but who do not fit this stereotype often leave due to disillusionment [105].

Much of the technology that we use in our daily lives has been developed by teams of software engineers who lack diversity. This has led to numerous examples where the perspectives of diverse users have not been taken into consideration. There are many examples where bias in AI-based predictive systems has been uncovered. Recently, AI-based technology has been shown to systematically discriminate against women, particularly Black women [12, 67]. These systems have been shown to reinforce social and historical human prejudices and people who are traditionally marginalised in our society are disproportionately negatively impacted [6]. It is largely acknowledged that diversity of team membership is important for the development of better systems [41]. However, if we want to increase the diversity of people studying and working in computing then we need to ensure that everyone feels like they belong.

Belongingness has been researched in various disciplinary contexts including Computer Science – however, we are aware of no studies comparing the belongingness of Computer Science students with other Science disciplines other than one study that had only 1.4% Computer Science students in their sample [49] which we discuss in Section 3.3. This is a similar situation to the reportedly high drop-out rates in computing – specifically introductory programming. In 2019, an ITiCSE Working Group by Simon & Luxton-Reilly, et al. compared notoriously low pass rates in introductory programming to other STEM disciplines [88]. They found very little difference between pass rates in introductory programming and introductory courses in other STEM disciplines in the last five years. Without knowing where computing stands in terms of other fields of study it is difficult to say how high ‘high’ is, and how low ‘low’ is. Although having a sense of belonging that is as high as possible is clearly desired, comparisons to other disciplines in similar contexts can be instrumental in identifying how to improve sense of belonging in that context.

Comparing belongingness between student groups can be difficult as belongingness is closely related to the environment that a student studies in. In this case, the study of a single university is instrumental as many environmental variables are naturally controlled for. We present the results of a study in this case, comparing the belongingness of Computer Science undergraduates and those in other Science disciplines within the context of a single university where many environmental and institutional variables are common. We looked for evidence of racial minoritisation, and/or minoritisation of identities relative to ethnicity, gender, socio-economic status, religion, sexuality, and

disability. We anticipated that if students in Computer Science are being minoritised more than students in other disciplines in the same institution, then the belongingness of Computer Science students would be lower than that for students in other Science disciplines.

3.2 Research questions

Our research questions are:

RQ1: How does the sense of belonging of students in Science, including Computer Science, vary by gender identity and minoritisation?

RQ2: How does the sense of belonging of Computer Science students compare to other Science students?

RQ3: How does the sense of belonging vary by gender identity and minoritisation for students in Computer Science compared to other Science students?

3.3 Related work

Research on humans' sense of belonging has been conducted by sociologists and psychologists for many decades on many different populations such as medical patients and older people [86]. However, research in the sense of belonging of university-aged students was considered relatively uncommon as recently as 2007 [23]. Since then substantial research has been conducted, for instance, in mathematics, where belongingness has been shown to be predictive of students' likelihood to continue in their studies [29]. In addition, the belongingness of students in physics [50], ecology and biology [71], and many other disciplines including computing have been investigated.

Sense of belonging in computing

In computing, belongingness is a known predictor of motivation and persistence [10]. It has been shown that belongingness can be predictive of pass rates, final exam scores and course grades for early-stage computing students - a finding that was noted as concerning by the authors [45]. Mayfield et al. [58] found that the sense of belonging increased for CS1 students in process-oriented guided inquiry learning (POGIL) course sections and decreased for students in other sections.

Comparing belongingness in computing & STEM

In 2012, sense of belonging was identified as an important variable to study when considering the causes and cures of the representation gap in mathematics and Science domains [29]. Lewis et al. explored the sense of belonging of students enrolled in pSTEM (pSTEM typically excludes the life sciences [50] which often have a better gender balance, or are even female-dominated) majors at a single university with a sample of 416 students (122 women, 294 men) from an introductory level, calculus-based physics course required for pSTEM majors. However, the breakdown of majors was only 1.4% Computer Science with the remainder being 83.7% engineering, 10.3% physical sciences, and 4.6% mathematics. This equates to just six Computer Science students. Further, their study focused on students' sense of belonging in *physics* (because it was a physics course) with the questions: "I feel like I belong in physics", "People in physics accept me", and "I feel like an outsider in physics".

3.4 Methods

This study was conducted at a large, European, research-intensive university. The language of instruction is English and many students, but not all, are native English speakers. Those who are not fluent have a proficient command of English. The university has six colleges: Arts & Humanities; Business; Engineering & Architecture; Health & Agricultural Sciences; Science; and Social Sciences & Law. All undergraduate students in the College of Science were invited to take part in our survey.

The College of Science has approximately 2,000 undergraduate students fairly evenly distributed across four years. There are seven schools in the college and their gender distributions vary. The seven schools, along with the approximate percentage of women are: Computer Science (CS) 22%, Physics 30%, Mathematics & Statistics (M&S) 30%, Chemistry 50%, Earth Science (ES) 50%, Biology & Environmental Science (BES) >60%, and Biomolecular & Biomedical Science (BBS) >60%. Other groups known to be under-represented in the college include members of the LGBTQIA+ community, members of the Irish Traveller community (The term Irish Traveller refers to 'the community of people who are commonly called Travellers and who are identified (both by themselves and others) as people with a shared history, culture and traditions including, historically, a nomadic way of life on the island of Ireland' (Ireland, Equal Status Act, 2000, Sec 2 (1)). Travellers are a recognised ethnic minority and their rights are specifically

protected in Irish law.), those with disabilities, those who are neurodiverse, and those from non-white/European racial and ethnic backgrounds, among others.

The survey was conducted with ethical approval from the Human Research Ethics Committee, number (LS-21-62-Mooney). Responses were gathered via a Google form which was advertised on email, the virtual learning environment, posters, and student societies. The survey questions were adapted from the “Math Sense of Belonging Scale” [29] containing 18 positively-framed questions (e.g., I feel accepted/I feel respected/etc.) and 12 negatively-framed questions (e.g., I feel excluded/I feel disregarded/etc.). A similar adaptation of this instrument was validated by Moudgalya et al. for use in undergraduate Computer Science courses [64]

All items in the survey were preceded by “As a student in the College of Science...”. The only modification made to our instrument from the original Good et al. [29] instrument was replacing “mathematics” with “the College of Science”. For each item, participants rated their agreement on an 8-point Likert-like scale (1 strongly disagree → 8 strongly agree).

A *Belongingness score* was calculated as the sum of positively framed question scores minus the sum of negatively-framed question scores, identical to Good et al [29]. Thus, belongingness scores can range between -78 and 132, with a midpoint of 27.

In addition to these “Sense of Belonging” questions we also asked the following questions¹:

1. What School are you in? *S*
2. What year are you in? *S*
3. What is your gender? (This refers to the gender you identify with. Note, gender non-binary is a person who does not identify exclusively as a man or woman.) *S* (*Woman / Man / Non-binary / Prefer not to disclose / Prefer to self-describe*) plus open answer field
4. How do you define your race/ethnicity? *O*
5. Do you consider yourself part of a minority in your School because of your gender, age, race, disability, ethnic origin, religion, sexual orientation, civil status, family

¹*L* denotes Likert-like items (1 lowest → 5 highest). For example, for the question “How much do you interact socially with other students in your School?”, the choices were: 1 (Not at all), 2, 3, 4, 5 (They are my main group of friends). *S* denotes selection from a list of options (if an open “other” field was present it is noted). *O* denotes open (free) text entry. *Y/N* denotes Yes/No plus open text field if Yes.

status, membership of the Irish Traveller community or socio-economic status, or for any other reason? *Y/N*

6. If you said yes to the last question, what minority group(s) do you identify with? *O*
7. How much do you interact socially with other students in your School? *L*
8. In your opinion, how much does success in STEM depend on inherent ability i.e. it is something you are born with? *L*
9. How much do you enjoy problem solving? *L*
10. How confident were you in your mathematical abilities before joining the College of Science? *L*
11. How confident are you in your mathematical abilities now? *L*
12. Are you a member of any clubs or student societies, for example, Women@STEM, Women@CompSci, Biological Society, International Students Society, LGBTQ+ Society? *Y/N*
13. What was your access route into the College? *S*
14. Is there anything that has positively or negatively impacted your Sense of Belonging to your School and/or College of Science? *O*
15. Are there ways that you think that Sense of Belonging might be improved in your School and/or College of Science? *O*

3.4.1 Statistical analysis

To test for statistical significance, I compared the means between groups and utilised Welch's two-sample t-test (two-tailed), $\alpha = 0.05$. One-way ANOVA was used to determine whether or not there is a statistically significant difference between the means of three or more independent groups, $\alpha = 0.05$.

3.5 Results & analysis

In this section, we present our results and analysis. In Section 4.5 we address our research questions informed by these. In figure captions we point out notable observations

– with or without statistical significance – as depending on what is being compared, finding no difference between groups can be as insightful as other comparisons where there is a significant difference. Details of these notable observations are provided in relevant subsections.

378 students completed the survey from December 2021 to March 2022. Missing values in responses deemed valid (e.g., skipping one Likert-like item) were replaced with the mean score for that item. Invalid responses (e.g., missing multiple items entirely, those from students outside of the College of Science, and those from students who were not undergraduates) were removed, leaving 355 valid responses. 190 students (54%) identified as women, 151 (43%) as men, 12 (3%) as non-binary and 2 (>1%) preferred to not disclose. Students were in years: 1 (35%), 2 and 3 (22% each), and 4 (21%). 20% were from the School of Computer Science and 80% were from other Schools in the College of Science (see Table 4.1). Overall, 34% of students identified as minoritised.

Figure 3.1 (A) shows a histogram of all belongingness scores. The distribution is near normal. The peak is very close to the neutral score of 27, and there are slightly more students on the positive side of this midpoint indicating that overall, the mean belongingness score of all students combined is close to neutral but positive. Figure 3.1 (B) shows a correlation matrix for the numbered questions presented at the end of Section 3.4. The features are coded as follows:

- Belongingness: score as described in Section 3.4
- Mathematical ability (now & prior), problem solving ability, social interaction, and inherent ability: Likert-like item scores
- Gender: man 0, women 1, non-binary 2
- Society/club membership, and minoritised: no 0, yes 1
- Access route: direct-entry school leaving 0, other access routes 1 (The direct-entry school leaving entry route is the exam-based entry route for students around 18 years of age who typically have no gap between leaving second-level Schooling and university entry. The other access routes include the higher education admissions scheme for students with disabilities, the higher education admissions scheme for students underrepresented in higher education due to their socio-economic background, and mature students).
- School: Computer Science 0, other Schools 1

It should be noted that the factors other than the belongingness score represent responses to the questions presented in Section 3.4 and should be interpreted as such.

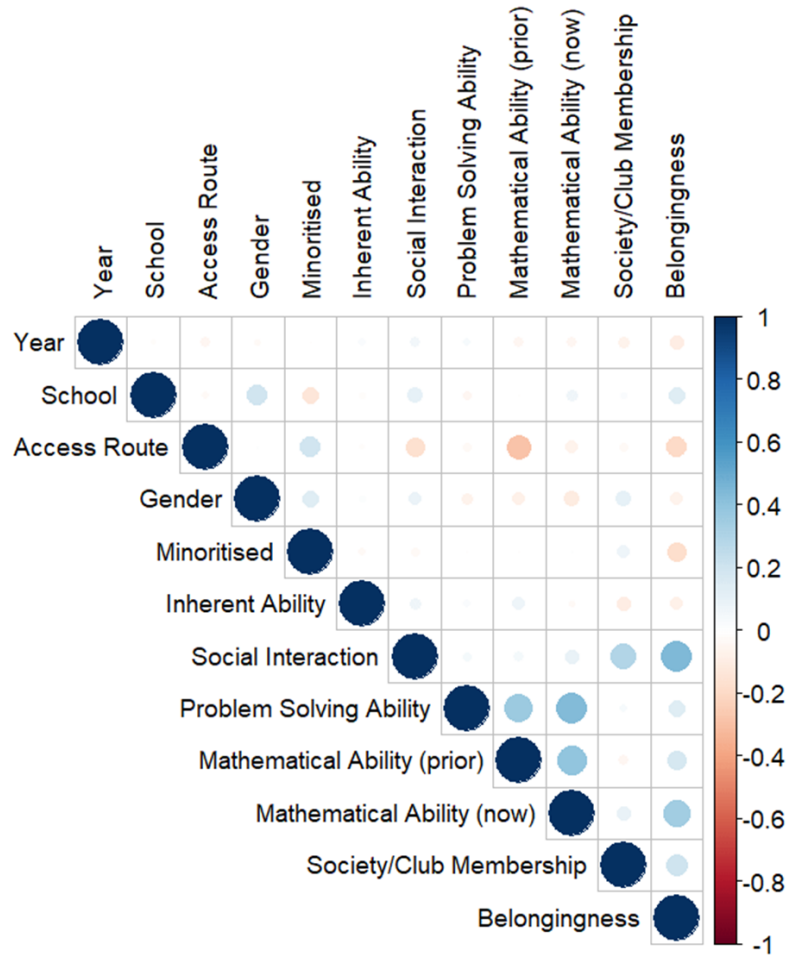
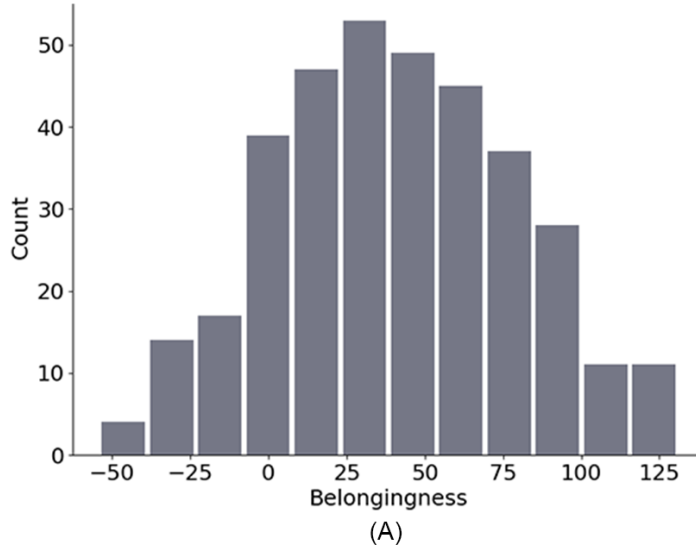


Figure 3.1: (A) Histogram of the distribution of belongingness scores for all students. (B) Correlation Matrix: Positive (blue) and negative (red) correlations (Pearson correlation coefficient (r)). Colour intensity and size of the circle are proportional to r . Feature codings are discussed in Section 4.4.

For instance “mathematical ability (now)” is a response to “How confident are you in your mathematical abilities now?” and not a direct assessment of students’ mathematical abilities.

We observed that some expected positive correlations are present, for instance, mathematical ability (prior) and mathematical ability (now) ($r = 0.393$). Similarly, problem solving ability with both mathematical ability (prior) ($r = 0.362$) and mathematical ability (now) ($r = 0.439$). While these observations may be interesting, they also lend some validity to the survey results and analysis. This allows us to interpret correlations with belongingness – our primary factor of interest – with some confidence, in addition to the fact that as discussed in Section 3.3, a very similarly adapted instrument was previously validated.

We observed that social interaction is most positively correlated with belongingness ($r = 0.450$) – an intuitive but not guaranteed observation. Similar was observed for society/club membership which is also positively correlated with belongingness ($r = 0.207$). Notably, belongingness is more positively correlated with mathematical ability (now) ($r = 0.342$) than it is with mathematical ability (prior) ($r = 0.178$). Belongingness is also weakly correlated with problem-solving ability ($r = 0.134$). A student’s School is positively correlated with belongingness ($r = 0.135$) providing evidence that in general, students in other Science subjects have a higher sense of belonging than students in Computer Science.

Belongingness is most negatively correlated with access route ($r = -0.192$), although this correlation is smaller in magnitude than the largest positive correlation. This provides evidence that non-competitive entry routes are correlated with lower belongingness. The next most negative correlation was identifying as minoritised ($r = -0.173$), followed by a weaker negative correlation with year ($r = -0.096$), evidence that in aggregate, students further into their programme have a slightly lower sense of belonging score. Belongingness is weakly negatively correlated with gender ($r = -0.069$), evidence that in aggregate students identifying as women or gender non-binary have lower belongingness. Finally, belongingness shows a weak negative correlation with self-perceived inherent ability ($r = -0.071$).

Belongingness is not statistically significantly different across genders.

When split by gender, a one-way ANOVA revealed that there is no statistically significant difference in the sense of belonging between students who self-identify as men, women, or non-binary ($F(2,350) = 1.036$, $p = 0.356$) (Figure 3.2(A)).

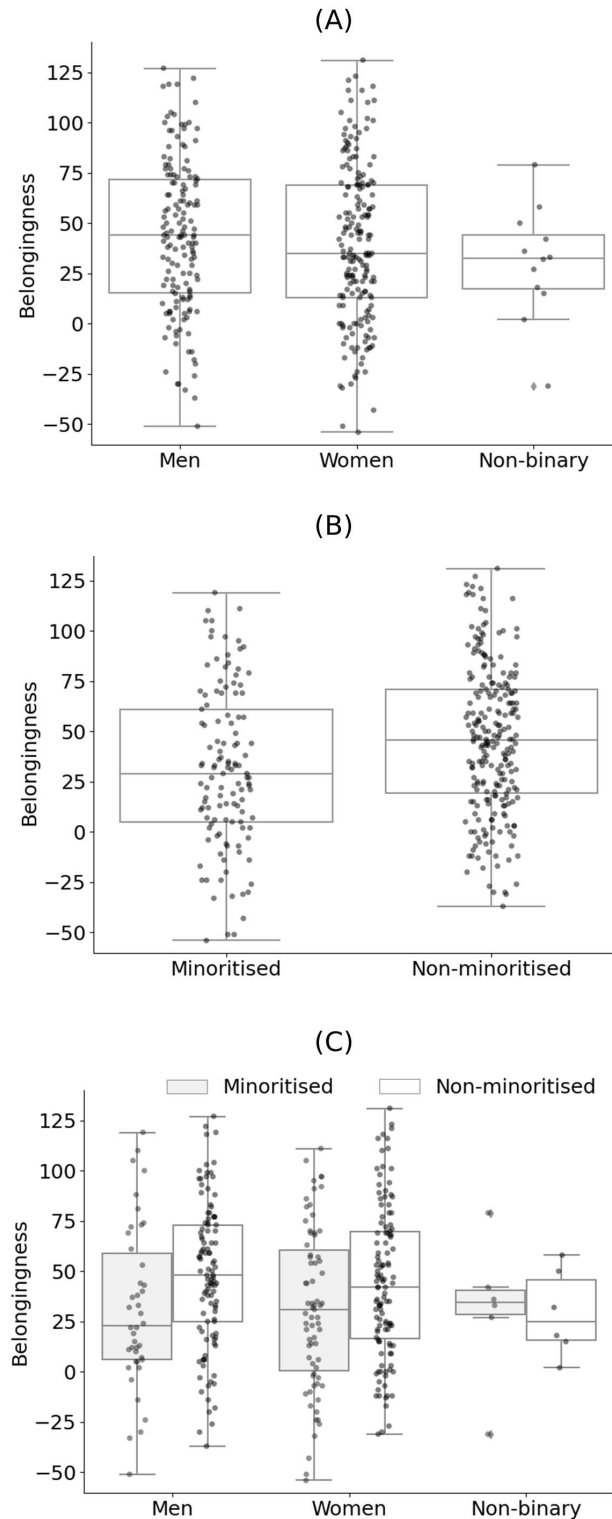


Figure 3.2: (A) Distribution of belongingness scores for all students split by gender. (B) Distribution of belongingness scores for minoritised and non-minoritised students. Minoritised students have a statistically significant lower belongingness. (C) Distribution of belongingness scores for all students who self-declared as being minoritised, compared to those who did not, split by gender identity. Men and women who identified as minoritised had statistically significantly lower belongingness.

Table 3.1: Distribution of students across the seven Schools. ‘Sciences’ refers to students in the College of Science who are not Computer Science students. The distribution of non-disclosed and non-binary students across Schools is not shown to protect their anonymity. M = men, W = women, Min = Minoritised, NM = Non-minoritised.

	N	M	W	Min	NM
All	355	151	190	121	234
Sciences	284	106	166	88	196
CS	71	45	24	33	38
M&S	47	25	21	13	34
Physics	32	21	11	10	22
Chemistry	49	17	27	20	29
BBS	67	16	50	22	45
BES	33	8	23	9	24
ES	10	5	4	3	7
Undecided	46	14	30	11	35

Minoritised students have statistically significantly lower belongingness, which varies by gender.

Figure 3.2(B) shows a box plot of the distribution of belongingness for minoritised ($N = 121$, $M = 31.7$, $SD = 39.4$) compared to non-minoritised ($N = 234$, $M = 45.7$, $SD = 36.5$) students. Minoritised students have a statistically significant lower belongingness ($t(227.05) = -3.22$, $p = 0.001$). Figure 3.2(C) shows box plots of the distribution of belongingness for all students who self-declared as being minoritised, compared to those who did not, split by gender identity. Men who identified as minoritised had a statistically significant ($t(68.113) = -2.334$, $p = 0.022$) lower mean belongingness ($N = 42$, $M = 31.7$, $SD = 39.7$) compared to those who did not ($N = 109$, $M = 48.3$, $SD = 35.7$). Women who identified as minoritised ($N = 71$, $M = 31.3$, $SD = 39.8$) also had a significantly lower belongingness ($t(140.44) = -2.186$, $p = 0.030$) compared to those who did not ($N = 119$, $M = 44.1$, $SD = 37.5$). Non-binary students who identified as minoritised ($N = 6$, $M = 31$, $SD = 32.4$) had higher mean belongingness compared to those who did not ($N = 6$, $M = 29.2$, $SD = 19.7$), however, this difference is not statistically significant ($t(8.3) = 0.11$, $p = 0.916$) and the sample size of non-binary students is small.

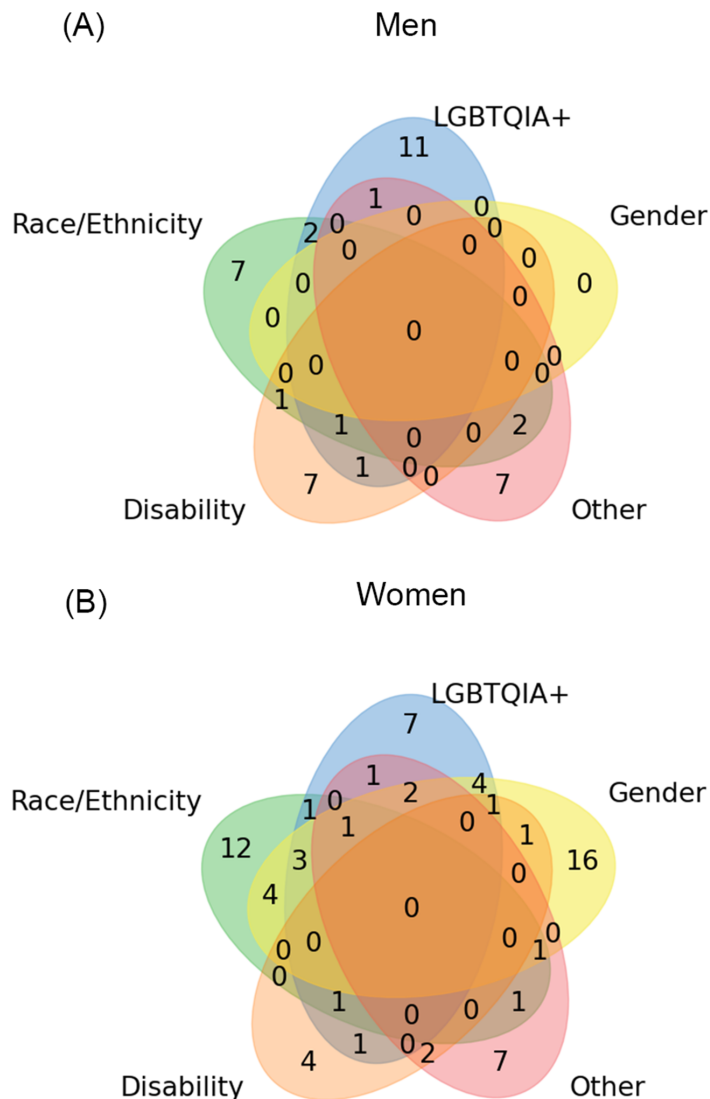


Figure 3.3: Venn diagrams showing the intersection of the self-described identities of minoritised students who identified as (A) men ($N = 40$ – Two additional men identified as being minoritised but did not declare why). (B) women ($N = 70$ – One additional woman identified as being minoritised but did not declare why). ‘Other’ reasons for minoritisation included being a mature student, being religious and socio-economic background.

Intersectionality and minoritisation

Figure 3.3 shows the intersection of students who are minoritised due to their gender identity, race and/or ethnicity, membership of the LGBTQIA+ community, ability, and/or other reasons. Other reasons provided by students included socio-economic background, being mature students (being older than their peers), and their religion or being religious.

In many cases, women identify as minoritised for multiple reasons. Of those identi-

fying as women, 37% identified as minoritised. Of these, 46% identified as minoritised due to their gender and 23% stated that the only reason they were minoritised was their gender. Of those identifying as men, 29% identified as minoritised, none of whom stated being minoritised due to their gender. Relatively few men identify as minoritised for multiple reasons. Of those identifying as non-binary, 50% identified as minoritised. 33% of these reported being LGBTQIA+ as their only reason for being minoritised. We did not report on gender non-binary students as a separate group in our analysis from this point on to preserve their anonymity due to the small sample size.

Computer Science students have statistically significantly lower belongingness compared to other science students.

Figure 3.4(A) shows a histogram of the distributions of belongingness scores for Computer Science students compared to other Science students. Both distributions are fairly normal and are slightly left-skewed.

Figure 3.4(B) shows a box plot of the distribution of belongingness for all Computer Science students and all Science students. Computer Science students have a lower belongingness ($N = 71$, $M = 30.7$, $SD = 38.4$) compared to other Science students ($N = 284$, $M = 43.5$, $SD = 37.6$) that is statistically significant ($t(106) = -2.50$, $p = 0.013$). Figure 3.4(C) shows the distribution of belongingness scores for Computer Science and other Science students split by gender. It was observed that men in Computer Science ($N = 45$, $M = 31.6$, $SD = 39.1$) have a statistically significantly lower belongingness ($t(76.66) = -2.5$, $p = 0.013$) than men in Science ($N = 106$, $M = 48.8$, $SD = 35.7$). Although there is a lower mean belongingness of women in Computer Science ($N = 24$, $M = 30.9$, $SD = 38.1$) compared to women in Science ($N = 166$, $M = 40.6$, $SD = 38.9$), this is not statistically significant ($t(30.36) = -1.14$, $p = 0.263$).

Figure 3.4(D) shows a box plot of the distributions of belongingness scores for Computer Science and other Science students split into those who are minoritised and those who are not. Although the belongingness of minoritised Computer Science students ($N = 33$, $M = 22.8$, $SD = 40.3$) is lower than the belongingness of Science students ($N = 88$, $M = 35.1$, $SD = 38.5$), the difference is not statistically significant ($t(55.25) = -1.49$, $p = 0.140$). The belongingness of non-minoritised Computer Science students ($N = 38$, $M = 37.53$, $SD = 35.24$) is also lower than non-minoritised Science students ($N = 196$, $M = 47.25$, $SD = 36.52$) however this difference is also not statistically significant ($t(53.57) = -1.53$, $p = 0.132$).

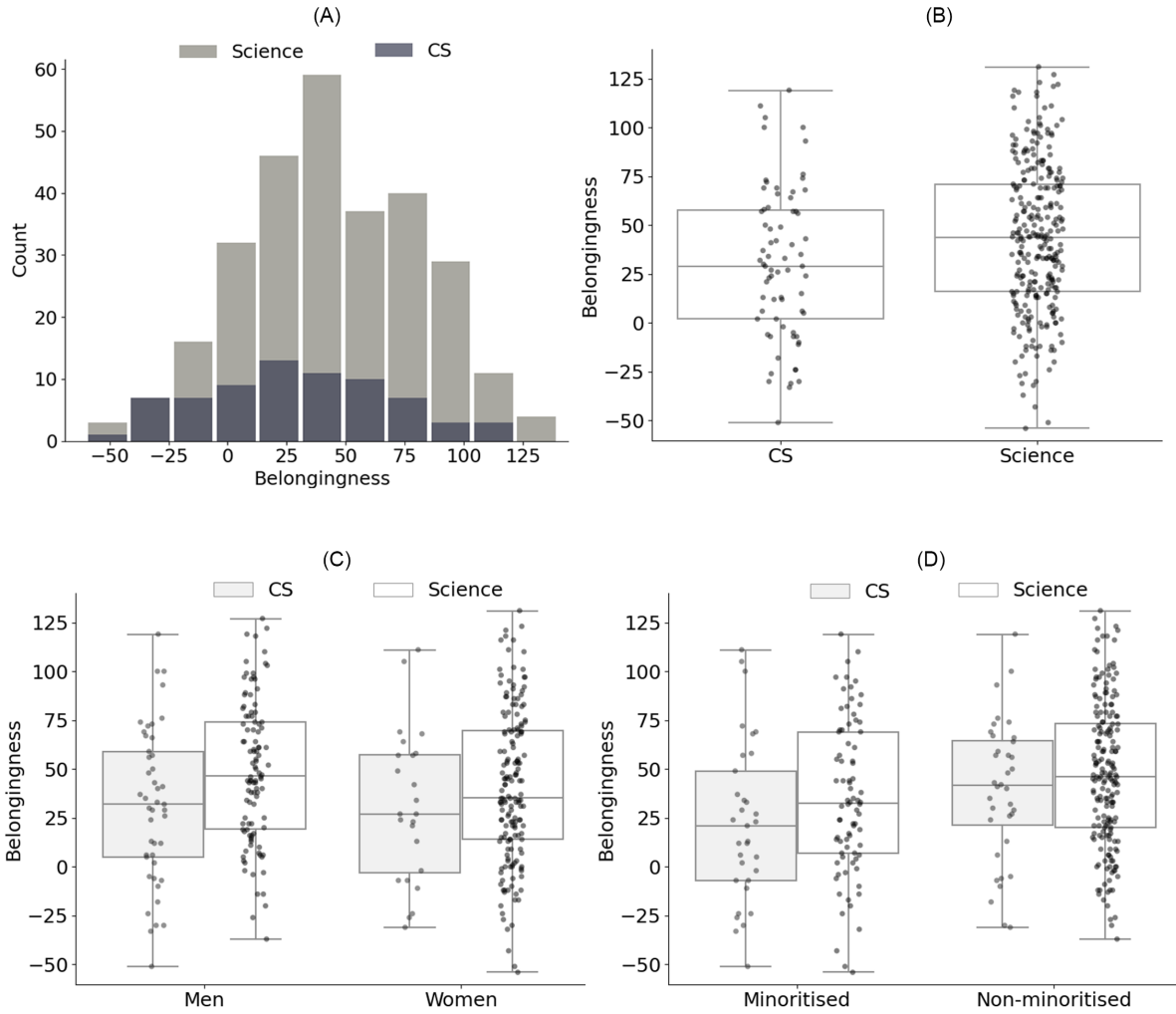


Figure 3.4: (A) Histogram showing the distributions of belongingness scores for Computer Science students compared to other Science students. (B) Distribution of belongingness scores for Computer Science students and other Science students. Computer Science students have statistically significant lower belongingness scores. (C) Distribution of belongingness scores for Computer Science and other Science students split by gender (men / women). We do not show non-binary students to preserve their anonymity due to the small sample size. The belongingness of men in Computer Science is statistically significantly lower than men in Science. (D) Distribution of belongingness scores for Computer Science and other Science students split into those who are minoritised and those who are not.

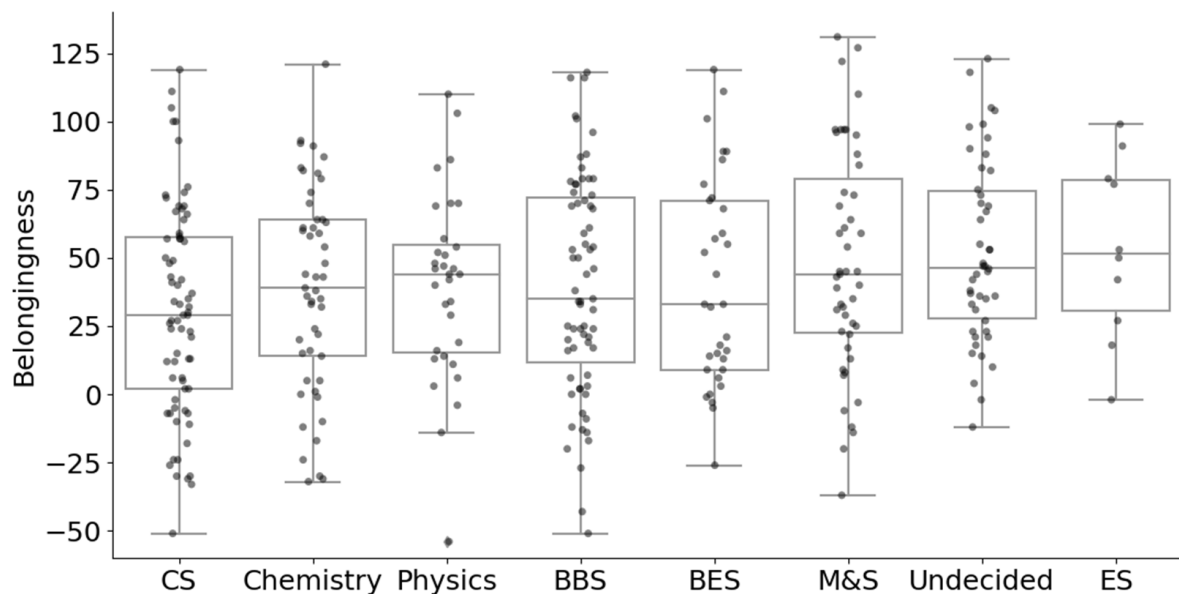


Figure 3.5: Distribution of belongingness scores for all students grouped by School.

Variations in belongingness across Science disciplines by gender and minoritisation.

Figure 3.5 shows box plots of the distributions of belongingness scores for all students grouped by School, sorted by mean belongingness scores (CS $M = 30.67$; Chemistry $M = 38.51$; Physics $M = 39.63$; BBS $M = 39.72$; BES $M = 40.52$; M&S $M = 48.36$; Undecided $M = 51.96$; ES 53.4). Students who do not state what School they are in are labelled as “Undecided”. These are Year 1 ($N = 36$) and Year 2 ($N = 10$) Science students. A one-way ANOVA revealed that there was not a statistically significant difference in belongingness between students in the seven Schools or undecided students ($F(7, 347) = 1.759$, $p = 0.094$). Nonetheless, Computer Science clearly has the lowest mean belongingness score.

Figure 3.6 shows a box plot of the distributions of belongingness scores for minoritised and non-minoritised students in each of the seven Schools (plus undecided students) split by gender. A one-way ANOVA showed no statistically significant difference in belongingness between minoritised men across the seven Schools and undecided students ($F(7, 34) = 1.45$, $p = 0.218$), or minoritised women ($F(7, 63) = 0.86$, $p = 0.543$). However, there is a statistically significant lower belongingness of minoritised men compared to non-minoritised men in Computer Science, and minoritised men and women compared to non-minoritised men and women in BBS.

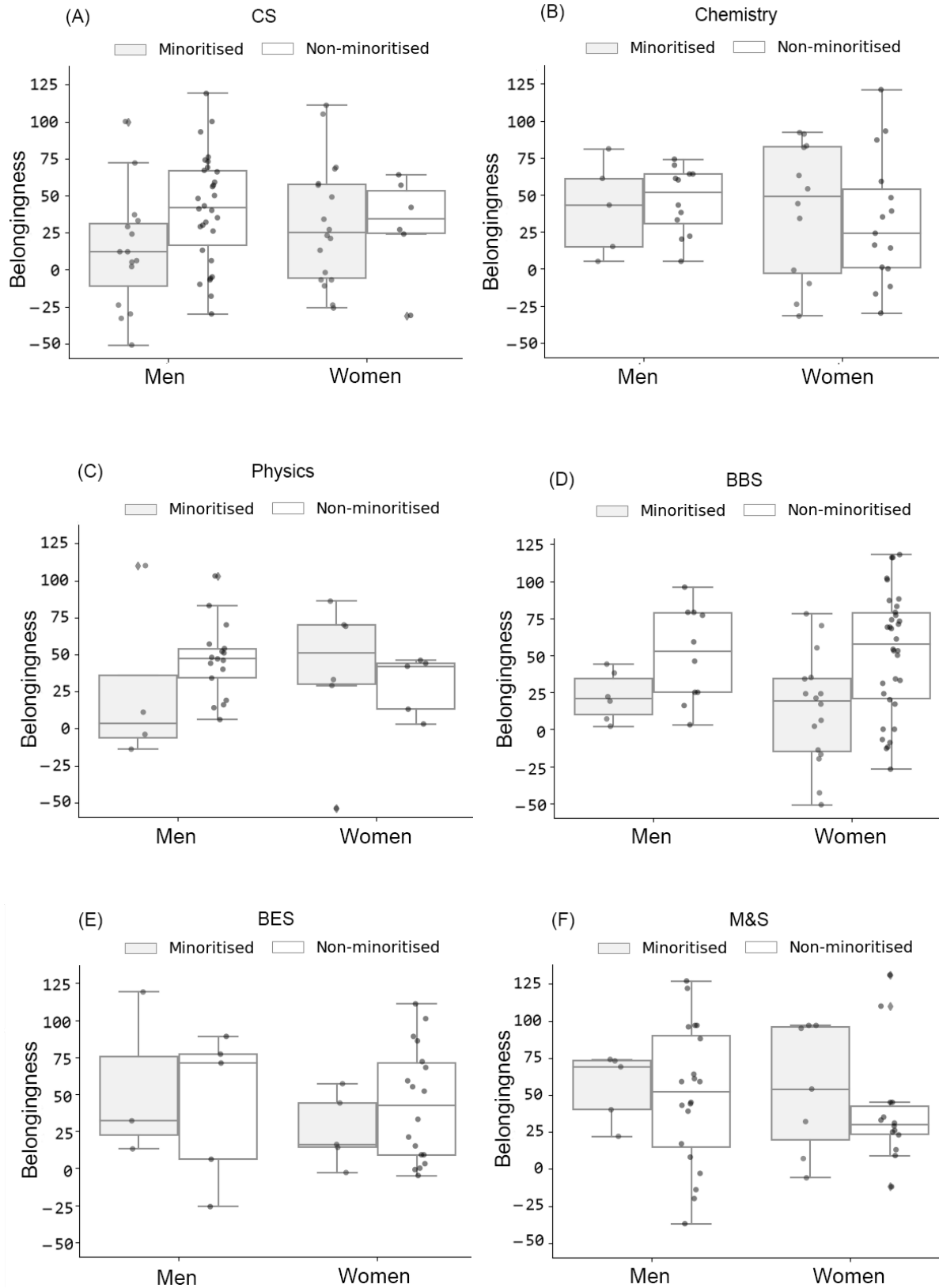


Figure 3.6: Box plots showing the distributions of belongingness scores for minoritised and non-minoritised students split by gender. We do not show non-binary students to preserve their anonymity due to the small sample size.

3.6 Discussion

We set out to explore the sense of belonging of Computer Science students compared to students in other Science disciplines to see if belongingness varies from School (discipline) to School, and what role gender identity and minoritisation play in this. We agree with authors who have expressed concern with acronyms such as URM (Underrepresented Minority) [107] and BAME (Black, Asian, and Minority Ethnic) [61]. Instead, we use the term racially minoritised [31]. This reflects the reality that our students are actively minoritised because of their race or ethnicity rather than naturally existing as a minority [61]. We placed a lot of importance on allowing students to self-describe in their survey responses both in terms of their gender identity [91] and their minoritisation. We chose this approach as there are unique differences among women of colour based on race, ethnicity, nationality, socio-economic class, sexuality, and disability, for example [79]. Our survey responses have opened our eyes to the range of identities that our students identify with, how they intersect, and the impact that this intersectionality is having on their sense of belonging [14, 17]. Students may also be minoritised because of their gender, socio-economic background, religion, membership of the LGBTQIA+ community, neurodiversity, disability, and many other reasons.

Research question 1

How does the sense of belonging of students in Science, including Computer Science, vary by gender identity and minoritisation? We observed that there is no statistically significant difference in belongingness across genders in the College of Science. We observed that the majority of women do not consider themselves to be minoritised, and non-minoritised women have a very similar mean belongingness to non-minoritised men ($M = 44.1$ and $M = 48.3$, respectively). Less than 4% of non-minoritised women identified as having a non-European background, and an even smaller percentage identified as Black. In contrast, 34% of minoritised women identified as having a non-European background, and more than a third of these women identified as Black. All women who identified as minoritised and Black gave being Black as a reason for their minoritisation, with some providing additional reasons (e.g., being a woman). Again, this contrasts with other women of colour. Most of these students identified as Asian or Indian but did not necessarily give their race/ethnicity as the reason for their minoritisation. These women were more likely to list age, gender, membership of the LGBTQIA+ community or socio-economic background as the reason for their minoritisation, although many of them did

also mention race/ethnicity. Interestingly, we found that Black women and Indian/Asian women had very similar mean belongingness (39 and 38 respectively) compared to White/European women who had a lower belongingness (27). The White/European women were minoritised primarily due to membership of the LGBTQIA+ community, gender, disability and socio-economic factors.

Research question 2

How does the sense of belonging of Computer Science students compare to other Science students? Overall we found a statistically significant lower belongingness for Computer Science students (mean 30.7; range 30.7-53.4). However, when analysed on a School to School basis, a one-way ANOVA showed no statistically significant difference between any two Schools.

Research question 3

How does sense of belonging vary by gender identity and minoritisation for students in Computer Science compared to other Science students?

We found that men in Computer Science have a statistically significant lower belongingness compared to other students in Science. Although there is a lower mean belongingness of women in Computer Science, and of minoritised and non-minoritised students, compared to students in Science these are not statistically significant. We also found variations in belongingness across all Science disciplines.

At the end of the survey, we asked students these two questions:

1. "Is there anything that has positively or negatively impacted your Sense of Belonging to your School and/or the College of Science?"
2. "Are there ways that you think that Sense of Belonging might be improved in your School and/or the College of Science?"

Employing inductive thematic analysis we found, one comment from a student succinctly captures the essence of sense of belonging and the importance of diversity: "I don't see a lot of people that look like me". Many more students commented on the lack of diversity, particularly of faculty. Specifically, women expressed the need for more role models and generally felt that they would be better understood if the faculty was more diverse. Some students commented on the need to educate faculty regarding the importance of using inclusive language (e.g., not 'Hey guys'), and using inclusive examples

in their teaching material (e.g., not stereotypical male-dominated sports analogies). Some students mentioned the importance of dignity & respect training for students and staff, however, interestingly, this was not one of the dominant themes.

The most dominant theme in the comments was the importance of friends, and the positive impact that having good friends has on sense of belonging. This is also reflected in our survey responses where we saw a strong positive correlation between belongingness and the response to the question *How much do you interact socially with other students in your School?* Students repeatedly mentioned the importance of socialising, meeting people, and making friends. Students felt that the Schools/Colleges need to make more of an effort to create opportunities for social interaction rather than leaving this to the students themselves, or to the student societies and clubs. Students struggled in large classes and there were many suggestions for more group work to facilitate students getting to know classmates better. Many students reported that they continue to be negatively impacted by the COVID-19 pandemic, that they have not been able to make friends during the pandemic, and the lack of opportunities to socialise. This is a possible explanation for the lower belongingness of students in years 2 to 4 as their College experience has been altered by the pandemic more than the year 1 students who have been largely taught in-person on campus.

Another dominant theme is, as one student put it “The feeling that I’m not doing enough and have to constantly prove myself”. Many students report lacking confidence in their abilities and describe feeling that other students have more prior experience. However, some students reported how they had been affected positively by other students and professors sharing that they have struggled. This lack of confidence appears to be linked with non-competitive entry routes, confidence in their mathematical ability now, inherent ability (i.e. fixed rather than growth mindset) and their overall belongingness. More positively, students mentioned the helpful impact that the mathematics support centre and peer mentors have had on them.

Many students reported challenges with their mental health and requested more access to support and counselling services. This was often exacerbated by financial difficulties. Students felt that faculty did not understand that many students need to work. Being unable to afford to socialise with classmates, and being unable to live on or near campus negatively impacted their belongingness.

These themes and the number of comments supported that informed our discussion on them are summarised in Table 4.4

Table 3.2: The themes of the discussion of RQ3

Theme	Number of comments supported
Friendship	28
Socialisation/need more social events	27
Covid-19 impact	18
Lack of confidence	5
Mental health, disability, counselling and other support	15

3.7 Implications

This work has given us much insight into the many reasons why our students are minoritised. The School of Computer Science has implemented a number of policies on gender identity & expression, dignity & respect, the reporting of bullying, harassment and sexual misconduct, and active consent, bystander intervention, and well-being workshops for students, as well as dignity & respect training for staff. There has also recently been an anti-racism campaign. Due to the pandemic and students learning online, we may not be seeing the positive impact of these policies, campaigns and training yet. This survey, which we will repeat annually, will serve as a baseline allowing us to monitor the impact that these policies, campaigns and workshops are having on the belongingness of our students over time.

3.8 Limitations

Although we gave students the freedom to self-describe wherever possible, we then categorised students into two very broad groups of minoritised and non-minoritised to allow us to conduct straight-forward comparisons across the seven Schools in the College of Science. In this work, other than highlighting that many students were minoritised for more than one reason, we have not looked in depth at the impact of multiple intersecting identities. Nor have we fully explored the differences in experience of students who are racially minoritised compared to those who are minoritised for other reasons, or the intersectional experience of women who are racially minoritised. We will explore this further in future work.

As this research was conducted at one university these results may not generalise

readily. However, this approach brought many positives. First and foremost, the factors that impact belongingness are many and include several local environmental variables such as the physical environment, faculty, programme structure, university culture, and most importantly the student body itself. A single university study naturally controls many of these variables to a much greater extent than multi-institutional studies can. Additional benefits include consistency in survey delivery, approach, and data analysis.

3.9 Conclusions & future work

We set out to answer three research questions with a broad view of comparing the belongingness of students in the context of computing as being one discipline of many in a single College of Science. Another way to state this is that we studied the sense of belonging of science students with a focus on computing specifically. Our approach allowed us to explore sense of belonging in a study where many environmental variables are naturally controlled.

Our first research question was *How does the sense of belonging of students in science, including computing, vary by gender identity and minoritisation?* We found no statistically significant difference in belongingness across genders. However, minoritised students have statistically significantly lower belongingness, which varies by gender, showing that intersectionality and minoritisation have a significant impact on belongingness.

Our second research question was *How does the sense of belonging of computing students compare to other science students?* We found a statistically significant lower belongingness in computing compared to other science students, and that computing has the lowest mean belongingness of all Schools in the College of Science including students yet to decide on their major.

Our third research question was *How does sense of belonging vary by gender identity and minoritisation for students in computing compared to other science students?*

The belongingness of students varies across science disciplines by gender and minoritisation. However, we did not find a statistically significant difference in belongingness between minoritised men or women across the seven Schools in the College, including undecided students. We did find a statistically significant lower belongingness of minoritised men compared to non-minoritised men in computing.

The issues raised in students' survey comments deserve more attention. We will continue to expand upon this work with particular emphasis on the intersection of

identities. We will also investigate the impact of interventions to increase belongingness. A number of these have recently been put in place in the School of Computer Science that aim to address many student concerns and we hope that over time we will see an increase in the belongingness of all of our students and that ultimately we can hope to eradicate the negative impact that minoritisation and gender identity are having on the sense of belonging of our students. We believe that our results may be of interest to other computing departments in similar contexts.

THE ROLE OF UNIVERSITY ENTRY ROUTES

This chapter is based on an article submitted to ACM Transactions on Computing Education (TOCE). This chapter covers how university entry routes affect Computer Science and Science students' sense of belonging, including a detailed examination of methods, results, and implications.

Author contributions

Conceptualisation: Catherine Mooney; Introduction: Shamima Nasrin Runa, Context: Shamima Nasrin Runa, Andrew McCartan, Catherine Mooney, Brett A. Becker; Quantitative analysis: Shamima Nasrin Runa, Qualitative analysis: Shamima Nasrin Runa and Andrew McCartan; Result and Discussion: Shamima Nasrin Runa and Andrew McCartan; Original Draft Preparation: Shamima Nasrin Runa and Andrew McCartan; Review and Editing: Shamima Nasrin Runa, Andrew McCartan, Catherine Mooney, Brett A. Becker; Supervision: Catherine Mooney. All authors have read and agreed to the submitted version of the manuscript.

Abstract

Sense of belonging, or belongingness, is an individual's personal conviction as to their acceptance as a valued member of an academic community. The importance of belongingness lies in correlations with motivation, persistence, mental health and well-being. Prior work has shown that belongingness can be lower in students who are minoritised due to their gender, race, nationality, socio-economic status, religion and/or disability. However, it is not well known how a student's university entry route impacts their sense of belonging in Computer Science and other Science disciplines. We utilised a survey adapted from the validated "Math Sense of Belonging Scale" to examine the belongingness of undergraduate Science students, including Computer Science. We examined how the belongingness of students varies by university entry routes, and how the belongingness of students in Computer Science varies by university entry routes compared to other Science students. Our results reveal a significant difference in belongingness between students entering university through the direct-entry school leaving route, compared to those who entered via combined access routes (e.g. university admissions schemes for school leavers from socio-economically disadvantaged backgrounds, with disabilities, and mature students). Specifically, within Computer Science, students entering university through the direct-entry school leaving route had significantly higher belongingness than combined access route students. These results provide insight that may help others improve the belongingness of undergraduate Computer Science students, with a particular focus on the intersection of identities.

4.1 Introduction

All computing students deserve to feel a sense of belonging [75]. However, a lack of diversity and equity throughout STEM disciplines and specifically within computing [20, 105] is linked to diverse students dropping out of university environments that deter and exclude them by centring only 'stereotypical' STEM and Computer Science students [104]. To date, most research addressing the 'leaky pipeline' for non-stereotypical students has focused on revealing and challenging the persistent gendered and racialised stereotypes of the discipline, and indeed there is much evidence of racist and misogynistic issues throughout the computing pipeline [65, 79, 102, 105]. However, much of this existing literature takes a narrow view of how students progress through computing careers, with a tendency to assume students move only through conventional direct-entry pathways from high school to university [7]. Recent efforts to broaden/widen participation in computing

at the undergraduate level mean that there are now more students, more frequently from low socio-economic backgrounds and with disabilities, entering computing programmes from a wider range of pathways [7, 9, 43, 70]. Recognising the unique needs of students entering through pathways to widen participation is therefore one necessary focus for computing departments seeking to create diversity and equity in the discipline.

To develop a sense of belonging to computing by feeling accepted and valued as a member of the discipline is increasingly acknowledged as having a positive relationship to student motivation, achievement, persistence, and retention at the undergraduate level [29]. Investigating sense of belonging across students entering university through direct-entry and pathways to widen participation may therefore offer a useful tool for revealing and contextualising the unique experiences of these students. Indeed, existing research has already discovered how students entering institutions in the UK and Ireland via widening participation pathways experience a lower sense of belonging compared to direct-entry school leaving students, and that students on different pathways can experience stronger or weaker shifts in belonging based on uneven levels of support offered across pathways by the institution [69]. This suggests that instead of employing a one-size-fits-all approach, it is necessary for research to be adaptive to the complex factors impacting students entering universities through different routes and from diverse backgrounds [51].

Yet, there is currently insufficient research on how different university admission routes affect students' sense of belonging, specifically in the fields of computing or STEM. To address this gap, we draw on data from our project monitoring sense of belonging in an undergraduate computing programme at a research-intensive higher education institution. Here, we compare sense of belonging among Computer Science undergraduates and students in other schools within the College of Science at the university. Our research questions are:

RQ1: How do measurements of student sense of belonging in the College of Science vary by university entry routes?

RQ2: How do measurements of sense of belonging by university entry routes compare between students in Computer Science and students in other schools in the College of Science?

RQ3: How do students from direct-entry school leaving and combined access routes experience their sense of belonging in university?

4.2 Context

Our university provides numerous entry routes for students. The direct-entry school leaving route is a ‘points’/exam-based entry route for students around 18 years of age with typically no gap between leaving second-level/high school and university. Our university also offers entry routes for international students and widening participation/access routes. The widening participation/access routes include: the Higher Education Access Route (HEAR), a college and university admissions scheme which offers places on reduced points and extra college support to school leavers from socio-economically disadvantaged backgrounds; the Disability Access Route to Education (DARE), a college and university admissions scheme which offers places on a reduced points basis to school leavers with disabilities; students who have completed QQI-FET qualifications (The Quality and Qualifications Ireland (QQI) Further Education and Training (FET) entry routes are designed for students coming through level 5 or level 6 courses from Colleges of Further Education and are seeking a level 8 (Bachelor’s) course. See www.qqi.ie/what-we-do/the-qualifications-system/national-framework-of-qualifications.), University Access Courses (One-year-long, part-time courses designed to prepare adults, who may not have formal qualifications, for successful study at university.), and/or the Open Learning Certificate (A flexible, part-time way of studying at university for those that do not yet qualify for entry to an undergraduate degree, want to get a feel for academic life before starting a full degree or want to upskill in particular areas.), and mature students. We collectively referred to these as combined access routes.

All students who enter the university through a widening participation/access route are eligible for additional support services. A dedicated team of student support specialists works closely with these students to identify and provide necessary support. These support services include financial aid and scholarship programs for low-income students, targeted social support, and disability support accommodations such as exam and classroom accommodations and assistive technologies. Support services are provided at the beginning of the academic year to help students transition into university life smoothly. Students with disabilities can identify themselves through an access route or by contacting the Disability Service directly after enrollment. Students are invited to engage in a Needs Assessment and supports are then agreed upon and put in place. The support services are visible to module coordinators through the online class list system but students are also encouraged to send their Certificate of Support to faculty if requesting specific support. The supports provided are based on the principle of encouraging the

development of autonomous learning skills and strategies.

Our study took place while there is an institutional and national push towards Universal Design which highlights the need to develop university modules for a diverse student population and not make assumptions about learners or their backgrounds/circumstances. The ‘University for All’ initiative is a long-term and whole-institution programme being implemented over a number of years, in line with the university’s EDI strategy and action plan. Some of the initiatives that are being undertaken in the university include the auto-enrollment of all staff in a one-hour online training in Universal Design, two ten-week digital badges on universal design for faculty and professional staff, student training and awareness-raising events and welcome programmes for those coming through access routes to encourage social interactions and making friends.

4.3 Methods

4.3.1 Data collection

We used the same survey responses which were collected through our sense of belonging survey and the detail data collection process is described in section 3.4.

4.3.2 Student sample

All undergraduate students in the College of Science were invited to take part in our survey. 378 students completed the survey from December 2021 to March 2022. Missing values in responses deemed valid (e.g., skipping one Likert-like item) were replaced with the mean score for that item. Invalid responses (e.g., missing multiple items entirely, those from students outside of the College of Science, those from students who were not undergraduates) were removed, leaving 355 valid responses, yielding a response rate of approximately 18%¹.

4.3.3 Statistical and qualitative analysis

To test for statistical significance, we compared the means between groups and utilised Welch’s two-sample t-test (two-tailed), $\alpha = 0.05$.² Thematic analysis was performed on

¹At the College of Science level, the student population over weeks or months is dynamic, but during the period of our survey was approximately 2,100

²Welch’s test is considered more reliable (than Student’s t-test) when the samples have unequal variances and possibly unequal sample sizes [83, 85].

the qualitative responses using the qualitative data analysis software package NVivo. A CSV file containing the survey data was imported into NVivo, and the responses to the two qualitative questions were coded following a process of open, axial, and thematic coding. First, raw data was coded to separate the responses into discrete parts that would capture the meaning of the student responses. Second, codes were categorised and ordered to draw connections and group similar codes together. Third, coding groups were evaluated against the literature to develop the overarching themes in the data. Matrix coding queries were then run to compare the codes for students from different entry pathways and draw out dominant themes for each cohort.

4.4 Results & analysis

Out of the total of 355 students that responded to the survey, the majority, 268 (76%), gained admission to the university through the direct-entry school leaving route, while 61 (17%) entered through combined access routes (Table 4.1). Additionally, there were 20 (6%) students who accessed the College of Science via various international pathways, including Non-EU, Mature Non-EU, International student, UK (A-level), EU or EEA, Mature and EU, and Spain International A-levels. Six (<2%) students were admitted through transfer or re-admission to the college.

For the purposes of this study, we exclusively focus on students admitted through the direct-entry school leaving or combined access routes i.e. excluding the 26 students who entered through international access pathways and transfer or re-admission pathway. Consequently, our study comprises a total of 329 students.

268 students entered the College of Science through the direct-entry school leaving route, 81% were from Science (excluding Computer Science) and 19% from Computer Science. 61 students entered through the combined access routes, 79% from Science and 21% from Computer Science. 113 students (42%) of the direct-entry school leaving students identified as men, 146 (55%) as women, eight (3%) as non-binary, and one (<1%) preferred to not disclose their gender.

26 (43%) of the combined access route students identified as men, 31 (51%) as women, three (5%) as non-binary, and one (<2%) preferred to not disclose their gender.

Intersectionality and minoritisation

For students admitted to the College of Science, 29% of the direct-entry school leaving route students and 48% of the combined access route students identified themselves as

Table 4.1: Distribution of students across the seven Schools by their university entry routes. ‘Sciences’ refers to students in the College of Science who are not Computer Science students.

	Total	School Leaving	Combined Access
All	355	268	61
Sciences	284	216	48
CS	71	52	13

minoritised. Within Computer Science, there were 52 students who gained entry through the direct-entry school leaving route. Among this group, 46% identified as minoritised individuals. Specifically, 16 students identified as women, while eight identified as men. Interestingly, out of the 16 minoritised women, 10 mentioned feeling minoritised due to their gender within their school. Conversely, the men identified factors such as race, nationality, socio-economic status, and physical and mental health issues as their main contributors to their sense of being minoritised. Thirteen students entered Computer Science through combined access routes. Within this group, 38% identified as minoritised individuals. All of these students attributed their sense of being minoritised to factors related to their socio-economic status, and physical and mental health (see Table 4.2).

Table 4.2: Distribution of gender identity and self-identified minoritisation by students’ entry route into the College of Science, Science and Computer Science. M = Men, W = Women, Min = Minoritised, NM = Non-minoritised, NB = Non-binary, ND = Preferred not to disclose, SL = Direct-entry school leaving route, Combined = Combined access routes, COS = College of Science, and CS = Computer Science.

	M	W	NB	ND	Min	NM
COS: SL	113	146	8	1	77	191
COS: Combined	26	31	3	1	29	32
Science: SL	82	126	7	1	53	163
Science: Combined	17	28	2	1	24	24
CS: SL	31	20	1	0	24	28
CS: Combined	9	3	1	0	5	8

RQ1: How do measurements of student sense of belonging in the College of Science vary by university entry routes?

Entry routes to the university play a crucial role in students’ sense of belonging. Our results reveal that students who entered the university through the direct-entry school

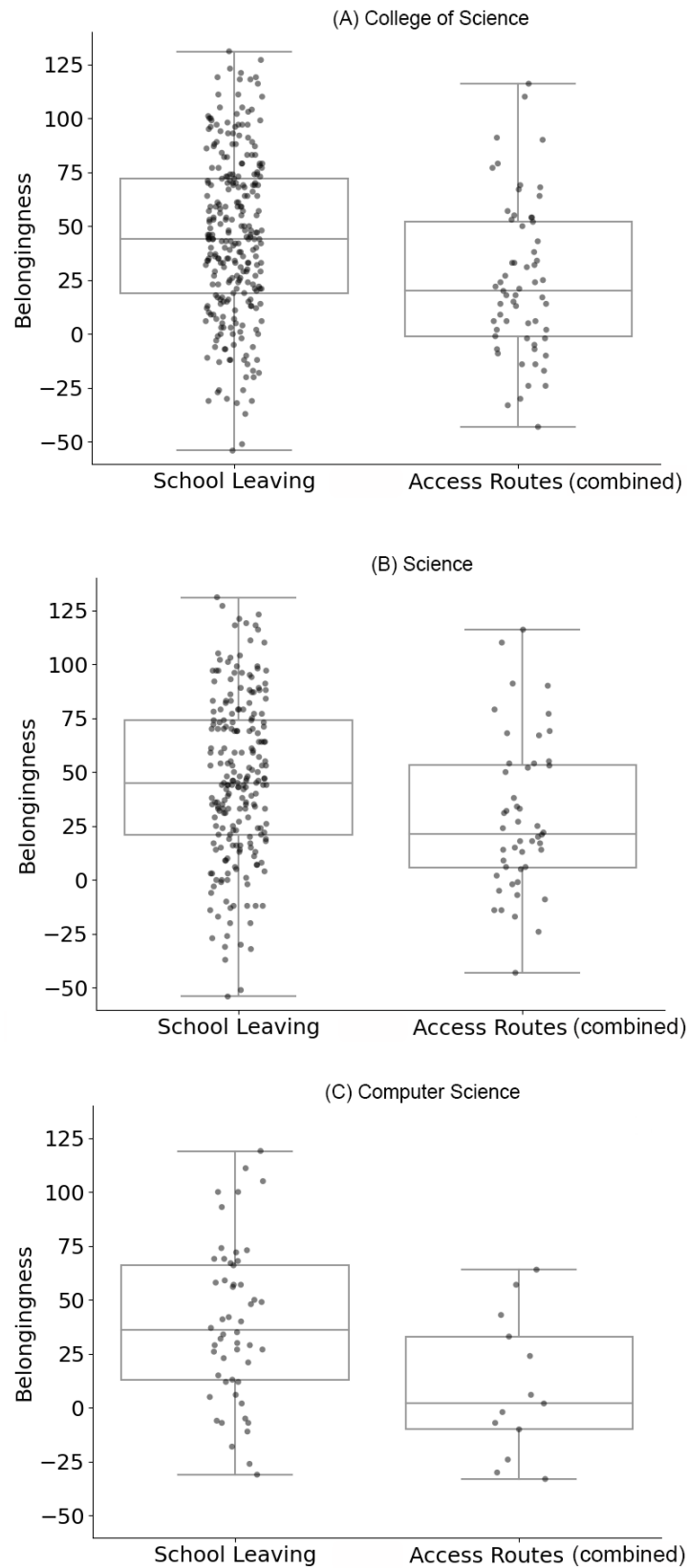


Figure 4.1: Boxplots showing the distribution of belongingness scores for all (A) College of Science, (B) Science, and (C) Computer Science students grouped by entry routes.

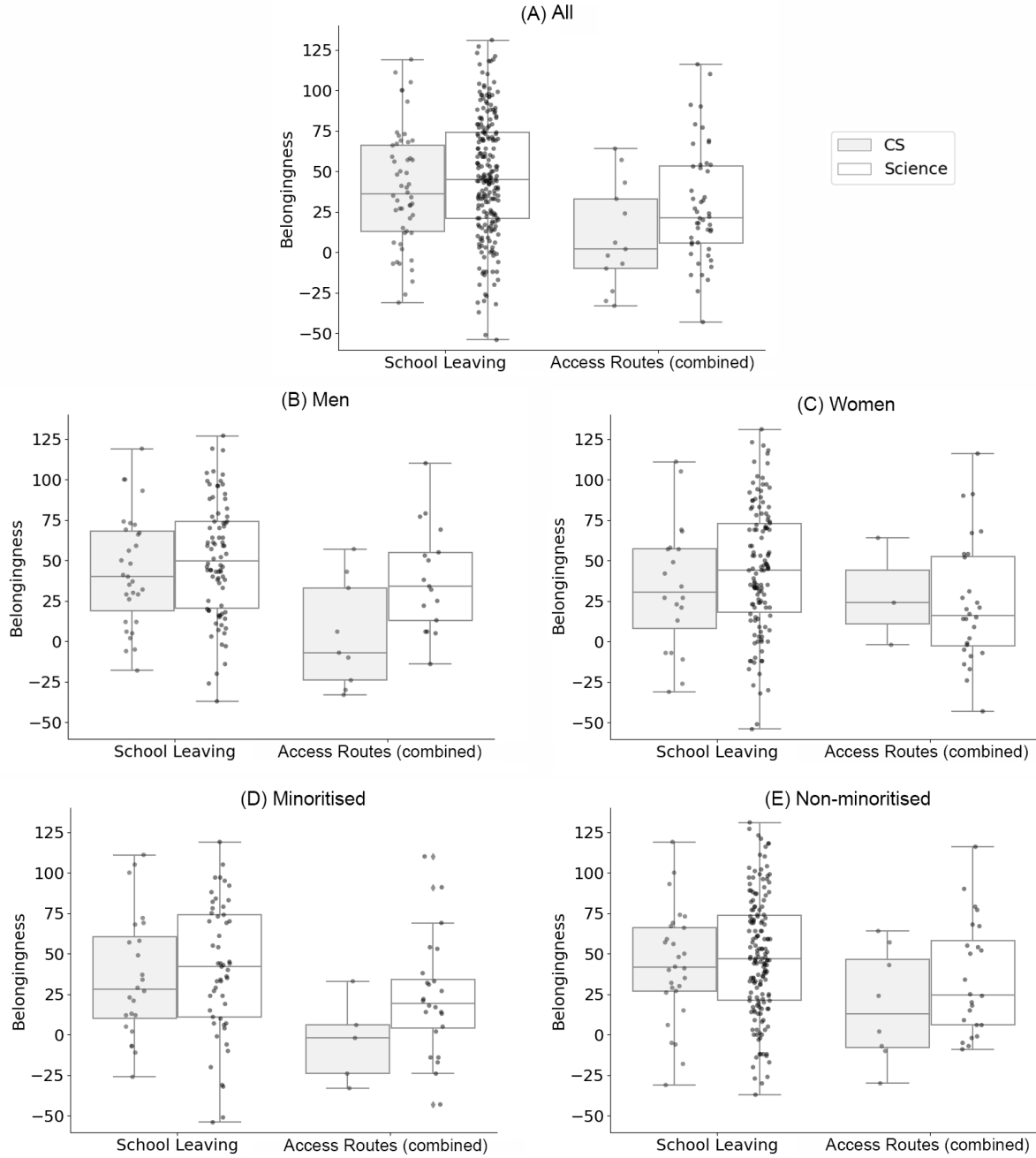


Figure 4.2: (A) Distribution of belongingness scores for all Computer Science (CS) and Science students split by entry route. (B) Distribution of belongingness scores for all men from Computer Science and Science students split by entry route. (C) Distribution of belongingness scores for all women from Computer Science and Science students split by entry route. (D) Distribution of belongingness scores for all self-identified minoritised students from Computer Science and Science students split by entry route. (E) Distribution of belongingness scores for all self-identified non-minoritised students from Computer Science and Science students split by entry route.

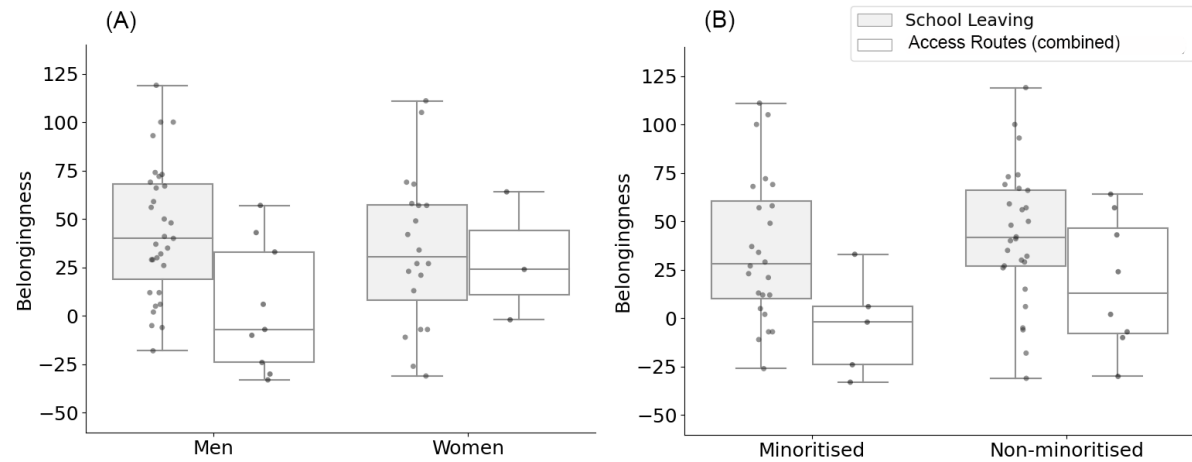


Figure 4.3: (A) Distribution of belongingness scores for Computer Science students grouped by gender and entry routes. There is a statistically significant difference between men and their entry routes, not for women. (B) Distribution of belongingness scores of Computer Science students grouped by minoritisation status and entry routes. Interestingly, there is a statistically significant difference between minoritised direct-entry school leaving and combined access routes entered students but not for non-minoritised students.

leaving route, have a higher sense of belonging compared to students who entered through the combined access routes. Figure 4.1 (A) shows boxplots of the distribution of belongingness for students entering the College of Science through traditional school-leaving entry route ($N = 268$, $M = 45$, $SD = 37$) and those entering via access routes ($N = 61$, $M = 25$, $SD = 35$). The difference between these two groups is statistically significant ($t = 3.99$, $p = 0.0001$).

RQ2: How do measurements of sense of belonging by university entry routes compare between students in Computer Science and students in other schools in the College of Science?

In order to investigate whether university entry routes differed for each group of students, we divided the analysis into two groups: Science and Computer Science students. Results reveal that within Science students, the sense of belonging of students who entered through the direct-entry school leaving route ($N = 216$, $M = 47$, $SD = 38$) is significantly higher ($t = 3.06$, $p = 0.003$) than the students who entered through combined access route students ($N = 48$, $M = 29$, $SD = 35$) see Figure 4.1 (B). Furthermore, similar results were observed in Computer Science. Figure 4.1 (C) shows that within Computer Science, the sense of belonging of students who entered through direct-entry school leaving (N

= 52, M = 39, SD = 36) is significantly higher ($t = 2.91$, $p = 0.008$) than students who were admitted through combined access route ($N = 13$, $M = 9$, $SD = 31$). It is clear that students who entered university through the direct-entry school leaving route have a higher sense of belonging in Science and Computer Science, indicating that the university entry route impacts students' sense of belonging, highlighting the need for universities and policymakers to consider entry routes when designing admissions policies.

Comparison of belongingness between Science and Computer Science students for both entry routes

When comparing the sense of belonging of students from Computer Science ($N = 52$, $M = 39$, $SD = 36$) and Science ($N = 216$, $M = 47$, $SD = 38$) who were admitted to the College of Science through the direct-entry school leaving route, the findings indicated that there is not much difference in the belongingness scores of these two groups, and there are no statistically significant differences between them either ($t = -1.26$, $p = 0.21$). Similarly, for those admitted through the combined access route, there is no statistically significant difference ($t = -1.90$, $p = 0.07$) between the belongingness of Computer Science ($N = 13$, $M = 10$, $SD = 31$) and Science students ($N = 48$, $M = 29$, $SD = 35$) (Figure 4.2 (A)). This indicates that students who entered through the same route, regardless of their school, have similar belongingness although direct-entry school-leaving students scored higher. However, Computer Science students who entered through other combined access routes have a lower mean belongingness score compared to Science. It is clear that the School should consider the effects of various entry routes on student well-being and sense of belonging. Teaching staff and faculty should also be mindful of the potential difficulties that students who enter through combined access routes may encounter and provide them with support to help them feel appreciated and part of the community.

Comparison of belongingness between Science and Computer Science students for both entry routes based on gender and minoritisation

In comparing the sense of belonging of the direct-entry school leaving route students in Computer Science and Science based on gender, the results indicate no statistically significant differences in belonging between men and women in Computer Science or Science (see Figure 4.2 (B & C) and Table 4.3 (Analysis 1 & 2)). However, when comparing the sense of belonging of combined access routes in Computer Science and Science based on gender, the sense of belonging reported by men from Computer Science students is lower than that of men from Science and this difference is statistically significant (see

Figure 4.2 (B) and Table 4.3 Analysis 3), but for women result is not significant (see Figure 4.2 (C) and Table 4.3 Analysis 4). The results indicate that men who enter the university through combined access routes experience a lower sense of belonging when they join the Computer Science program. This is also true for women, although the result is not statistically significant due to the small sample size.

Comparing minoritised students by entry routes between Computer Science and Science shows that the belongingness of minoritised and non-minoritised Computer Science and Science students who entered university through the direct-entry school leaving route do not differ significantly (see Figure 4.2 (D & E) and Table 4.3 (Analysis 5 & 6)). Additionally, minoritised and non-minoritised Computer Science and Science students who entered through other access routes do not differ significantly (see Figure 4.2 (D & E) and Table 4.3 (Analysis 7 & 8)) although, the mean belongingness scores of both minoritised and non-minoritised Computer Science students are lower than those of Science students. This may be due to the smaller sample size of Computer Science students. This result suggests that further research is needed to explore the reasons behind the lower belongingness scores of Computer Science students.

Variations in belongingness across both entry routes by gender and minoritisation in Computer Science

When assessing the belongingness of Computer Science students who were admitted through the combined access route, there is no statistically significant difference between men and women, despite the fact that the mean belongingness score of men is lower than that of women and the number of participants is very small (see Table 4.3 (Analysis 9 & 10)). However, we observed that there is a lower mean belongingness score of men who entered through combined access routes compared to the direct-entry school leaving route and the difference is statistically significant. Whereas, for women, this difference is not significant, possibly due to the relatively small number of men and women participants from combined access routes (see Figure 4.3 (A) and Table 4.3 (Analysis 11 & 12)).

Concerning minoritisation, minoritised and non-minoritised students who entered through the direct-entry school leaving route reported similar belongingness scores. However, minoritised students who entered through the combined access route reported significantly lower levels of belongings compared to non-minoritised students (see Table 4.3 (Analysis 13 & 14)). There is a noticeable difference in belongingness between students who entered through direct-entry school leaving routes and those who entered through combined access routes. This difference is statistically significant for minoritised

Table 4.3: Summary statistical analysis of Computer Science and Science students based on gender, minoritisation and entry routes to the university. M = Men, W = Women, Min = Minoritised, NM = Non-minoritised, SL = Direct-entry school leaving route, Combined = Combined access routes, COS = College of Science, and CS = Computer Science, N = number of participants, M = mean belongingness score, SD = standard deviation.

Analysis	Student_Group	N	M	SD	t-value	p-value	Significant
1	CS_SL_M	31	44	34	0.97	0.34	No
	Science_SL_M	82	51	35			
2	CS_SL_W	20	34	38	1.07	0.29	No
	Science_SL_W	126	44	39			
3	CS_Combined_M	9	4	31	2.5	0.02	Yes
	Science_Combined_M	17	39	31			
4	CS_Combined_W	3	29	27	-0.24	0.83	No
	Science_Combined_W	28	24	37			
5	CS_SL_Min	24	36	37	0.5	0.6	No
	Science_SL_Min	53	41	40			
6	CS_SL_NM	28	43	34	0.8	0.43	No
	Science_SL_NM	163	48	36			
7	CS_Combined_Min	5	-4	23	1.97	0.09	No
	Science_Combined_Min	24	23	35			
8	CS_Combined_NM	8	18	32	1.2	0.25	No
	Science_Combined_NM	24	35	34			
9	CS_SL_M	31	44	34	0.97	0.37	No
	CS_SL_W	20	34	38			
10	CS_Combined_M	9	4	31	-1.12	0.34	No
	CS_Combined_W	3	29	27			
11	CS_SL_M	31	44	34	3.14	0.007	Yes
	CS_Combined_M	9	4	31			
12	CS_SL_W	20	34	38	0.25	0.82	No
	CS_Combined_W	3	29	27			
13	CS_SL_Min	24	36	37	-.7	0.5	No
	CS_SL_NM	28	43	34			
14	CS_Combined_Min	5	-4	23	-1.3	0.22	No
	CS_Combined_NM	8	18	32			
15	CS_SL_Min	24	36	37	2.8	0.02	Yes
	CS_Combined_Min	5	-4	23			
16	CS_SL_NM	28	43	34	1.8	0.99	No
	CS_Combined_NM	8	18	32			

students, which suggests that their access routes have a strong impact on their sense of belonging. For non-minoritised students, there is also a difference in belongingness between these two types of access routes, but it is not statistically significant. Non-minoritised students who entered through the combined access routes have a lower sense of belonging compared to those who entered through the direct-entry school leaving routes (see Figure 4.3 (A) and Table 4.3 (Analysis 15 & 16)).

RQ3: How do students from direct-entry school leaving and combined access routes experience their sense of belonging in university?

Our statistical analysis has shown that students who enter the university through combined other access routes, such as DARE, HEAR, QQI-FET, the open learning certificate, and mature students experience a lower sense of belonging compared to those who entered through the direct-entry school leaving route. Student comments regarding their sense of belonging in the College of Science reveal insights into the distinct concerns of combined access route students that contextualise their lower sense of belonging.

When analysing the qualitative data from combined access route students, key themes emerge around validation, representation, and alienation. Combined access route student's understanding of belonging is prominently underpinned by the idea that belonging is something that is earned through achievement. One open learning certificate student in science expresses how this limits their feeling of validation as a STEM student as they 'don't necessarily feel part of the STEM community... because I haven't accomplished anything yet, and still feel like I have so much to learn'. Similarly, a DARE science student describes how 'as a student who didn't get the CAO points for my course, I often feel like I'm not intelligent enough to be in it,' and a QQI/FET science student further reflects on how they 'feel like I haven't properly earned my place'. In these comments, the linking of belonging to achievement and perceived intelligence is underpinned with an understanding that direct-entry school leaving students will have always already achieved more than combined access route students, creating a hierarchy of belonging across the cohorts. This hierarchy plays out in the interpersonal relations between students, where one HEAR Science student describes how their belongingness is negatively impacted by 'people being obnoxious about what points they got in the leaving cert and obnoxious about their grades in college'. This evidences an atmosphere on campus that alienates students from combined access routes who 'feel like [they] don't

belong surrounded by people who do belong.’

When combined access route students do not recognise their admission into the university as being an equal achievement of entry through the direct-entry school leaving route, this creates a precarious and uncertain environment for them on campus. For example, one QQI/FET student commented on how they felt ‘like I’m here out of circumstances... and now I’m here and I haven’t a clue what to do with myself’. The student goes on to describe how it ‘seems like my time in my course is suspended on a thread and past due’, illustrating the vulnerability of the student’s sense of belonging. This experience of ‘suspended’ belonging is shared by a DARE science student who explains how entering the university through DARE ‘has given me imposter syndrome from the start’. For those students who identify as a minority, imposter syndrome due to their entry route is further reinforced by exclusions due to their minoritisation. A Black woman who entered science through QQI-FET discussed how a lack of representation of diverse students on campus made her feel like there was no place or future for her in STEM: ‘I don’t see a lot of people that look like me. But there’s nothing you can do about it other than encourage more Black girls to join. Convince them that there is career for them in STEM. I had to convince myself and I still don’t see it. It’s no one’s fault. It’s just the way society has made some things but it must be broken.’ In this comment, the student’s belief that her low sense of belonging is ‘no one’s fault’ shows a failure in the college to highlight the collective responsibility of fostering a sense of belonging in an inclusive environment.

Issues of representation of diverse students coming through combined access routes occur alongside limits in awareness of the unique backgrounds of these students. The alienation felt by combined access route students is further reinforced through interactions with teaching staff and faculty. As one mature student explains, mature students ‘are really overlooked in science and are forgotten about constantly’. One DARE science student explains how ‘instructors don’t always realise that things that are easy or straightforward to them are not for everyone’ coming through, and that ‘has a negative impact on my perceived ability and belonging’. A mature science student explains how this is due to lectures presuming an existing knowledge within students that favours direct-entry school leaving students, saying that ‘a lot of the time in science you hear ‘this is leaving cert material’ but mature students don’t come that way so we’re left out’. A HEAR student further describes how a lecturer ‘practically mocked me for asking a question about the work’. This illustrates a campus environment where exclusions and low belonging are created from assumptions that professors make about students

that centre around the experiences of direct-entry school leaving students. It should be noted that this is not the policy of the university but rather a practice of some faculty who do not follow the guidelines sent each semester. These alienating assumptions are not only surrounding previous knowledge but also the socio-economic situations of the students. One HEAR science student 'one of the professors laughed at the idea of having a part-time job during the term. [This] made me feel like an outsider as I don't have a choice about working during the term'. Combined access route students from low socio-economic backgrounds are therefore shown to have needs which may be different from the average direct-entry student, and belonging is impacted when these are not met.

Most prominent in our data is a failure to recognise the needs of combined access route students. A HEAR science student discussed how some lecturers 'constantly have the attitude that you're trying to get out of something and lying if you claim you can't attend [a class or lab because you] are sick'. Another student further states how 'every term I feel like I have to beg each lecturer to have compassion and do me the favour of making their module accessible'. This represents how students feel burdened with a responsibility to ensure their disability needs are met, where it is also described how 'some lecturers want me to explain my private medical diagnosis to them which I don't want to do. I feel like I have to prove myself every term'. Not only do these comments show a lack of awareness of hidden chronic illnesses, but they also illustrate the persistence of instances which lower sense of belonging. Within this environment, a mature student 'considered not coming back' and only decided to persist because they understood that, unlike others, this was their 'only chance at a degree due to family money situation and really enjoy content once made accessible'.

Moreover, our data from the direct-entry school leaving students showed a recognition from some students of the privileges and advantages that come with entering university through the direct-entry school leaving route. One student who reported a high sense of belonging contended that this was 'probably [positively impacted by] the fact that I'm a white male Irish student who came through the Leaving Cert system who is very confident in myself and also a very extroverted'. Yet, leaving cert students are not a homogenous group and while their cohort experiences a higher mean sense of belonging, some comments from direct-entry school leaving students reveal similar concerns that resonate with those from combined access route students. For example, a woman science student in her first year explains that while 'I felt reasonably confident in my abilities at leaving cert and I enjoyed maths and physics... when I started first year [at university],

I was made speechless by the content of my modules.’ She describes how she ‘feels like everyone around me has so much more skill and natural talent than I do. There have been countless amount of times where I have compared myself to my classmates, basically telling myself that they’re all better than me and that I’ll never reach their level. On a daily basis I feel like I don’t belong in my course and this has led me to stop attending certain lectures and tutorials, which is something I’m not proud of and makes me feel even worse.’ This comment reveals the resonances between combined access routes and direct-entry school leaving students with a low sense of belonging. This is further evidenced when another direct-entry school leaving student describes how they ‘see so many people in my class really struggling with the huge jump for secondary to university’ and how direct-entry school leaving students also ‘need more help’ to adjust to university. This suggests that efforts to increase the sense of belonging for combined access route students should also have positive impacts on belonging for direct-entry school leaving students who experience low belonging, particularly women and other minoritised students. While a comparison between combined access routes and direct-entry school leaving students is useful for revealing significant differences in sense of belonging, it is important to recognise that all students would benefit from initiatives to improve belonging for combined access route students on campus.

Common themes emerge across all entry routes, emphasising the importance of socialisation, building friendships, peer support, and more opportunities for social interaction. Students frequently mention issues related to large class sizes and difficulties with course content. Women, regardless of whether they identified as minoritised or not, express a desire for greater diversity, particularly more representation of Black women and female role models. Many students reported negative impacts to their sense of belonging due to the COVID-19 pandemic, and the housing crisis in Ireland which can influence their living arrangements far from campus, creating lengthy commutes that are difficult to manage around busy class schedules and heavy, time-intensive workloads. A common thread in students’ comments is the impact of socio-economic background on their sense of belonging, often due to part-time work and time constraints affecting their ability to socialise and participate in college activities. Many students reported challenges with mental health and stress and requested more accessible support and counselling services.

Student suggestions for improving sense of belonging revolve around the need for increased social events, inclusive college activities, women-centric events in Computer Science, more societies and seminars, enhanced group work opportunities, recognition of

women in STEM achievements, and a reduction in isolation between Computer Science and other schools within the university.

These themes and the groups of students experienced that informed our discussion on them are summarised in Table 4.4

Table 4.4: The themes of the discussion of RQ3

Theme	Experienced by students
Validation, representation and alienation	Combined access routes students
Lack of representation	Combined access routes students
Campus environment	Combined access routes students
Very confident	Direct-entry school leaving students
Importance of socialisation	All entry routes students
Building friendships	All entry routes students
Need peer support	All entry routes students
Need more opportunities for social interaction	All entry routes students

4.5 Discussion

Our research analysed the influence of student entry routes on their sense of belonging. Our primary aim was to investigate whether there are variations in the sense of belonging among Computer Science students compared to students in other Science disciplines based on entry route. In answering RQ1, we discovered that students who entered the university through a direct-entry school leaving route and those who entered through combined access entry routes felt a statistically significantly different sense of belonging. This supports findings from Li and Jackson (2023) [51] that students from combined access routes have lower retention outcomes and poorer course completion, recognising the relationship between belonging and student retention. This is different from what McNeil et al. (2016)'s [59] study found about engineering students, which highlights how experiences of belonging can be discipline-specific. However, our results for RQ2 further revealed that the significantly lower sense of belonging of combined access route students was particularly evident among Science students, with a statistically significant difference between the two groups across the multiple schools in the College of Science. The results were also consistent among Computer Science students. This

seems to suggest that differences in belonging based on entry route are influenced more by institutional than discipline-specific factors.

However, we also sought to identify factors which might influence sense of belonging for combined access route students, who may also identify as minoritised because of their gender, race, sexuality, neurodiversity, disability, socio-economic background, religion, and/or other social factors. In this part of the analysis for RQ2, we focussed on gender and observed that while students who enter Computer Science or Science through the same route tend to experience a similar sense of belonging regardless of their gender, there are significant gendered differences in belongingness by discipline for men entering through combined access routes. Combined access routes entry students in Computer Science have a lower sense of belonging than both direct-entry school leaving students in the school and combined access route students in the other science schools combined, and this is greater for men. These results suggest that it is the combination of entry route and gender that plays a more significant role in influencing student's sense of belonging than gender alone. This finding has the potential to shape how universities can create gender-inclusive environments by being attuned to how entry pathways shape student belonging across genders.

Findings of our qualitative analysis (RQ3), provide insights into how universities can better support combined access route students, that can inform the development of current and future institutional universal design initiatives. The literature pointed to the level of institutional support received as being the main influence to ameliorate the lower sense of belonging of combined access route students [51]. Indeed, our findings also point to structures of support as impacting combined access route students' belongingness, although this was primarily for minoritised students who seek support from services relating to their disability. However, the issues discussed by our survey respondents are not only in relation to the disability services themselves, but also how disabilities are viewed and understood by teaching staff, faculty, and other students, where there is a lack of recognition of accessibility needs for HEAR and DARE students. This informs a key insight from our qualitative data, that while improving support channels to navigate the university structures might be beneficial for increasing sense of belonging for combined access route students, more crucial is shifting the atmosphere of a hierarchical culture on campus that produces direct-entry school leaving students (assumed as being able-bodied, and of school leaving age etc.) as the norm. Our findings indicate that combined access route students often associate their sense of belonging with their academic achievements due to competitive disciplinary cultures, leading to the experience of imposter syndrome.

For minoritised students, imposter syndrome is compounded by the lack of representation and diversity on campus, causing students to feel overlooked and out of place. Combined access route students also commonly cite interpersonal relationships and expectations of them by other students and staff as shaping their sense of belonging. Similar to findings from the literature that show a positive correlation between peer support and sense of belonging for all students [8], our results also show that socialisation, inclusion in groups with peers, and encouragement from more senior students helped students to feel valued and had a positive impact on their sense of belonging.

It is important for universities to create a welcoming and inclusive environment for all students, regardless of their background or academic history. This can be achieved in part through initiatives such as diversity and inclusion training for staff and students, and promoting a culture of respect and understanding. However, staff and faculty being inclusive is different to peers being inclusive and it can be challenging for university departments to engage with students in terms of training and awareness. At our university, there is work in progress to address this during student orientation, highlighting for all students their role in a 'University for All'.

4.6 Limitations

The results of this study, which was conducted in one university, may not be immediately/directly applicable to all institutions. However, many of the themes and challenges that we discuss here are of concern to most universities. Investigating these issues is an important step towards developing targeted initiatives, policies, and actions to address them. Our response rate of approximately 18% warrants statistical analysis, as does the near-normal distribution of belongingness scores (see Figure ??). There is the possibility that our responses include a difficult to determine response bias. For instance, students who feel strongly about their sense of belonging and related issues may have been more likely to respond to the survey. However, the near normality of the distribution of belongingness scores provides some evidence that any response bias present has not had an undue effect on the results.

4.7 Conclusions & future work

This study explored the impact of entry routes on students' sense of belonging in higher education. It revealed significant differences in belongingness between direct-entry

school leaving and combined access route students in the College of Science, separately in Science, and even in Computer Science. Student feedback emphasised the need for more social activities, inclusivity, and support, particularly for women in Computer Science. These findings highlight the importance of creating inclusive environments and supporting students' academic and social well-being. This can be achieved in part through initiatives such as diversity and inclusion training for staff and students, and promoting a culture of respect and understanding.

Future research aims to compare the sense of belonging among students across all schools and colleges in the university. We welcome schools and colleges who are interested in collaborating with us to understand the impact of university entry routes on their students. In addition, future research will broaden its scope by including multiple universities, offering a more comprehensive understanding of students' experiences with university access routes. This will involve annual surveys to track changes in students' feedback regarding their entry pathways and the impact of targeted initiatives to improve the sense of belonging of all students.

Acknowledgement

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DISCUSSION, CONCLUSION AND FUTURE WORK

Discussion

Sense of belonging refers to the feeling of being accepted and valued by a group or community. It is an important factor in a student's academic life as it can influence their motivation, persistence, and overall mental health and well-being. When students feel a sense of belonging, they are more likely to engage in academic activities, seek help when needed, and have a positive attitude towards their education. Belongingness has been shown to be lower in minoritised students due to various factors such as gender, race, nationality, socio-economic status, religion, and disability. These students may feel excluded or discriminated against, which can negatively impact their academic performance and mental health. It is important for educators and institutions to create a welcoming and inclusive environment for all students, regardless of their background or identity. This can include promoting diversity and cultural awareness, providing support services, and addressing any instances of discrimination or bias.

The primary objective of this research was to gain an understanding of undergraduate sense of belonging in computing. To answer my first research question, *How has sense of belonging been studied in undergraduate computing?*, I conducted a comprehensive literature review (Chapter 2). The review focused on the sense of belonging among undergraduate computing students in research published between 2012 and 2022, following the PRISMA guideline. After applying a set of inclusion and exclusion criteria, 22 articles that met the final consideration criteria were reviewed. Valuable

insights were discovered, including theoretical and methodological similarities, in the growing but limited research field on sense of belonging. Although belonging does not have a universal definition, it is consistently associated with acceptance, inclusion, value, and connection in academic or social contexts. The literature highlights that sense of belonging varies among different student groups, including gender, sexuality, racially minoritised groups, and those with varying academic pathways. The literature also shows that there is still a gender gap in computing, and more research is needed to address this issue and improve the sense of belonging for undergraduate computing students. Researchers have emphasised the importance of examining intersectionality and exploring how multiple identities intersect.

To contribute to the existing literature, my second research question focused on *How does sense of belonging vary by gender identity and minoritisation?* To answer RQ2, I compared the sense of belonging of computing students with that of students in other science disciplines, considering the role of gender identity and minoritisation (Chapter 3). Previous research indicates that women and other groups including Black and Latinx students often experience a lower sense of belonging. The limited literature on LGBTQIA+ women suggests a higher likelihood of considering leaving their program due to a lack of belonging. However, the study reveals no statistically significant difference in overall belongingness across genders. Nevertheless, minoritised students experience statistically significantly lower belongingness, which varies by gender. While non-minoritised women show similar belongingness to men, 34% of minoritised women, particularly Black women, attribute their minoritisation to race. Women of colour, especially Asian or Indian women, link minoritisation to age, gender, LGBTQIA+ membership, or socio-economic factors, with race as a secondary concern. Interestingly, Black and Indian/Asian women demonstrate similar belongingness, while White/European women, primarily minoritised due to LGBTQIA+ membership, gender, disability, and socio-economic factors, exhibit lower belongingness. Additionally, Computer Science students' belongingness is significantly lower than other Science students, with variations across Science disciplines by gender and minoritisation.

According to the existing literature, students' sense of belonging can vary depending on their academic pathways/routes and student groups. However, there is currently insufficient research on how different university admission routes affect students' sense of belonging, specifically in the fields of computing or STEM. To address this gap, my third research question focused *How does sense of belonging vary by university entry routes?* (Chapter 4). I analysed and compared the measurements of students' sense of belonging

in the College of Science based on university entry routes. The study examines how students' sense of belonging varies depending on whether they entered the University through a direct-entry school leaving route or other access routes. Findings indicate that students who entered through the direct-entry school leaving route have a higher sense of belonging compared to those who entered through combined access routes. Additionally, I explored variations in belongingness across entry routes by gender and minoritisation status. I found that there is no significant difference in belongingness between men and women admitted through the direct-entry school leaving route or combined access routes. However, there is a significant difference in belongingness between men and women who entered through the direct-entry school leaving route compared to those who entered through combined access routes. Examining factors influencing belonging for combined access route students, I discovered gendered differences, especially in Computer Science. Men entering through combined access routes in Computer Science reported a lower sense of belonging compared to their counterparts in other science schools or direct-entry school leaving students in Computer Science. This intersection of entry route and gender plays a crucial role in shaping belonging.

Student comments highlight the importance of sense of belonging and promoting diversity. Lack of representation, particularly among faculty, and the need for more diverse role models are major concerns. The result indicates that peer relationships and social interaction emerge as key contributors to a positive sense of belonging. Students emphasise the need for the College of Science to create opportunities for socialising, especially in large classes. The impact of the COVID-19 pandemic on social interactions potentially contributes to lower belongingness in upper-year students and challenges related to mental health, finances, and work obligations, underscore the complex factors influencing belonging. The inability to afford to socialise and live on or near campus further affected belongingness negatively. Positive influences include shared struggles by peers and professors and support from resources like the mathematics support centre and peer mentors.

Qualitative analysis also emphasises the significance of institutional support, especially for combined access route students identifying as minoritised. The constant pressure to prove oneself and a lack of confidence is often linked to combined entry routes and perceived inadequacy compared to peers. A cultural shift on campus, addressing imposter syndrome, and fostering inclusivity is crucial for improving belonging. Overall, the comments underscore the complex interplay of social, academic, and personal factors in shaping students' sense of belonging. Creating an inclusive environment through

diversity training and a culture of respect is essential. Ongoing efforts to engage students during orientation reflect the commitment to establishing a 'University for All', aiming to enhance belonging among diverse student groups.

Conclusion

My research aimed to investigate the dynamics of belongingness among students at the UCD College of Science, with a specific focus on the field of Computer Science. Through my research, I discovered valuable insights that shed light on the nuances of belongingness. Although I observed no significant differences in belongingness between genders, I found that minoritised students experienced considerably lower levels of belongingness than others, with variations based on gender. Notably, the study revealed that Computer Science students reported the lowest mean belongingness in the College of Science, which highlights the unique challenges faced by these students within the discipline.

I also examined the impact of different entry routes on belongingness, and my findings revealed that direct-entry school leaving students and combined access route students experienced significant differences in belongingness. The feedback received from students highlighted the importance of social activities, inclusivity, and support, particularly for women in Computer Science. These findings emphasise the need to create inclusive environments that foster a sense of belongingness among all students, enhancing their academic and social well-being.

Future work

The feedback provided by students in the survey has brought to light important issues that need to be investigated further. The goal is to eliminate the negative impact of minoritisation and gender identity on students' sense of belonging and the negative impact of university entry routes. To achieve this, my future research will not be limited to the College of Science, but will also encompass all Schools and Colleges within the University. Additionally, I will collaborate with other universities to gain a broader understanding of students' experiences. In the future, I plan to conduct an annual survey to track changes in students' sense of belonging and conduct a longitudinal study. Based on the research findings, I will develop a set of recommendations to enhance students' sense of belonging. These recommendations will be put into action, and their effectiveness

will be evaluated through annual surveys. I believe that this approach can also be useful to other computing departments facing similar challenges.



SURVEY ITEM

A.1 SoB Survey items utilised by the literature review articles in Chapter 2

Two-item SoB survey questions used by Stout & Wright (2016) [97]

1. “I do not feel welcomed in the computing community”
2. “I do not feel like I fit in the computing community”

Three-item SoB survey questions used by Sax *et al.* (2018) [87], and Blaney & Stout (2017) [10]

1. “I feel like I belong in computing”
2. “I feel like an outsider in the computing community”
3. “I feel welcomed in the computing community”

Three-item SoB survey questions used by Blaney *et al.* (2022) [9], and Blaney & Barrett (2022) [8]

1. “I feel like I belong in computing”
2. “I do not have much in common with other computing students”
3. “I feel welcomed in the computing community”

Three-item SoB survey questions used by Lewis *et al.* (2019) [48], and Nguyen & Lewis (2020) [66]

1. "I feel like I belong in computing"
2. "I see myself as a computing person"
3. "I feel like an outsider in the computing community"

Four-item SoB survey questions used by Krause-Levy *et al.* (20221) [45], and Agarwal *et al.* (2022) [1]

1. "I feel accepted in this class"
2. "I feel comfortable in this class"
3. "I feel supported in this class"
4. "I feel like I don't belong in this class"

Eleven-item SoB survey questions used by Geller & Walker (2022) [26]

1. "I enjoy going to school"
2. "The institution has useful resources"
3. "I feel comfortable reaching out to non ECS professors"
4. "I feel connected and supported by my peers"
5. "I feel comfortable working with peers"
6. "I have at least one friend"
7. "I feel comfortable reaching out to ECS professors"
8. "Faculty expressed interest in me as a person"
9. "I feel there is a sense of community here"
10. "I wish I selected another major"
11. "Intend to stay in my major"

30-item SoB survey questions used by Mooney & Becker (2020, 2021) [62, 63], and Moudgalya *et al.* (2021) [64]

1. "I feel that I belong to the computer science community"
2. "I consider myself a member of the computer science world"
3. "I feel like I am part of the computer science community"
4. "I feel a connection with the computer science community"
5. "I feel accepted"
6. "I feel respected"
7. "I feel valued"
8. "I feel appreciated"
9. "I feel disregarded"
10. "I feel neglected"
11. "I feel excluded"
12. "I feel insignificant"
13. "I feel at ease"
14. "I feel anxious"
15. "I feel comfortable"
16. "I feel tense"
17. "I feel nervous"
18. "I feel calm"
19. "Even when I do poorly, I trust my instructors to have faith in my potential"
20. "I trust my instructors to be committed to helping me learn"
21. "I have trust that I do not have to constantly prove myself"
22. "I trust the testing materials to be unbiased"
23. "I wish I could fade into the background and not be noticed"

24. "I try to say little as possible"
25. "I enjoy being an active participant"
26. "I wish I were invisible"
27. "I feel like an outsider"
28. "I feel like I fit in"
29. "I feel content"
30. "I feel inadequate"

Two-item belongingness uncertainty survey questions used by Hohne & Zander (2019a, b) [35, 37]

1. "Sometimes I feel that I belong to this study program, and sometimes I feel that I don't belong to this study program"
2. "When things don't go well, I often think that maybe I don't belong to this study program"

Three-item intellectual sense of belonging survey questions used by Stout & Blaney (2017) [95]

1. "Within your computing department and/or classes, how often do you feel that: people tend to attribute your success to special treatment or luck rather than to your competence?"
2. "Within your computing department and/or classes, how often do you feel that: You are 'talked down to' by classmates, instructors, or advisors?"
3. "Within your computing department and/or classes, how often do you feel that: Your ideas or opinions are minimised or ignored?"

Five-item intellectual sense of belonging survey questions used by Holanda *et al.* (2020, 2021) [39, 40]

1. "Do you believe that your classmates think that you are not smart enough for your major?"

2. “How many study hours have you spent on the course outside the classroom, by week?”
3. “Do you think that you need more hours of study than your friends?”
4. “Do you think that your efforts were rewarded (study hours/grade)?”
5. “How often have you felt that you had a great idea that was ignored by your friends?”

A.2 Survey item utilised in Chapters 3 and 4

Demographic questions:

1. What is your gender? (This refers to the gender you identify with. Note, gender non-binary is a person who does not identify exclusively as male or female.) *S* (*Woman / Man / Non-binary / Prefer not to disclose / Prefer to self-describe*) plus open answer field (*S* denotes selection from a list of options (if an open “other” field was present it is noted))
2. How do you define your race/ethnicity? *O* (*O* denotes open (free) text entry.)
3. Do you consider yourself part of a minority in your School because of your gender, age, race, disability, ethnic origin, religion, sexual orientation, civil status, family status, membership of the Traveller community or socio-economic status, or for any other reason? *Y/N* (*Y/N* denotes Yes/No plus open text field if Yes.)
4. If you said yes to the last question, what minority group(s) do you identify with? *L* (*L* denotes Likert-like items (1 lowest → 5 highest))

Background questions:

1. What School are you in? *S*
2. What stage are you in? *S*
3. How much do you interact socially with other students in your School? *L*
4. In your opinion, how much does success in STEM depend on inherent ability i.e. it is something you are born with? *L*

5. How much do you enjoy problem solving? *L*
6. How confident were you in your maths abilities before joining UCD Science? *L*
7. How confident are you in your maths abilities now? *L*
8. Are you a member of any UCD clubs or student societies, for example, Women@STEM, Women@CompSci, UCD Biological Society, International Students Society, LGBTQ+ Society? *Y/N*
9. What was your access route into UCD? *S*

Sense of belonging questions: For each item, participants rated their agreement on an 8-point Likert-like scale (1 strongly disagree → 8 strongly agree).

18 positively-framed questions:

1. As a student in the UCD College of Science [I feel that I belong to the STEM community.]
2. As a student in the UCD College of Science [I consider myself a member of the STEM world.]
3. As a student in the UCD College of Science [I feel like I am part of the STEM community.]
4. As a student in the UCD College of Science [I feel a connection with the STEM community.]
5. As a student in the UCD College of Science [I feel accepted.]
6. As a student in the UCD College of Science [I feel respected.]
7. As a student in the UCD College of Science [I feel valued.]
8. As a student in the UCD College of Science [I feel appreciated.]
9. As a student in the UCD College of Science [I feel like I fit in.]
10. As a student in the UCD College of Science [I feel at ease.]
11. As a student in the UCD College of Science [I feel content.]
12. As a student in the UCD College of Science [I feel comfortable.]

13. As a student in the UCD College of Science [I feel calm.]
14. As a student in the UCD College of Science [I enjoy being an active participant.]
15. As a student in the UCD College of Science [I trust the testing materials to be unbiased.]
16. As a student in the UCD College of Science [I have trust that I do not have to constantly prove myself.]
17. As a student in the UCD College of Science [I trust my instructors to be committed to helping me learn.]
18. As a student in the UCD College of Science [Even when I do poorly, I trust my instructors to have faith in my potential.]

12 negatively-framed questions:

1. As a student in the UCD College of Science [I feel like an outsider.]
2. As a student in the UCD College of Science [I feel disregarded.]
3. As a student in the UCD College of Science [I feel neglected.]
4. As a student in the UCD College of Science [I feel excluded.]
5. As a student in the UCD College of Science [I feel insignificant.]
6. As a student in the UCD College of Science [I feel anxious.]
7. As a student in the UCD College of Science [I feel tense.]
8. As a student in the UCD College of Science [I feel nervous.]
9. As a student in the UCD College of Science [I wish I were invisible.]
10. As a student in the UCD College of Science [I feel inadequate.]
11. As a student in the UCD College of Science [I wish I could fade into the background and not be noticed.]
12. As a student in the UCD College of Science [I try to say as little as possible.]

Two open ended questions:

APPENDIX A. SURVEY ITEM

1. Are there ways that you think that Sense of Belonging might be improved in your School and/or the College of Science? *O*
2. Is there anything that has positively or negatively impacted your Sense of Belonging to your School and/or the College of Science? *O*

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