BELONGING AND IDENTITY IN STEM HIGHER EDUCATION

EDITED BY

CAMILLE KANDIKO HOWSON
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Introduction

Camille Kandiko Howson and Martyn Kingsbury

Our goal for this book is to celebrate, promote and provide a critique of belonging in Science, Technology, Engineering and Mathematics (STEM) higher education. We offer 17 chapters, a compilation of theoretically grounded empirical research, conceptual analysis and case study contributions, to explore what is unique about STEM educational environments. Leading scholars, teachers, practitioners and students explore belonging and identity in STEM fields, and how these are impacted by wider sector and disciplinary changes and by the post-Covid-19 pandemic higher education context. The book explores the role of STEM pedagogies in facilitating belonging, variable impacts across student characteristics, and the particular experiences STEM students face in their higher education studies. Three parts explore the notion of belonging (and what it is not to belong), address the role of student identities in supporting and challenging belonging, and present evidence-based findings on how belonging and inclusive excellence can be supported in STEM fields. The book is grounded in offering examples from research to apply in practice for teachers, academics, students and those leading and supporting STEM higher education.

Student enrolments in STEM are rising and are widely promoted by governments looking to develop future generations of scientists and innovators. While education, research and development in STEM are promoted for their innovation and economic potential, there are wide variations in students' experiences, well-being, sense of belonging and feeling part of a community. Decades of efforts to promote diversity and inclusion have had less success than hoped and inequalities remain in access, progression and success in STEM fields, as well as in academic STEM careers. Much of the current literature and policy effort focuses on outreach and admissions: getting diverse students interested in, prepared for, and qualified to enter, STEM courses. Awarding gaps, differential outcomes and student survey feedback across a wide range of characteristics show that getting students in is not enough; students' experiences on their courses, in their institutions and in their engagement with the wider community matter as well. Enabling equitable outcomes is fundamental to expanding and diversifying STEM fields in order to better equip society to tackle the complex problems we all face.

In this book we focus on the STEM context. Across disciplines, STEM courses are often seen as more demanding, competitive and highly structured, leaving students with fewer opportunities to customise their educational experience or make connections across their institution. As noted in Chapters 11 and 16, we include medicine in our discussion of STEM (but use the more common STEM abbreviation, rather than STEMM, throughout). Medical student training has significant overlap with other STEM fields, particularly biology and life sciences, and is increasingly interrelated with broader STEM fields through bioengineering and the use of artificial intelligence (AI) in health care.

In *Belonging and Identity in STEM Higher Education* we draw on mathematical and scientific ways of thinking and research specifically in STEM fields to explore student and staff identities and belonging. The book highlights current research, ongoing initiatives, large-scale efforts and localised practices that explore how to enhance and support belonging in STEM, and how identities are shaped and nurtured in STEM contexts. Throughout, we highlight the integration of staff and student belonging and identity, with a selection of chapters focusing on each as well as several that bring them together, particularly through partnership projects and co-designed activities. We take a critical lens, exploring how students may prefer not to belong, or strategically choose not to identify closely with their STEM educational experience. Through evidence-based chapters, case studies and practical examples, this book sets a new agenda for research on belonging in STEM higher education, taking an intersectional approach to identity, including neurodiversity.

Overview of Belonging and Identity in STEM Higher Education

The following chapters detail how students develop their STEM identity and agency towards belonging and not belonging, and how belonging can be supported. Part I explores 'What is, and is not, belonging?'. This part explores the efforts that higher education institutions make to address a sense of belonging and what it means to belong in STEM fields. How students are welcomed and encouraged to feel part of their course is considered. More critical questions are asked about what it means not to belong, and how staff and students can have agency to choose not to belong, and where belonging may not always be a positive experience. As STEM fields adopt new pedagogical approaches, students have new responsibilities and staff take on new roles.

Chapter 1 argues that the abstract, mathematical and logical ways of thinking present in STEM can provide a basis for belonging in STEM, going beyond socio-demographic characteristics. This STEM identity is linked with how one sees the world and interacts with others. Examples of STEM ways of thinking in practice show how this idea can be the basis of staff and student engagement, authentically collaborating through their disciplinary ways of thinking. In Chapter 2 Sheena Hyland applies a complementary philosophical lens to the exploration of belonging. The theme of hospitality, and the tensions of 'guest' and 'host' this concept raises, are a useful way to consider who is welcomed into STEM communities and who feels part of them already. The notion of a guest – welcomed but not feeling or being 'at home' – offers a critical view of belonging. Ong et al.'s (2017) 'counterspaces' are referenced as sites of refuge for underrepresented students. This theme is carried forward in Chapter 4 by Murray et al., who address not belonging and consider students who actively choose not to belong (Gravett & Ajjawi, 2022; Guyotte et al., 2021;). It offers an important reminder that belonging can be an exclusionary practice for some individuals and is not always a positive good in and of itself.

The important aspect of transition is covered by Voice et al. in Chapter 3, providing an overview of seminal literature in the field. Research before and during the Covid-19 pandemic draws on social, cultural and science capital to explore factors that affect belonging during the transition phase of students' higher education experiences. The authors identified the impact of students' backgrounds impacting on their sense of belonging but also noted the breadth of measures of success across student characteristics, linking with Chapter 4 and the multiplicity of students' views. Chapter 5 explores the notion of inclusive excellence and through four case studies shows how delivering this requires a reconceptualisation of success, incorporating wider indices which embed inclusion as an essential aspect of excellence. This aligns with the position that variety within a context or system is beneficial, increasing both opportunities to respond to changing contexts and challenges and the resilience of the whole (Kinchin, 2024).

Part II covers 'Identities and belonging in STEM'. It explores how students and staff articulate their identities and belonging in STEM fields. Chapters explore stereotypes, barriers and challenges across specific groups, including underrepresented students, and across intersectional identities. Other chapters explore how staff create and support a sense of belonging through innovative pedagogical approaches and how these can impact on their own sense of belonging and identity in STEM fields.

In Chapter 6, Myyry et al. examine STEM students' sense of belonging and social identity in Finland. Similarly to Chapter 3, the study covers students in the years before and after the Covid-19 pandemic. The authors noted that students' social identity came from interaction and collaboration with peers; they discuss ways to enhance their sense of belonging. Chapter 7 links with the insider/outsider themes from Chapter 2, presenting an enhanced ethnography of a unique teaching practice. Hauke explores the changing identities and development of belonging of STEM students in a non-STEM module, detailing the interactions between staff and students, and how they can challenge each other in carving out and forming their sense of who they are and where they belong. Horsburgh in Chapter 11 also explores teachers' identity development, analysing the identity challenges faced by those in STEM-based teaching-focused roles and linking this analysis with how they can be supported.

Chapters 8, 9 and 10 delve into the thorny issues faced by those underrepresented in STEM. Wong et al. in Chapter 8 identify the barriers faced by racially minoritised students. The lived experience of students highlights ongoing racism in STEM and the need for a longer-term approach of decolonisation to support the belonging of all students. In Chapter 9 Smith details the experiences of a group of women physics graduates and the stereotypes that remain endemic. The women reported how they had to negotiate aspects of their identity to try to belong; tackling the masculine discourse in physics is recommended as a way to address these challenges. In Chapter 10 Al Arefi highlights the importance of intersectionality in exploring women's experiences in STEM. Similarly to Chapters 8 and 9, she highlights how being underrepresented in STEM can inhibit staff and students from being their authentic selves, particularly in the engineering community.

The third part focuses on 'Supporting belonging and alternative ways of engaging'. It explores pedagogical philosophies and practices that support belonging in the context of specific STEM disciplinary traditions, and alternative ways in which students may choose to engage with their higher education experience. These chapters report how research on identity and sense of belonging can align with discipline-based research, as well as how high-impact practices, such as project-based learning, student research opportunities and staff–student partnerships impact students' sense of belonging. Innovative methods, approaches and findings that can enhance belonging are identified across a range of STEM disciplines.

In Chapter 12, Ohmori et al. show the positive benefits of active learning in STEM. They explore how widespread innovative pedagogies are across Japan, and how they are experienced by students. This research links cognitive and affective aspects, their intersection being key to developing students' science identity and sense of belonging. Luk et al. present findings in Chapter 15 on the impact of undertaking project-based teamwork in engineering. This high-impact practice shows benefits for supporting students' sense of belonging. Chapter 16 by Ommering and Dekker provides another example of a high-impact practice in action, detailing the experiences of medical students undertaking undergraduate research opportunities. Self-determination theory provides a lens to explore how to motivate students to undertake research.

McCrone presents in Chapter 13 a case study that highlights the importance of physical spaces in fostering students' sense of belonging, which links with themes presented in Chapter 7. He draws on his experiences as a student, as a student representative and of working with students as partners to detail the complex relationships between space, ownership and belonging. Picking up on this practice, Chapter 17 focuses on the outcomes of staff–student research partnerships in STEM, and how new epistemological approaches can challenge and extend the identities of those in STEM. In this chapter Kinchin et al. identify themes noted in Chapters 7 and 11 of the issues faced when those in STEM go beyond the confines of their discipline. This is complemented by Chapter 14, in which Leigh et al. explore challenges presented by doing science when disabled, chronically ill or neurodivergent. Linking with the intersectional lens offered by Chapter 10, they present a number of case studies addressing these challenges, and further emphasise that there is not a 'one size fits all' answer to supporting belonging in STEM.

These chapters lay a path for future learning, which offers education in more hybrid and flexible formats, for an increasingly diverse student body, while adopting the more active and discovery-based ways of learning required if students are to engage effectively in an uncertain and rapidly changing world. Acknowledging existing identities, building science identities and developing STEM ways of thinking provide ways to enhance both staff and student belonging in STEM higher education.

References

Gravett, K. & Ajjawi, R. (2022). Belonging as situated practice. *Studies in Higher Education*, 47(7), 1386–96. https://doi.org/10.1080/03075079.2021.1894118.

Guyotte, K. W., Flint, M. A. & Latopolski, K. S. (2021). Cartographies of belonging: Mapping nomadic narratives of first-year students. *Critical Studies in Education*, 62(5), 543–58. https://doi.org/10.1080/17508487.2019.1657160.

Kinchin, I. M. (2024). *How to Mend a University: Towards a sustainable learning environment in higher education*. London: Bloomsbury Academic.

Ong, M., Smith, J. M. & Ko, L.T. (2017). Counterspaces for women of color in STEM higher education: Marginal and central spaces for persistence and success. *Journal of Research in Science Teaching*, 55(2), 206–45. https://doi.org/10.1002/tea.21417.

Part I
What is, and is not, belonging?

1

STEM ways of thinking: belonging and identity

Camille Kandiko Howson and Martyn Kingsbury

Introduction

In science, technology, engineering and mathematics (STEM) fields with positivist approaches and a focus on numerical data, there can be assumptions that the disciplines are unemotional and impersonal. The need for mathematical competency, logical thinking and disciplinary contexts can be barriers to engagement and belonging in STEM. The data-led narrative is not centred on people, as it is in many social science and humanities fields, and this can marginalise the individual. At the same time, the knowledge of the subject can be synonymous with identity: to be a physicist is to know physics. Discourse in STEM fields, on what can be seen as impersonal, detached and cognitively challenging data, influences both access to data and who engages with it. STEM fields are highly competitive, especially for grant funding and journal publication, where cutting-edge research can have a short shelf life, and this competitiveness can provide a perverse pressure that inhibits open collaboration. There can be self-fulfilling stereotypes in STEM fields, such as the isolated geek who struggles with communication, personal interaction and team working. However, such characteristics of STEM fields can make it easier for some individuals to identify with these fields and can help them feel part of a scientific community, proud of the challenges they have had to 'overcome' to be there.

STEM ways of thinking, such as those underpinning abstract and complex mathematics, can form the basis of new ways of conceptualising belonging for both staff and students. Logical, abstract ways of thinking posit that it is these 'ways of thinking' that signal belonging (not who you are), which opens up new approaches to tackling belonging, not yet belonging, and the acceptance of 'not-belonging'. This raises further points about who has access to that knowledge and how it is shared.

We argue that this mathematical way of thinking can be a key feature of belonging in STEM, going beyond socio-demographic and cultural differences, possibly even transcending them. We see parallels with ways of thinking in music, where groups of musicians can communicate in embodied behaviours, language and sounds. Similarly, there are ways of thinking for artists, enabling them to connect with one another through presentational forms and expression. These communities may be exclusionary for outsiders, leading to stereotypes or pejorative statements such as 'He is an artist; his head is always in the clouds' and 'She is always tapping away with her fingers, seemingly somewhere else'. Yet within these communities individuals can be supported, with ways of thinking and being that connect people despite where they came from, how they speak or how they dress. Fostering logical, abstract and mathematical ways of thinking and being can be a mechanism for fostering such belonging in STEM.

This chapter sets the scene for the book, interrogating and critiquing notions of identity and belonging. Drawing on STEM education research before, during and after the Covid-19 pandemic, and recognising policies normalised as a response to crisis, can have positive and negative effects on students' experiences. Online lectures can be alienating for some, but can facilitate access for others, such as students with a disability or who are learning in a language that is not their native tongue. The pandemic raised questions about what it is people belong to and what powers they have to influence where and how they belong, or do not belong. This chapter provides a catalyst to inform this debate.

Belonging and identity

Sense of belonging has emerged as one of the most significant factors in students' success and their retention in higher education (Brooman & Darwent, 2014; Hausmann et al., 2007; Kuh et al., 2010; Thomas, 2012). Research on sense of belonging in the US-based literature is dominated by the exploration of differences across demographic and social characteristics (Strayhorn, 2018). Much of the UK-based research is small-scale (Trowler, 2010), set in specific institutional contexts (Ahn & Davis, 2020; Read et al., 2003; Wilcox et al., 2005) or focused on expectations, attitudes and satisfaction (Harvey & Drew, 2006).

And although the curriculum is seen as being at the heart of addressing differential sense of belonging, as it is the one thing students have in common (Kift et al., 2010), there is little discipline-specific literature on the topic: most explore it holistically across the sector or an institution. This chapter, and those in this book, address some of these gaps in the literature.

In 2020 the US-based National Survey of Student Engagement (NSSE) presented findings from its new survey items on sense of belonging, which asked to what extent students agreed or disagreed with the following:

1. I feel comfortable being myself at this institution.
2. I feel valued by this institution.
3. I feel like part of the community at this institution.

They found belonging to be positively correlated with engagement, retention and perceived gains from higher education in first-year students (National Survey of Student Engagement, 2020). Through subsequent years, they found a lower sense of belonging for students studying STEM subjects, first-generation students, multiracial students, and non-cisgender identities, and a higher sense of belonging for women and students without a declared disability (Lofton & Kinzie, 2022). They found that students involved in campus activities had a higher sense of belonging, and noted that this 'strengthens the value of student life and co-curricular programming and the benefit of investments in creating a vibrant campus life' (p. 15). The impact of socio-demographic characteristics highlights that sense of belonging is not solely an 'institutional' concept but is experienced differently by different groups of students. Furthermore, the difference across subjects suggests the impact of the curriculum and disciplinary culture, which indicates the importance of students' academic experiences in their sense of belonging.

Following the pandemic, a large-scale project on belonging in the UK identified four pillars that form the foundation of belonging: connection, inclusion, support and autonomy (Blake et al., 2022). They identified a reciprocally beneficial relationship between these areas, with development in any one facilitating and enhancing the others. However, they also noted barriers to belonging, including a lack of integration of the curriculum with wider student experience, poor mental health, and structural, systemic and cultural issues, including the capacity of staff to deliver inclusive practice.

Ahn and Davis (2020) identified four domains of belonging: academic, social, surroundings (including living space and geographical and cultural location), and personal space (capturing life satisfaction, life attitudes, identity and personal interests). Personal space is also linked with an individual's subjective feeling, as well as broader relational and emotional aspects (Thomas, 2012). From a psychological perspective, identity can be seen as 'a set of internalized role expectations' (Simon, 2004, p. 23) as well as being an evolving, flexible and fluid process (Tomlinson, 2010). Thus, as part of student identity development, 'Students need to learn how they relate to themselves, as students, as well as how they interact with, and are perceived by, their peers, mentors, tutors and lecturers' (Daniels & Brooker, 2014, p. 69).

Contemporary research focuses on belonging as situated and relational (Gravett & Ajjawi, 2022). Richardson (2018) links themes of the learning environment and identity with relational aspects of engaging with one's surroundings. Belonging includes an individual's need for affiliation, relatedness, social connectivity, positive regard and affection (Cureton & Gravestock, 2019). In their seminal work, Baumeister and Leary (1995) identified regular social interaction, with friends, clubs and societies, as a key factor in students' sense of belonging. However, Ahn and Davis (2020, 2023) argue that academic and social engagement can be seen as two different factors; they highlight generic versus specific notions of belonging in higher education.

For the individual, the relationship between identity and belonging follows the work of Haggis, seeing learners 'as uniquely situated within a matrix of intersecting factors and dimensions of experience. These intersecting dimensions are neither solely internal (as in phenomenological explanations of "experience" or "self") nor solely external (as in the "structuring effects of society/discourse")' (2004, p. 339). Moreover, situated notions of identity aim to move past individualised notions premised on independent, white, Western and male cultural constructions (Leathwood & O'Connell, 2003).

While belonging can be clearly identified as important, it also functions as a meta-construct with multiple factors feeding into it. In research on identifying 'intangible assets' in higher education that are 'clearly important aspects of higher education which are not easily measurable or quantifiable', Robertson et al. (2019, p. 1) found sense of belonging was rated by academic and professional services staff, senior managers and student representatives as the highest priority. It was noted as an important area in their practice, but also as the one for which they had the most difficulty in identifying tangible measures of ‘value’. Similarly, research with students found they struggled to separate individual and institutional responsibility or agency for developing a ‘sense of belonging’; at the same time, the research acknowledged the importance of the concept (Kandiko Howson & Matos, 2014).

While ‘solving’ belonging can be seen as a panacea to recruitment and awarding gaps and retention failures, there are also negative views of belonging and cases of students choosing not to belong. Indeed, belonging is not always a positive experience (Guyotte et al., 2021), and historically underrepresented groups can feel marginalised in their higher education experience. Such feelings are often directed at the wider institution, seen as a corporate entity (Ahn & Davis, 2020). Higher education can also lead to feelings of ‘alienation’ (Mann, 2001) and that it is an alienating environment (Christie et al., 2004). Students who feel they are being excluded may disengage from their course, resulting in lower attainment and a lower likelihood of completion (Hussain & Jones,, 2021; Lewis et al., 2021). And belonging can be challenging for non-traditional students (Read et al., 2003). Just as students have multiple identities in their lives, students have a variety of ‘belongings’ which can wax and wane over their experience in higher education. In this book more widely we bring out these critical notions of belonging, and not belonging, in STEM higher education.

STEM context

There are high levels of government interest in promoting education in STEM fields to support future generations of scientists and innovators in STEM careers (Department for Business, Energy & Industrial Strategy, 2020). The Covid-19 pandemic highlighted the role of science in addressing global concerns and has led to a more diverse interest in STEM careers. In terms of education, it brought new approaches to hybrid learning, which offered benefits to some students, particularly those with disabilities. But online learning highlighted differences between the efficient delivery of content and education as developing a disciplinary identity. This is a time to reconceptualise STEM fields; there is a greater need for mixed quantitative and qualitative research methodologies, and for ever more collaboration across individual, team, disciplinary and institutional boundaries.

STEM fields are dominated by notions of objectivity and neutrality and the approach of positivism, asserting that knowledge is obtained through observation and empiricism. This blends into disciplinary cultures which present science as inherently objective and fair. The ontology of STEM fields can separate the disciplines from students and their wider social environment. For many students, their sense of self is situated in their STEM identity and thus the teaching and learning of STEM can be seen as a process of acculturation. Acculturation is the process individuals undertake when they adapt to a new culture (Kuo, 2014 ; Sam & Berry, 2006). It can entail students taking on additional identities, but also losing touch with, or letting go of, aspects of themselves. Individuals are identified as 'clever' or 'a maths person', and part of STEM education is providing the environment and learning to allow students to take on and embrace that identity. However, 'For students, the assumed neutrality of STEM disciplines can reinforce inequalities, positioning these as individual rather than systemic outcomes' (Kandiko Howson & Mun, 2022, p. 124).

For underrepresented students, there are questions about the extent to which belonging is achieved by fitting individuals into a pre-identified identity, and about whether the widening participation agenda adequately signals the need to broaden notions of STEM identity and allow for more ways to belong in STEM. This positions identity as dynamic, and belonging as a process that happens between cultures and people but is also felt both positively and negatively by individuals.

STEM ways of thinking

How one sees oneself, and the wider world around, is informed by one's ways of thinking. In higher education, academic disciplines are aligned with developed ways of thinking, enmeshed in the inner logic of the subject and its pedagogy (Entwistle, 2017). 'The great disciplines like physics or mathematics, or history, or dramatic forms in literature, were … less repositories of knowledge than … methods for the use of mind' (Bruner, 1960, p. 20). Learning processes, and the type of academic understanding they develop, differ across subjects. 'Decoding the disciplines' is a process of uncovering the specifics of thinking and learning in disciplinary contexts (Middendorf & Pace, 2004, p. 2). This process can show pathways of thinking and uncover 'signature cognition' of disciplines, akin to the signature pedagogies of professions (Shulman, 2005). Understanding thinking in a disciplinary context is key to understanding how individuals identify with and feel part of or alienated from the disciplinary community.

STEM ways of thinking are discussed more in research on school-level education than in research on higher education. School-level research can be summarised in three approaches. The first involves separating learning goals across each discipline, an 'isolated approach to STEM (or S-T-E-M) education' (Slavit et al., 2021, p. 466). The second involves interdisciplinary approaches, focusing on connecting the disciplines and descending epistemologies across STEM fields (Vasquez, 2015). The third is task-based, through, for example, projects or solving 'real-world' problems. The focus of this research is usually on how to teach STEM subjects and develop students' ways of thinking in problem solving (Ersoy & Guner, 2015; Schoenfeld, 2016).

STEM disciplines are dominated by a mathematical way of thinking:

> This is not the same as 'doing math', which usually involves the application of procedures and some heavy-duty symbolic manipulations. Mathematical thinking, by contrast, is a specific way of thinking about things in the world. It does not have to be about mathematics at all. (Devlin, 2012, p. 1)

The question 'What is mathematical thought?' is usually answered with 'What is taught in schools', but the notions of aesthetics and simplicity are the basis for the highest-level mathematical thinking (Dreyfus & Eisenberg, 1996). 'Mathematicians think about mathematical objects and the mathematical relationships between them using the same mental faculties that the majority of people use to think about other people' (Devlin, 2000, p. 262). We use the term 'mathematical thinking' as an umbrella phrase to cover the scientific, analytical, logical, computational and abstract ways of thinking that underpin STEM fields.

Exploring mathematical ways of thinking

Mathematical thinking follows functional thinking, that is, thinking in terms of variables and functions (Weyl, 1940). It highlights the importance of using symbols instead of words, as symbolising leads to abstraction and the possibility of generalisation. Mathematical thinking includes quantitative reasoning and logical and analytic thinking, but the key to 'maths thinking' is in handling abstractions. More specifically, computational thinking has been defined as the 'conceptual foundation required to solve problems effectively and efficiently (i.e., algorithmically, with or without the assistance of computers) with solutions that are reusable in different contexts' (Shute et al., 2017, p. 142). This links aspects of thinking and acting, bringing the social element into ways of thinking, as well as embodied cognition, that which involves our brains and our bodies (Wilson, 2002). Embodied cognition can be seen in the gestures and bodily movements one may make when explaining abstract phenomena.

Research on mathematical thinking is predominantly explored from the perspective of teaching mathematics (see Tall, 2013 on the worlds of mathematics). It draws from work in psychology on what understanding means (Brown et al., 1983), connecting with an intrinsic link between mathematics and psychology in processes of advanced mathematical thinking (Dreyfus, 1991). The concept of 'reflective abstraction' is used to describe the cognitive construction of logico-mathematical structures. This includes research on areas from early individual development (Beth & Piaget, 1966) to the broader societal development of mathematics (Piaget, 1985).

There are challenges in attempting to study abstract mathematical thinking (Dubinsky, 2002): in essence, it changes when expressed, in either numbers or words. Indicating the dominance of a specific way of thinking, in the literature on abstract mathematical ways of thinking there is constant reference to visual and numerical mathematical problems and worked solutions to make points that are challenging to make with words alone (see Leikin, 2007; Restrepo & Villaveces, 2012).

Research on maths education challenges notions of a biological basis to mathematical ways of thinking, such as 'you either get it or you don't', or tropes of some 'just not being a maths person'. Hersh (1986) argues that mathematics is about 'ideas', and is a natural part of human activity. Mathematical ways of thinking contrast with 'mathematics mastery' based on rote learning and memorisation (Schoenfeld, 1988). Mathematical thinking is different to numeracy and the idea of mathematics as products, bodies of knowledge and skills to be acquired. Contemporary mathematics education reframes mathematics and science education as sites of 'sense-making' activity (Li & Schoenfeld, 2019; Odden & Russ, 2019) and positioning mathematics as a vehicle for 'making sense' (McCallum, 2018).

Belonging and identity within STEM ways of thinking

Solomon (2007) found that students develop a negative mathematics identity due to fixed ability beliefs, exacerbated by pedagogical practices and the wider student community. This is strongest when mathematics is seen as a product, a set of rules and strategies to be learnt, versus mathematics being seen as constructed or done by students (Solomon, 2006, 2007). Mathematics teaching that is marginalising (Boaler, 2002) can lead to identities of exclusion (Solomon, 2007). Research on gender gaps in mathematics has noted that 'seeing "doing mathematics" as "doing masculinity" is a productive way of understanding why mathematics is so male dominated' (Mendick, 2005, p. 235). The dominant discourses in mathematics often preclude women seeing their future selves as mathematicians (Bartholomew & Rodd, 2003).

There are multiple dimensions of mathematical identity, in addition to it being situated (Kaspersen et al., 2017). Students' sense of belonging in mathematics, including feeling that they are members of the mathematics community and accepted by those in power, predicts whether they intend to progress in mathematics (Good et al., 2012). A negative mathematics identity is linked with fixed views of intelligence and fixed views of mathematical mindsets, and the idea that only the smartest and cleverest people can do mathematics (Boaler, 2022). However, such views can also shape the identity of those good at mathematics. Many students continue with mathematics because they are good at it, and it makes them feel special, but once surrounded by others equally good at mathematics they can lose their identity (Solomon, 2007). However, for some students, a performative orientation and state of not belonging are not a problem (Solomon, 2007).

Ways of thinking within STEM subjects can go beyond notions of mastery and figuring out the one 'right' answer. Sengupta, Dickes and Farris (2018, p. 49) suggest, 'Rather than viewing computing as regurgitation and production of a set of axiomatic computational abstractions, we argue that computing and computational thinking should be viewed as discursive, perspectival, material, and embodied experiences, among others'. This neatly connects ways of thinking with the experiences of thinking, more closely linking the peer-to-peer and student–staff interactions in STEM education.

A mathematical way of thinking can also be considered a mathematical way of being. This view involves rethinking mathematical affect as emotion, which challenges assumptions: '"No emotion, please! We're researching mathematics"' (Evans, 2002, p. 108). While most school-level research in this area focuses on developing mathematical ways of thinking across STEM fields, little explores mathematical ways of being, acting, interacting and communicating. The following examples provide insights into how STEM ways of thinking and being can be the foundation of bringing staff and students together, fostering belonging and a positive student experience.

Examples in practice

High-impact practices are those that have a disproportionately positive effect on student success (Kilgo et al., 2015). These include bringing staff and students together through shared activities, such as undergraduate research opportunities, active and collaborative learning, and final-year projects. Aligning such activities with students' studies can have a significantly beneficial impact. At Imperial College London, there are academics working in collaboration with students to advance ways of thinking and practising in STEM subjects (Meyer & Land, 2003). In the spirit of broad communities of practice, the projects below extend beyond a single discipline, and in some cases the institution, and are open to students, staff and the wider STEM community.

The Xena project

Kevin Buzzard is a professor of pure mathematics at Imperial College London. He has developed a way to get undergraduate mathematics students to use computer proof verification software.

> The Xena project is an attempt to show young mathematicians that essentially all of the questions which show up in their undergraduate courses in pure mathematics can be turned into levels of a computer game called Lean. Furthermore, they have a bewildering array of tools with which to solve these levels – the so-called interactive tactics. It's like Zen Zelda.
>
> The Xena Project is an attempt to change mathematics departments from the ground up, by teaching students new techniques. (Xena, 2023)[1]

Through the use of software called 'Lean', students and staff work to digitalise mathematical ways of thinking. There are dozens of staff and student research projects, the development of a compendium of resources and at times weekly drop-in meetings. The project has also been used in outreach activities and has spread to an international consortium of collaborators.

Issie and Addie

In the Department of Electrical and Electronic Engineering at Imperial College London, the Interactive Schematic Simulator with Integrated Editor (ISSIE) is an educational desktop application.

> [ISSIE] is a very easy to use desktop application which supports digital circuit design and simulation. It is targeted at both novice University and professional users who want to implement and test high productivity hierarchical digital circuit design. Issie is designed to be beginner-friendly and guide the users toward their goals via clear UI signposting, error messages that explain how to correct the error, and visual clues. (Issie, 2024)

There are related tools, including Visual2 and Addie. These provide innovative visualisations of taught concepts and support the teaching of complex design languages. These tools are co-produced with students, the core development being done through final-year student projects. Third- and fourth-year students have opportunities to enhance and maintain the tools. Engagement provides students with real-world development project experience. The tools are used to support discovery-based learning in the early years of the curriculum. Future use of the Issie and Addie software aims to improve their use in laboratory settings, further support the first-year curriculum, and offer further undergraduate research opportunities and the use of the tools in outreach efforts and pre-university activities.

These design tools allow students to partake in a highly visual style of learning. Students can move quickly from developing prototypes to testing their effectiveness, which empowers them and lets them 'see' their thinking in action. The collaborative nature of this project allows students to have multiple roles, from small-scale maintenance to larger-scale designed research projects. The staff and students working on the project have been described as the 'Issie community', which indicates the identity and belonging that they feel through being part of the development of these tools.

Lambda Feedback

Lambda Feedback is a web platform that hosts coursework problem sets, with a focus on mathematical subjects. The platform hosts question content and provides online step-by-step solutions, which are particularly popular with students. It also provides automated feedback on student responses. This personalised feedback is developed by applying mathematical rules which group similar responses and then prioritise popular cases for specific feedback. Teachers encode the automated feedback in a process enhanced by analysis of data from student usage, for example identifying the most common responses and providing custom feedback for them.

> In this project students and staff are providing input throughout the design of the software. This engagement helps us prioritise. For example, autonomy is important to teachers. Content and feedback is [*sic*] curated by the teacher according to their pedagogy; students are in control of their experience according to their study preferences. (Johnson, 2023)

This project was developed with staff and students working in collaboration across a wide variety of departments, including Mechanical Engineering, Aerospace Engineering, Civil Engineering, Design Engineering, Physics and Life Sciences. There have been over 1,000 student users, and the project has been integrated into nine modules in its first year. There are eight students working on extended summer projects, and a 'community approach' allows the evaluation cycle to go beyond the work of a single instructor, utilising public repositories to develop feedback.

Tellingly, the group of staff and students who worked on the project in the first year were called the 'Lambda Feedback Pioneers', which highlighted the group identity the project brought. There have been high levels of student interest in the project, and it is being developed for outreach projects and use in schools. This project brings a conversational approach to a mathematical way of thinking and being, through iterative feedback based on common misconceptions or repeated 'wrong' answers. Worked examples provide students with a blueprint for mathematical ways of thinking and problem solving.

Imperial Visualisations

Abstract concepts can be challenging for teachers to explain and for students to comprehend. The Imperial Visualisations project, ImpVis, is a staff–student partnership initiative designed to develop interactive online visualisations about abstract concepts. Teams of staff and students work together on a visualisation for a specific module, based on principles of mutual respect, joint ownership and shared responsibility. In 2017 the first year of the project developed 23 interactive visualisations in physics. The project, still ongoing, has now expanded across the institution.

Topics include 'The dynamic modes of a Boeing-747', which shows the dynamic behaviour of an aeroplane, 'Electromagnetic waves at a dielectric boundary', which allows exploration of evanescent waves, and 'Snell's law of wave refraction', which explores total internal reflection. Dr Caroline Clewley, the ImpVis project lead, has noted:

> Interactive visualisations are excellent learning tools to help students gain an intuitive understanding of abstract concepts. However, as an instructor it can be hard to find visualisations that fit your module just right, aligning with your own intended learning outcomes. The ImpVis visualisations are all designed based on specific learning goals and co-created by staff and students. This gives our team insight into how students learn the material, resulting in visualisations that are a good fit for both the module content and their audience. (ImpVis, 2023)

The resulting visualisations are embedded into the curriculum, and are also available for anyone to access. They are structured for students to learn, instructors to teach, and as ways to learn coding to create new visualisations. The project takes abstract concepts, and provides a concrete way to see and manipulate those abstract concepts. In a way they can function as a visual language within STEM.

Conclusion

We argue that a mathematical way of thinking can function as a badge of belonging and support a student's STEM identity. For this reason, belonging can be thought of as an academic, cognitive function rather than as being purely socially based, although the cognitive and social are interrelated and can feed into each other. We argue that the cognitive togetherness of a shared mathematical way of thinking is akin to artistic and musical ways of thinking and belonging. The logical mathematical way of thinking can be more accepting than others of neurodiverse ways of thinking and being. Furthermore, a cognitive, rather than social, form of belonging can be more accepting of all aspects of diversity, as there is less focus on who you are or where you come from. However, it can be argued that mathematical understanding is the key to belonging to the community in an academic way, which under-recognises the inequalities in access to developing the necessary high-level mathematical skills. Integrating ways and thinking and belonging can be part of the solution to this challenge.

Note

1 'The Legend of Zelda' is an iconic action-adventure game franchise created in the 1980s by the Japanese game designers Shigeru Miyamoto and Takashi Tezuka that features a mix of puzzles, action, adventure/battle gameplay, and exploration. This quote refers both to using the gaming platform to engage with abstract thinking that is challenging and to the fact that Xena, like the Zelda game, has a following and a community.

References

Ahn, M. Y. & Davis, H. H. (2020). Four domains of students' sense of belonging to university. *Studies in Higher Education*, 45(3), 622–34. https://doi.org/10.1080/03075079.2018.1564902.

Ahn, M. Y. & Davis, H. H. (2023). Students' sense of belonging and their socio-economic status in higher education: A quantitative approach. *Teaching in Higher Education*, 28(1), 136–49. https://doi.org/10.1080/13562517.2020.1778664.

Bartholomew, H. & Rodd, M. 2003. A 'fiercely held modesty': The experiences of women studying mathematics. *New Zealand Journal of Mathematics*, 32 (Supplementary Issue), 9–18.

Baumeister, R. F. & Leary, M. R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin*, 117(3), 497–529. https://doi.org/10.1037/0033-2909.117.3.497.

Beth, E. W. & Piaget, J. (1966). *Mathematical Epistemology and Psychology* (trans. W. Mays). Dordrecht: Reidel.

Blake, S., Capper, G. & Jackson, A. (2022). Building belonging in higher education: Recommendations for developing an integrated institutional approach. Pearson & Wonkhe. https://wonkhe.com/wp-content/wonkhe-uploads/2022/10/Building-Belonging-October-2022.pdf.

Boaler, J. (2002). *Experiencing School Mathematics: Teaching styles, sex and setting*. Buckingham: Open University Press.

Brooman, S. & Darwent, S. (2014). Measuring the beginning: A quantitative study of the transition to higher education. *Studies in Higher Education,* 39(9), 1523–41. https://doi.org/10.1080/03075079.2013.801428.

Brown, A. L., Bransford, W. F., Ferrara, R. & Campione, J. (1983). Learning, remembering and understanding. In J. H. Flavell & E. M. Markman (eds), *Handbook of Child Psychology. Volume 3: Cognitive Development* (4th edn), pp. 77–166. New York: John Wiley & Sons.

Bruner, J. S. (1960). *The Process of Education*. Cambridge, MA: Harvard University Press.

Christie, H., Munro, M. & Fisher, T. (2004). Leaving university early: Exploring the differences between continuing and non-continuing students. *Studies in Higher Education,* 29(5), 617–36. https://doi.org/10.1080/0307507042000261580.

Cureton, D. & Gravestock, P. (2019). We belong: Differential sense of belonging and its meaning for different ethnicity groups in higher education. *Compass: Journal of Learning and Teaching*, 12(1). https://doi.org/10.21100/compass.v12i1.942.

Daniels, J. & Brooker, J. (2014). Student identity development in higher education: Implications for graduate attributes and work-readiness. *Educational Research*, 56(1), 65–76. https://doi.org/10.1080/00131881.2013.874157.

Department for Business, Energy & Industrial Strategy (2020). Multi-million government investment in the future of UK science. https://www.gov.uk/government/news/multi-million-government-investment-in-the-future-of-uk-science.

Devlin, K. J. (2000). *The Math Gene: How mathematical thinking evolved and why numbers are like gossip*. New York: Basic Books.

Devlin, K. J. (2012). *Introduction to Mathematical Thinking*. Palo Alto, CA: Keith Devlin.

Dreyfus, T. (1991). Advanced mathematical thinking processes. In D. Tall (ed.), *Advanced Mathematical Thinking*, pp. 25–41. Dordrecht: Kluwer Academic Publishers.

Dreyfus, T. & Eisenberg, T. (1996). On different facets of mathematical thinking. In R. J. Sternberg & T. Ben-Zeev (eds), *The Nature of Mathematical Thinking* (pp. 253–84). Mahwah, NJ: Lawrence Erlbaum.

Dubinsky, E. (2002). Reflective abstraction in advanced mathematical thinking. In D. Tall (ed.), *Advanced Mathematical Thinking*, pp. 95–123. Dordrecht: Springer. https://doi.org/10.1007/0-306-47203-1_7.

Entwistle, N. (2017). *Teaching for Understanding at University: Deep approaches and distinctive ways of thinking*. London: Bloomsbury Publishing.

Ersoy, E. & Güner, P. (2015). The place of problem solving and mathematical thinking in the mathematical teaching. *The Online Journal of New Horizons in Education*, 5(1), 120–30.

Evans, J. (2002). *Adults' Mathematical Thinking and Emotions: A study of numerate practices*. London: Routledge/Falmer.

Good, C., Rattan, A. & Dweck, C. S. (2012). Why do women opt out? Sense of belonging and women's representation in mathematics. *Journal of Personality and Social Psychology*, 102(4), 700–17. https://doi.org/10.1037/a0026659.

Gravett, K. & Ajjawi, R. (2022). Belonging as situated practice. *Studies in Higher Education*, 47(7), 1386–96. https://doi.org/10.1080/03075079.2021.1894118.

Guyotte, K. W., Flint, M. A. & Latopolski, K. S. (2021). Cartographies of belonging: Mapping nomadic narratives of first-year students. *Critical Studies in Education*, 62(5), 543–58. https://doi.org/10.1080/17508487.2019.1657160.

Haggis, T. (2004). Meaning, identity and 'motivation': Expanding what matters in understanding learning in higher education? *Studies in Higher Education*, 29(3), 335–52. https://doi.org/10.1080/03075070410001682538.

Harvey, L. & Drew, S. (2006). *The First-Year Experience: A review of literature for the Higher Education Academy*. York: Higher Education Academy.

Hausmann, L. R. M., Schofield, J. W. & Woods, R. L. (2007). Sense of belonging as a predictor of intentions to persist among African American and white first-year college students. *Research in Higher Education*, 48(7), 803–39. https://doi.org/10.1007/s11162-007-9052-9.

Hersh, R. (1986). Some proposals for reviving the philosophy of mathematics. In T. Tymoczko (ed.), *New Directions in the Philosophy of Mathematics: An anthology*, pp. 9–28. Boston, MA: Birkhäuser.

Hussain, M. & Jones, J. M. (2021). Discrimination, diversity, and sense of belonging: Experiences of students of color. *Journal of Diversity in Higher Education*, 14(1), 63–71. https://doi.org/10.1037/dhe0000117.

ImpVis (2023). Introducing the ImpVis community. Imperial Visualisations. https://impvis.co.uk/about. Accessed 11 December 2023.

Issie (2024). The Interactive Schematic Simulator and Integrated Editor. https://tomcl.github.io/issie/. Accessed 1 March 2024.

Johnson, P. (2023). Computers make us human. Teaching Engineers blog, 18 July. https://teachingengineers.wordpress.com/2022/07/18/computers-make-us-human/. Accessed 11 December 2023.

Kandiko Howson, C. B. & Matos, F. (2014). UK Engagement Survey 2014: Full report of the cognitive testing. York: Higher Education Academy. https://www.advance-he.ac.uk/knowledge-hub/uk-engagement-survey-2014. Accessed 18 March 2024.

Kandiko Howson, C. & Mun, O. (2022). Academic activism in STEM fields: Discipline in theory and practice. *Philosophy and Theory in Higher Education*, 4(2), 123–42. https://doi.org/10.3726/PTIHE.022022.0009.

Kaspersen, E., Pepin, B. & Sikko, S. A. (2017). Measuring STEM students' mathematical identities. *Educational Studies in Mathematics*, 95(2), 163–79. https://doi.org/10.1007/s10649-016-9742-3.

Kift, S., Nelson, K. & Clarke, J. (2010). Transition pedagogy: A third generation approach to FYE – a case study of policy and practice for the higher education sector. *International Journal of the First Year in Higher Education*, 1(1), 1–20. https://doi.org/10.5204/intjfyhe.v1i1.13.

Kilgo, C. A., Ezell Sheets, J. K. & Pascarella, E. T. (2015). The link between high-impact practices and student learning: Some longitudinal evidence. *Higher Education*, 69(4), 509–25.

Kuh, G. D., Kinzie, J., Schuh, J. H. & Whitt, E. J. (2010). *Student Success in College: Creating conditions that matter*. San Francisco, CA: Jossey-Bass.

Kuo, B. C. (2014). Coping, acculturation, and psychological adaptation among migrants: A theoretical and empirical review and synthesis of the literature. *Health Psychology and Behavioral Medicine*, 2(1), 16–33. https://doi.org/10.1080/21642850.2013.843459.

Leathwood, C. & O'Connell, P. (2003). 'It's a struggle': the construction of the 'new student' in higher education. *Journal of Education Policy*, 18(6), 597–615. https://doi.org/10.1080/0268093032000145863.

Leikin, R. (2007). Habits of mind associated with advanced mathematical thinking and solution spaces of mathematical tasks. In D. Pitta-Pantazi & G. Philippou (eds), *Proceedings of the Fifth Conference of the European Society for Research in Mathematics Education*, pp. 2330–9.

Lewis, J. A., Mendenhall, R., Ojiemwen, A., Thomas, M., Riopelle, C., Harwood, S. A. & Browne Huntt, M. (2021). Racial microaggressions and sense of belonging at a historically white university. *American Behavioral Scientist*, 65(8), 1049–71. https://doi.org/10.1177/0002764219859613.

Li, Y. & Schoenfeld, A. H. (2019). Problematizing teaching and learning mathematics as 'given' in STEM education. *International Journal of STEM Education*, 6(1), art. no. 44, 1–13. https://doi.org/10.1186/s40594-019-0197-9.

Lofton, C. E. & Kinzie, J. (2022). Using sense of belonging data to foster equitable student success: New findings from NSSE. 2022 NASPA Annual Conference, 19–23 March. Baltimore, MD. https://scholarworks.iu.edu/dspace/bitstream/handle/2022/27454/NASPA_22%20NSSE_Sense%20of%20Belonging%20Lofton%20%26%20Kinzie.pdf?sequence=1&isAllowed=y. Accessed 11 December 2023.

Mann, S. J. (2001). Alternative perspectives on the student experience: Alienation and engagement. *Studies in Higher Education*, 26(1), 7–19. https://doi.org/10.1080/03075070020030689.

McCallum, W. (2018). Sense-making and making sense. 5 December. https://blogs.ams.org/matheducation/2018/12/05/sense-making-and-making-sense/. Accessed 11 December 2023.

Mendick, H. 2005. 'Mathematical stories: Why do more boys than girls choose to study mathematics at AS-level in England'? *British Journal of Sociology of Education*, 26(2): 235–51.

Meyer, J. H. F. & Land, R. (2003). Threshold concepts and troublesome knowledge (1): Linkages to ways of thinking and practising within the discplines. In C. Rust (ed.), *Improving Student Learning Theory and Practice, Ten Years On: Proceedings of the 2002 10th International Symposium Improving Student Learning*, pp. 412–24. Wheatley: Oxford Centre for Staff & Learning Development.

Middendorf, J. & Pace, D. (2004). Decoding the disciplines: A model for helping students learn disciplinary ways of thinking. *New Directions for Teaching and Learning*, 2004(98), 1–12. https://doi.org/10.1002/tl.142.

National Survey of Student Engagement (2020). Annual results 2020 – engagement insights: Survey findings on the quality of undergraduate education. National Survey of Student Engagement. https://nsse.indiana.edu/research/annual-results/2020/index.html. Accessed 11 December 2023.

Odden, T. O. B. & Russ, R. S. (2019). Defining sensemaking: Bringing clarity to a fragmented theoretical construct. *Science Education*, 103(1), 187–205. https://doi.org/10.1002/sce.21452.

Piaget, J. (1985). *The Equilibration of Cognitive Structures: The central problem of intellectual development* (trans. T. Brown and K. J. Thampy). Chicago, IL: University of Chicago Press.

Read, B., Archer, L. & Leathwood, C. (2003). Challenging cultures? Student conceptions of 'belonging' and 'isolation' at a post-1992 university. *Studies in Higher Education*, 28(3), 261–77. https://doi.org/10.1080/03075070309290.

Restrepo, G. & Villaveces, J. L. (2012). Mathematical thinking in chemistry. *Hyle: International Journal for Philosophy of Chemistry*, 18(1), 3–22.

Richardson, J. (2018). *Place and Identity: The Performance of Home*. Abingdon: Routledge.

Robertson, A., Cleaver, E. & Smart, F. (2019). Beyond the metrics: Identifying, evidencing and enhancing the less tangible assets of higher education. QAA Scotland. https://www.enhancementthemes.ac.uk/docs/ethemes/evidence-for-enhancement/beyond-the-metrics-identifying-evidencing-and-enhancing-the-less-tangible-assets-of-higher-education.pdf?sfvrsn=ca37c681_8. Accessed 11 December 2023.

Sam, D. L. & Berry, J. W. (eds). (2006). *The Cambridge Handbook of Acculturation Psychology*. Cambridge: Cambridge University Press.

Schoenfeld, A. H. (1988). When good teaching leads to bad results: The disasters of 'well-taught' mathematics courses. *Educational Psychologist*, 23(2), 145–66. https://doi.org/10.1207/s15326985ep2302_5.

Schoenfeld, A. H. (ed). (2016). *Mathematical Thinking and Problem Solving*. Abingdon: Routledge.

Sengupta, P., Dickes, A. & Farris, A. (2018). Toward a phenomenology of computational thinking in STEM education. In M. Khine (ed.), *Computational Thinking in the STEM Disciplines: Foundations and research highlights*, pp. 49–72. Cham: Springer.

Shulman, L. S. (2005). Signature pedagogies in the professions. *Daedalus*, 134(3), 52–9.

Shute, V. J., Sun, C. & Asbell-Clarke, J. (2017). Demystifying computational thinking. *Educational research review*, 22, 142–58. https://doi.org/10.1016/j.edurev.2017.09.003.

Simon, B. 2004. *Identity in Modern Society: A social psychological perspective*. Malden, MA: Blackwell Publishing.

Slavit, D., Grace, E. & Lesseig, K. (2021). Student ways of thinking in STEM contexts: A focus on claim making and reasoning. *School Science and Mathematics*, 121(8), 466–80. https://doi.org/10.1111/ssm.12501.

Solomon, Y. (2006). Deficit or difference? The role of students' epistemologies of mathematics in their interactions with proof. *Educational Studies in Mathematics*, 61(3): 373–93. https://doi.org/10.1007/s10649-006-6927-1.

Solomon, Y. (2007). Not belonging? What makes a functional learner identity in undergraduate mathematics? *Studies in Higher Education*, 32(1), 79–96. https://doi.org/10.1080/03075070601099473.

Strayhorn, T. L. (2018). *College Students' Sense of Belonging: A key to educational success for all students* (2nd edn). New York: Routledge.

Tall, D. (2013). *How Humans Learn to Think Mathematically: Exploring the three worlds of mathematics*. Cambridge: Cambridge University Press.

Thomas, L. (2012). Building student engagement and belonging in higher education at a time of change: Final report from the What Works? Student Retention & Success programme. Paul Hamlyn Foundation. https://web.archive.org/web/20220207011512/https://www.phf.org.uk/wp-content/uploads/2014/10/What-Works-report-final.pdf. Accessed 11 December 2023.

Tomlinson, M. (2010). Investing in the self: Structure, agency and identity in graduates' employability. *Education, Knowledge and Economy* 4(2), 73–88. https://doi.org/10.1080/17496896.2010.499273.

Trowler, V. (2010). Student engagement literature review. Higher Education Academy. https://s3.eu-west-2.amazonaws.com/assets.creode.advancehe-document-manager/documents/hea/private/studentengagementliteraturereview_1_1568037028.pdf. Accessed 11 December 2023.

Vasquez, J. A. (2015). STEM – Beyond the acronym. *Educational Leadership*, 72(4), 10–15.

Weyl, H. 1940. The mathematical way of thinking. *Science*, 92(2394), 437–46.

Wilcox, P., Winn, S. & Fyvie-Gauld, M. 2005. 'It was nothing to do with the university, it was just the people': The role of social support in the first-year experience of higher education. *Studies in Higher Education*, 30(6), 707–22. https://doi.org/10.1080/03075070500340036.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review*, 9(4), 625–36. https://doi.org/10.3758/BF03196322.

Xena (2023). What is the Xena project? https://xenaproject.wordpress.com/what-is-the-xena-project/. Accessed 11 December 2023.

2
Hospitality and belonging: insiders and outsiders in STEM higher education

Sheena Hyland

Introduction

What does it mean to speak of inclusion in science, technology, engineering and mathematics (STEM) higher education? What conditions are needed to make students and academics feel part of a community, an institution or a discipline? How do disciplinary histories shape disciplinary identities and their associated norms, conventions and practices? And how might this position some groups as natural *insiders* while rendering others *outsiders*?

This chapter critically explores the question of inclusion in STEM through a philosophical lens. By starting from the perspective of those traditionally underrepresented in STEM education and its related professions, we may be able to shed light on some of the implicit conditions of inclusion that function within our academic institutions and disciplinary communities. Although universities work hard to communicate that they 'welcome' diversity, and despite the widespread use of the language of inclusion and belonging in higher education, remarkably little critical attention is paid to what we mean when we use these terms. Even as institutions 'celebrate' diversity on campus, efforts at inclusion may be undermined by a contradictory impulse to maintain and protect the status quo. O'Donnell (2015) and Graham and Slee (2008) challenge and problematise the common notion of inclusion conceived as a straightforward process of 'bringing in' those who have been excluded or marginalised. Their work offers a powerful argument for why we must first critically interrogate the ways in which power, authority and prestige function within our disciplinary communities, and their traditional connection to certain identities, attributes and characteristics.

STEM's glass ceiling

Despite decades of widening participation (WP) policy in higher education, disparities in admissions, retention and academic outcomes persist for women, working-class students, students of colour, and other marginalised groups in STEM fields. While these policies have successfully boosted overall enrolment of traditionally underrepresented groups, disparities in completion rates and academic performance remain (see Smith et al., 2013; Thoman et al., 2014; Walton & Cohen, 2011).

In the United States, studies consistently point to the underrepresentation of women of colour in STEM degree programmes, particularly in fields such as physics, engineering, astronomy and computer science (see Hurtado et al., 2010; Ong, Smith & Ko, 2018; Ong, Wright et al., 2011). Black, Hispanic and American Indian or Alaska Native women are significantly less likely than white men to complete science and engineering degrees (NSF/NCSES, 2015, pp. 74–6).

However, over the past decade there has been steady progress. There has been an increase in the attainment of science and engineering degrees among all traditionally underrepresented groups (National Center for Science and Engineering Statistics, 2023). This is most notable at the level of associate's degrees,[1] where representation of minoritised students (male and female) in science and engineering programmes has grown from 31 per cent in 2011 to 43 per cent in 2020. At doctoral level, the increase in completion rates is less pronounced, with a more modest overall change from 13 per cent to 15 per cent. Ong, Smith and Ko (2018) point out that, after admission to STEM programmes, underrepresented students continue to face challenges and are less likely to 'persist' in their chosen fields than their white male peers. Ong et al. attribute this attainment gap to 'social and interpersonal factors', arguing that women of colour in particular tend to 'struggle and leave because they do not experience a sense of social belonging' (p. 208; see also Ong, Wright et al., 2011; Varma et al., 2006).

Other studies highlight the relationship between students' sense of belonging and rates of retention in STEM programmes; women and people of colour report a far weaker sense of belonging and poorer academic outcomes than men and white students (see Good et al., 2012; Johnson, 2012; Smith et al., 2013). The work of Rainey et al. (2018) explores connections between one's sense of belonging in a STEM field and the likelihood of completing a chosen programme of study. They draw on Goodenow's definition of belonging as the 'sense of being accepted, valued, included, and encouraged by others (teachers and peers) in the academic classroom setting and of feeling oneself to be an important part of the life and activity of the class' (1993, p. 25). In their research, they note that, for women and students of colour, the link between their sense of belonging and the likelihood of completing a programme of study is particularly strong (see also Strayhorn, 2012). Marginalised groups are more likely to experience what Walton and Cohen (2007) call 'belonging uncertainty', 'which arises when people feel unsure of their ability to "fit in"' (Rainey et al., 2018, p. [2]; see also Smith et al., 2013). The extent to which a student can see their social group represented in the field, among their peers and faculty, has a profound impact on their sense of belonging to the academic community (see Murphy et al., 2007).

However, it is important to note that there are distinct differences in the experiences of belonging across STEM subfields, for instance, although women generally report a lower sense of belonging than men in STEM, female students in the biological sciences tend to report a stronger sense of belonging than those in the physical sciences (see Rainey et al., 2018). At undergraduate level, women's representation in the biological sciences is almost the same as men's, reflecting a clear positive link between the level of female representation and women's perceived sense of belonging within their subfield. However, as Rainey et al. (2018, p. 6) point out, the converse also appears to be true:

> As a student's demographic group becomes less represented, the less likely a person is to report a sense of belonging. We also note that lower sense of belonging was most commonly reported by people of color, suggesting that race significantly impacts belonging, perhaps even more than gender.

They argue that in the physical sciences, where they are most underrepresented, women of colour report the lowest sense of belonging of any demographic group. This finding is reflected in low levels of 'persistence', especially in subfields where they are least represented among students and faculty.

Belonging and non-belonging

Recognised as a key factor shaping student behaviour and completion rates across STEM programmes, fostering students' sense of belonging in higher education is typically seen as a positive, achievable aim. Often characterised in terms of being at ease within one's environment, belonging is described as referring to 'feelings of approval and comfort, as well as the processes of gaining acceptance among peers in which meaningful relationships are developed' (Guyotte et al., 2021, p. 544).

Belonging may thus be understood as a feeling of being accepted, or valid, as a member of an academic community. It may be bound up with students' sense of their ability to engage with the formal curriculum and with STEM ways of thinking (see Kandiko Howson and Kingsbury, Chapter 1 in this volume); it is shaped by the dominant norms, conventions, expectations and practices embodied and enacted by peers and teaching staff. The development of a sense of belonging may, therefore, arguably, be affected by STEM students' perceptions of their personal proximity to the prevailing intellectual, social, cultural and embodied norms of those who hold positions of power, authority and prestige within STEM communities. How students make sense of the meaning and relevance of these norms may be mediated, positively or negatively, through their own identities and links to social class, race, gender, culture, sexuality, personal and academic interests, characteristics, abilities or attributes.

Although it is generally viewed as a positive 'goal', the question of what it means to belong, how a sense of belonging functions and may be fostered, is not a settled matter (see Kandiko Howson and Kingsbury, Chapter 1 in this volume). Guyotte et al. (2021) problematise the suggestion that belonging may be reducible to a sense of comfort or feeling of ease in an environment, arguing that, instead, it is a complex, dynamic and ongoing process. Belonging, they maintain, is never complete or fully achieved. It is constantly shifting, coming up against experiences of non-belonging as students relate to an ever-changing environment. Moreover, belonging is not always positive; it may be experienced as oppressive or restrictive (see Murray et al., Chapter 4 in this volume).

Students may experience a sense of having to assimilate or conform to certain norms in order to be accepted and respected in STEM. This may involve relinquishing or minimising aspects of oneself or concealing them from peers or academic staff in order to be seen as a legitimate member of the academic community. Such conditions for belonging may involve deep personal sacrifices or a damaging disruption to one's identity and sense of self. For other students, it may not be possible, or indeed desirable, to 'fit in'. The question for us, then, is, 'What is it that STEM students are expected to fit in to?'

Conceptualising inclusion

Aislinn O'Donnell (2015) traces the philosophical tensions and contradictions inherent in our ideas about inclusive education. She argues that how we think about inclusion ultimately shapes how it is practised, and she reminds us that there are very real practical consequences of failing to reflect critically on what is meant by 'including others', within our universities, disciplines and programmes of study, or indeed in society at large. O'Donnell argues that, while inclusion is sometimes conceptualised through a 'frame of tolerance', this approach carries the risk that we will end up adopting 'a position of relative indifference to the other' (p. 249). Inclusion, she points out, is not a matter of merely tolerating the other. Furthermore, she problematises notions of inclusion understood as hospitality directed at and extended to *others*. It is not uncommon to see the language of 'welcoming diversity' in university communications. Implicit in these messages is the acknowledgement that these spaces have not always been hospitable to diverse *others*.

And yet, as O'Donnell writes:

> If inclusion is understood as 'welcoming inside', this presupposes that those to be welcomed are seen as the other to an 'us', as it relies upon images of a pre-existing home, hearth or territory into which someone is invited (or not). If one is invited, one is a guest in that house. In this respect, the other *qua* guest, stranger or alien is not at home and does not belong. (2015, p. 249)

Although the language of welcoming might appear inclusive at first glance, we are reminded that host and guest are not equal. The visitor is ultimately 'dependent upon the good will of the host' (O'Donnell, 2015, p. 250). Inclusion conceived in terms of hospitality, welcoming or as 'bringing in' comes with conditions. As a guest, I may be required to behave in a manner that is not habitually my own, abide by pre-existing house rules or learn to assimilate so effectively that my presence (and difference) is largely imperceptible to the host.

O'Donnell draws on Richard Kearney's philosophical exploration of the shared etymological root of the terms 'hospitality' and 'hostility'. Kearney notes that, in most Indo-European languages, the words for 'enemy', 'friend', 'host' and 'guest' are 'the same: *xenos* in Greek; *hostis*, *hospes* in Latin; both of these derivations of the root can mean either "enemy" or "friend", either "host" or "guest"' (O'Rourke, 2018, p. 28). Even as we welcome the guest, we should nonetheless be aware of how hospitality can 'readily shift into hostility, with the concomitant desire to extirpate those who are identified as other, foreign or strange' (O'Donnell, 2015, p. 250). Moreover, Kearney recognises the foundational role that the figure of the Other plays in the formation of our cultural identities. He argues that the image of the 'stranger', 'foreigner' or outsider functions in a similar way across different human societies, serving as a 'limit-experience for humans trying to identify themselves over and against others' (Kearney, 2003, p. 3). This, he maintains, is seen in the figure of the 'barbarians' for the Greeks, the Etruscans for the Romans, and the exotic 'savage' for the Europeans. Time and again, the image of the Other is mobilised to consolidate and define identities 'over and against others'.

This approach offers a productive starting point from which to interrogate the framing of inclusion *qua* hospitality. It is important to note that, while difference is a universal human feature, common to all people, diversity is typically associated with those coded as different. Following Graham and Slee (2008), we might then ask: '[D]ifferent to *what*?' (p. 279). It is this *what* that they strive to render visible in their work, the inconspicuous 'unnamed and unexplored' centre that invisibly yet powerfully sets the conditions for exclusion in the first place. It is populated by socially dominant groups around whom 'diverse others' are positioned. Graham and Slee argue that the very idea of inclusion implies a problematic '*bringing in*' (Graham, 2006, p. 20; emphasis added) of others from the outside to the 'centre', which prompts them to ask: '[W]hen we talk of including, into what do we seek to include?' (Graham & Slee, 2008, p. 277). They point to an 'implicit centredness' at the heart of our prevailing notions of inclusion, based on the idea of an imagined neutral 'naturalised space' into which *others* may be readily integrated (Graham & Slee, 2008, p. 278). This builds on the assumption that outsiders may be 'naturalised' and assimilated into a *centre* which itself remains structurally intact despite the presence of 'diverse others'.

While Kearney reminds us of how the image of the Other may be used by society to consolidate identity 'over and against others' (p. 3), he also highlights the emphasis on sameness operating within the concept of identity. We might therefore reflect on what, if anything, this tells us about how identities – and related communities, including those within STEM education – are formed and maintained. If identity is premised on 'sameness', what does it mean to include those who are different from 'us'? And if inclusion in STEM education is conceptualised as a process of 'welcoming' or 'bringing in' to the centre those who are on the outside, does this imply that diverse others might be expected to become the same as those on the inside?

In response to feelings of isolation, non-belonging and exclusion in STEM programmes, some students have created or sought out so-called 'counterspaces' (Ong, Smith & Ko, 2018). These are designed to function as 'havens from isolation' for underrepresented students, by offering a safe 'refuge' from learning environments that may be experienced as unwelcoming or alienating, and by opening up new social and educational landscapes. Such spaces may also serve to counter the cultural and structural 'norms of success' in STEM that tend to focus on 'competitive, individualistic, and solitary practices' (p. 206). From addressing experiences of social isolation and exclusion, through to the impacts of bias and stereotype threat in the classroom, counterspaces can provide students with peer-to-peer and mentor-to-peer support from which to address some of the impacts of marginalisation on underrepresented students. Opportunities to build relationships and network with others in these spaces can build new scientific communities and help jettison the long-standing, damaging and ultimately false notion of the figure of the scientific genius as white, male and solitary.

Conclusion

At the centre of this chapter is a critical interrogation of the framing of inclusion *qua* hospitality in STEM higher education. The philosophical insights of O'Donnell, Kearney, and Graham and Slee afford us an opportunity to reflect deeply on the the prevailing power asymmetries that exist between guest and host, problematising the idea of inclusion as the 'welcoming in' of those positioned on the margins of STEM communities. The experience of underrepresented students may thus be seen as analogous to that of a stranger or foreigner crossing into alien territory. The outsider may be welcomed inside as a visitor, but is ultimately not at home in the host's native place.

The notion of inclusion as a welcoming gesture may therefore perpetuate social hierarchies within STEM communities, and thereby reinforce the idea of certain groups as natural 'insiders' and others as 'outsiders'. Such dynamics may compel marginalised students to conform to alien norms and behaviours, to obey or adhere to pre-existing customs, or to sacrifice and compromise their identity in order to 'fit in' and gain acceptance and respect within a scientific community.

'Counterspaces' in STEM have arisen as a response to experiences of non-belonging or exclusion among marginalised students and may be seen as a deliberate and self-conscious decision to not belong to mainstream educational environments. These spaces purposely challenge ideas of who is afforded legitimacy in science. They function as platforms for underrepresented students to construct their own scientific communities, thereby resisting the idea of scientific work as essentially isolated and competitive, and they serve to recognise and support the fundamentally social nature of education.

Creating a sense of belonging in education demands that we critically examine how inclusion is framed and conceived, and develop a deeper awareness of how efforts to include 'others' may unintentionally serve to exclude or marginalise. Rather than understanding inclusion as the seamless integration of those from the outside into the inside, true inclusion does not seek to uphold, maintain and protect a traditional 'centre' that admits only those who are easily incorporated. It involves opening up new space within the mainstream, not only in terms of rectifying systemic barriers to entry and access to resources, but by addressing exclusion at the level of policy, procedure and practice. It also means interrogating how power functions within STEM communities, and how the underrepresentation of certain demographic groups among administrative and teaching staff, particularly those in leadership positions, perpetuates powerful messages about who belongs as a natural 'insider'. By reimagining inclusion in STEM from the perspective of those on the 'outside', we may be able to create educational environments in which students do not have to compromise their identities in order to 'fit in', where nobody feels like a guest, and all individuals are acknowledged and supported as full and equal members of the academic community.

Note

1 In the United States, an associate degree or associate's degree is typically a two- or three-year undergraduate degree, more advanced than a high school diploma but below a bachelor's degree.

References

Good, C., Rattan, A. & Dweck, C. S. (2012). Why do women opt out? Sense of belonging and women's representation in mathematics. *Journal of Personality and Social Psychology*, 102(4), 700–14. https://doi.org/10.1037/a0026659.

Goodenow, C. (1993). Classroom belonging among early adolescent students: Relationships to motivation and achievement. *Journal of Early Adolescence*, 13(1), 21–43. https://doi.org/10.1177/0272431693013001002.

Graham, L. J. (2006). Caught in the net: A Foucaultian interrogation of the incidental effects of limited notions of inclusion. *International Journal of Inclusive Education*, 10(1), 3–25. https://doi.org/10.1080/13603110500173217.

Graham, L. J. and Slee, R. (2008). 'An illusory interiority: Interrogating the discourse/s of inclusion'. *Educational Philosophy and Theory*, 40(2), 277–93. https://doi.org/10.1111/j.1469-5812.2007.00331.x.

Guyotte, K. W., Flint, M. A. and Latopolski, K. S. (2021). Cartographies of belonging: Mapping nomadic narratives of first-year students. *Critical Studies in Education*, 62(5), 543–58. https://doi.org/10.1080/17508487.2019.1657160.

Hurtado, S., Newman, C. B., Tran, M. C. and Chang, M. J. (2010). Improving the rate of success for underrepresented racial minorities in STEM fields: Insights from a national project. *New Directions for Institutional Research*, 2010(148), 5–15. https://doi.org/10.1002/ir.357.

Johnson, D. R. (2012). Campus racial climate perceptions and overall sense of belonging among racially diverse women in STEM majors. *Journal of College Student Development*, 53(2), 336–46. https://doi.org/10.1353/csd.2012.0028.

Kearney, R. (2003). *Strangers, Gods and Monsters: Interpreting otherness*. London: Routledge.

Murphy, M. C., Steele, C. M. & Gross, J. J. (2007). Signaling threat: How situational cues affect women in math, science, and engineering settings. *Psychological Science*, 18(10), 879–85. https://doi.org/10.1111/j.1467-9280.2007.01995.x.

National Center for Science and Engineering Statistics (NCSES). 2023. *Diversity and STEM: Women, minorities, and persons with disabilities 2023*. Special Report NSF 23-315. Alexandria, VA: National Science Foundation. https://ncses.nsf.gov/wmpd. Accessed 12 December 2023.

NSF/NCSES (National Science Foundation, National Center for Science and Engineering Statistics). (2015). Women, minorities, and persons with disabilities in science and engineering: 2015 (Special Report NSF 15–311). Arlington, VA: National Science Foundation. https://www.nsf.gov/statistics/.

O'Donnell, A. (2015). Beyond hospitality: Re-imagining inclusion in education. In A. O'Donnell (ed.), *The Inclusion Delusion? Reflections on democracy, ethos and education*, pp. 249–69. Oxford: Peter Lang.

Ong, M., Smith, J. M. & Ko, L.T. (2018). Counterspaces for women of color in STEM higher education: Marginal and central spaces for persistence and success. *Journal of Research in Science Teaching*, 55(2), 206–45. https://doi.org/10.1002/tea.21417.

Ong, M., Wright, C., Espinosa, L. & Orfield, G. (2011). Inside the double bind: A synthesis of empirical research on undergraduate and graduate women of color in science, technology, engineering, and mathematics. *Harvard Educational Review*, 81(2), 172–209. https://doi.org/10.17763/haer.81.2.t022245n7x4752v2.

O'Rourke, B. (2018). Intercultural encounters as hospitality: An interview with Richard Kearney. *Journal of Virtual Exchange*, 1, 25–39. Research-publishing.net. https://doi.org/10.14705/rpnet.2018.jve.2.

Rainey, K., Dancy, M., Mickelson, R., Stearns, E. & Moller, S. (2018). Race and gender differences in how sense of belonging influences decisions to major in STEM. *International Journal of STEM Education*, 5, art. no. 10. https://doi.org/10.1186/s40594-018-0115-6.

Smith, J. L., Lewis, K. L., Hawthorne, L. & Hodges, S. D. (2013). When trying hard isn't natural: Women's belonging with and motivation for male-dominated STEM fields as a function of effort expenditure concerns. *Personality and Social Psychology Bulletin*, 39(2), 131–43. https://doi.org/10.1177/0146167212468332.

Strayhorn, T. L. (2012). *College Students' Sense of Belonging: A key to educational success for all students*. New York: Routledge.

Thoman, D. B., Arizaga, J. A., Smith, J. L., Story, T. S. & Soncuya, G. (2014). The grass is greener in non-science, technology, engineering, and math classes: Examining the role of competing belonging to undergraduate women's vulnerability to being pulled away from science. *Psychology of Women Quarterly*, 38(2), 246–58. https://doi.org/10.1177/0361684313499899.

Varma, R., Prasad, A. & Kapur, D. (2006). Confronting the 'socialization' barrier: Cross-ethnic differences in undergraduate women's preference for IT education. In J. M. Cohoon & W. Aspray (eds), *Women and Information Technology: Research on underrepresentation*, pp. 301–22. Cambridge, MA: MIT Press.

Walton, G. M. & Cohen, G. L. (2007). A question of belonging: Race, social fit, and achievement. *Journal of Personality and Social Psychology,* 92(1), 82–96. https://doi.org/10.1126/science.1198364. https://doi.org/10.1037/0022-3514.92.1.82.

Walton, G. M. & Cohen, G. L. (2011). A brief social-belonging intervention improves academic and health outcomes of minority students. *Science*, 331(6023), 1447–51. https://www.science.org/doi/10.1126/science.1198364.

3

Belonging and engaging for successful transition to university

Alison Voice, Rob Purdy, Nicolas Labrosse and Helen Heath

Introduction

Feeling that you belong on your course is crucial to flourishing in your academic studies. This chapter explores factors that affect belonging as students transition to university STEM courses through the lenses of social, cultural and science capital, and considers the impact of stereotyping. A mixed-methods longitudinal study of physics students at three institutions in the UK was undertaken to understand how students' pre-university background influences their expectations of and lived experience during their first year of study. Data obtained in 2019–20 is compared with that acquired during the pandemic in 2020–21, when much study was undertaken remotely, to reveal the essential aspects that promote feelings of belonging and identity in STEM.

Belonging, engaging and success

Patricia Broadfoot summarised What Works research on student retention and success and stated: 'It is the human side of education that comes first – finding friends, feeling confident and above all, feeling a part of your course of study and the institution – that is the necessary starting point for academic success' (Broadfoot, 2012). Hausmann, Schofield and Woods (2007) similarly report that student belonging and engagement are crucial for retention and success in the first year at university. This link between belonging and transition is expanded by Vaz et al. (2014): they show that high school pupils have better mental health if they have previously felt a good sense of belonging at their primary school; this suggests that a sense of belonging at university could be equally important for successful transition into their future career. It is thus imperative to get the transition from school to university right.

Maslow (1954), in his hierarchy of needs, placed belonging, along with love and affection, immediately after physiological and safety requirements. He described the need for belonging as something where a person will 'hunger for affectionate relations with people in general, … for a place in his group' (p. 89). Many other authors have described this sense of belonging. Goodenow (1993) defines belonging as 'students' sense of being accepted, valued, included, and encouraged by others (teachers and peers) in the academic classroom setting and of feeling oneself to be an important part of the life and activity of the class' (p. 25).

More recently, Lambert et al. (2013) phrase belonging as 'the subjective experience of having relationships that bring about a secure sense of fitting in' (p. 1418). Goodenow and Grady (1993) showed that students who have a greater sense of belonging have a higher chance of being 'motivated and academically engaged' (p. 67), but where schools were unable to foster a sense of belonging this led to reduced academic drive, reduced engagement and increased incidence of students leaving school. Definitions of engagement in the literature suggest that it is about student involvement with their desired goal. Astin ([1984] 1999), one of the first to propose a model for student engagement, defines it as 'the amount of physical and psychological energy that the student devotes to the academic experience' (p. 518).

Through a student experience questionnaire Pace (1984) found that the more students put into their college experience, the more they got out of it, and that this quality of effort was the best predictor of students' progress. Kuh (Kuh et al., 2006; Kuh, 2009) goes a step further, to place responsibility not only on the student but also on the institution, identifying student–faculty interactions as an important factor in retention. Harper (2008) suggests that engagement can afford students higher social capital, as demonstrated by high-achieving African American male graduates on predominantly white campuses. The interplay between belonging and engagement is highlighted by Liz Thomas and colleagues (Thomas, 2012; Thomas et al., 2017), who suggest that a sense of belonging is developed through engagement. Hausmann, Schofield and Woods (2007) also raise this link in their work with first-year college students, finding that early social experiences are more likely than their academic experience to dictate a student's initial sense of belonging, but that as the year progresses academic integration becomes more important.

Success at university can mean different things to different students, which makes it hard to give a simple or concise definition. Thomas suggests a broad definition: 'helping all students to become more engaged and more effective learners in higher education, thus improving their academic outcomes and their progression opportunities after graduation' (2012, p. 10). And Kuh et al. give an even broader statement: 'academic achievement, engagement in educationally purposeful activities, satisfaction, acquisition of desired knowledge, skills and competencies, persistence, attainment of educational objectives, and postcollege performance' (2006, p. 7). Despite their all-encompassing views, both these definitions have the common themes of effective engagement, academic achievement and post-university success.

Theoretical model

If we draw these ideas together, it becomes evident that the process of transition and integration into life at university requires students to have a sense of belonging and to become engaged in their new environment if they are to achieve their potential academically and in their future life. These processes can be explored through a Bourdieusian approach that uses the ideas of social and cultural capital (Bourdieu, 1986). In this context social capital relates to networking or membership of a group, and the opportunities afforded by this. Cultural capital relates to the knowledge of how to act in certain situations, such as using correct language.

In the context of science, technology, engineering and mathematics (STEM) courses, the concept of 'science capital', introduced by Archer, Dawson et al. (2015), can be added. This is a measure of the extent to which someone has prior experience of science, for example close relatives who have science qualifications or work in science, childhood play with science kits, or trips to museums and science centres. This finding resonates with those of Hausmann, Schofield and Woods (2007) that sense of belonging requires not only social but also academic engagement. The concept of 'science identity' proposed by Carlone and Johnson (2007) provides a related lens through which to view the transition of students into university science degrees. Science identity is a measure of the extent to which a person views themselves, and is recognised by others, as a 'science person'.

Social identity theory is useful here (see also Myyry, Kallunki and Sahoo, Chapter 6 in this volume). This describes a person's sense of who they are, based on the groups they belong to (Tajfel, 1981). Such groups can be based on gender, family, class, nationality or following a sports team. They afford a sense of belonging, pride, solidarity and self-esteem. Similarly, Bourdieu (1986) proposed the concept of 'habitus', simply a notion of 'who we are', or what is 'normal for us', given the groups we are members of.

Finally, in this context there is relevant research on 'stereotype threat' (Steele & Aronson, 1995). If people acquire their identity through being a member of a certain group, and see others outside that group as different, then stereotypes can develop. If those stereotypes have negative connotations, and members of the group believe them, they can be adversely affected. For example, a commonly held stereotype is that women are less suited to science, and physics especially (Archer, Moote et al., 2017); this stereotype can inhibit women and girls from choosing to study these subjects, or lead to them feeling out of place in science contexts (see also Smith, Chapter 9 in this volume).

Using this framework of social, cultural and science capital, along with the concepts of social identity and stereotype threat, this chapter investigates the effect of different demographics and backgrounds on students' sense of belonging and engagement as they transition to higher education in STEM. It proposes ways strong learning communities can be built to allow all students to achieve success.

Transition to university

Prior factors

Before students arrive at university, there are many 'forces' at play influencing whether they will even apply for a STEM course. The gender ratio of students studying STEM has not changed much over recent decades, with physics, computing and engineering degrees having around 25 per cent or fewer female students. Chemistry and maths have around 40 per cent female students, whereas biology typically attracts 60 per cent females (Institute of Physics, 2018). These statistics are self-perpetuating, as they set the 'visible norm' for who should take these subjects, which only serves to enhance the stereotypes.

In the framework of kinds of capital and stereotypes, girls typically have stronger social capital and interact with peers more easily (Hajovsky et al., 2022). Their academic capital is at least equal to boys'; they often outperform them at school, not only in the UK, but in nearly all developed countries (Adams, 2021). Girls perform better than boys even in countries where women lack equality with men (Richardson, 2015). But it is the cultural capital they lack, when the world around them suggests that STEM is mainly for males. This stereotype is so strongly held that it influences not only prospective students but their teachers and parents. There has been much debate about whether this tendency is mitigated when students attend single-sex schools (Abraham & Barker, 2020), but the jury is still out.

Research has been undertaken on the wider factors that influence students' decisions whether to study STEM. Archer and DeWitt (2017) undertook a five-year longitudinal study of young people (age 10–14 years) and their views and aspirations in science. They looked at the impact of ethnicity, class, gender and parental influence, using the lens of family habitus and science capital, and concluded that it is not lack of interest in science that prevents students from choosing to study it at university, but lack of science capital during their upbringing. Jones and Hamer (2022) have researched the influence of parental views on their children's continued study of physics, and have shown that children's attitudes towards physics correlate strongly with those of their parents and carers.

The stereotype that science is for brainy, white, male, middle-class people raises a high barrier for students who tick few or none of those boxes. Through the lens of Bourdieu's habitus, young people may simply feel 'That's just not me'. Archer and DeWitt (2017) have shown that the science capital of Black families is low as they often have a narrow view of what science can lead to, and that of many working-class families is almost non-existent. Students who 'overcome' these challenges and stereotypes sufficiently to apply and be admitted to university to study science often need much ongoing support and affirmation if they are to belong and succeed.

Arrival at university

The first few weeks at university are crucial for building a sense of belonging which sets the foundation for subsequent learning (Thomas, 2017). Each student is unique, and categorising does not explain the nuances of each individual's situation and feelings, but a consideration of the following aspects can help raise awareness of the wide range of factors that need to be addressed to extend a welcome and safe environment to all newcomers.

First-generation students

Students who are in the first generation of their family to attend university can have a significant cultural deficit. They can lack prior knowledge of the daily norms of academic behaviour at university: how to talk with staff, who to ask for help, how and when they are supposed to study independently. They may have no family members to help prepare them for this 'hidden curriculum' (Jackson, 1990). Gillen-O'Neel (2021) reports that being in this first generation can cause daily fluctuations in sense of belonging, because of the unfamiliarity of the environment. Padgett et al. (2012) comment that first-generation students do not benefit as much as other students from contact with staff, because of their lack of familiarity with university culture.

Foundation courses

Students who enter their degree programme from a foundation course (a preparatory, pre-degree year of study) have already spent a year at university. They are thus more familiar with the system than other new students, which raises their cultural capital. Even if they are in the minority on their course, their sense of belonging can be fostered through making connections with peers from similar backgrounds (O'Sullivan et al., 2019).

Mature students

Mature students are defined as those entering university aged 21 or over. They have a very wide age range, and hence huge variety in prior experience and situation, not least in that their preferred social activities or availability may differ significantly from the 18-year-olds who are in the majority. Mature students have been observed to have lower levels of belonging than their peers (Coates, 2014; Erb & Drysdale, 2017) but to have higher levels of engagement and self-efficacy in their studies (Erb & Drysdale, 2017; Thomas et al., 2017). Their academic capital may also differ significantly from that of the majority because of the length of time since they obtained their previous qualifications, or because they have taken a different route to university. Students who commute to university from their family or own home can experience problems in interacting socially with peers because of travel difficulties or because of other commitments, which can affect their sense of belonging.

International students

Students from overseas may lack academic capital if they have studied a different curriculum from the majority of their cohort, and if English is not their first language they may feel they lack the social or cultural capital of their native peers. This lack of capital can manifest as lack of familiarity with current music, TV programmes, social activities or food and drink, which may make international students feel at a disadvantage in social interactions. University international societies often extend a great welcome to new students, to help them acclimatise and feel a sense of belonging within a community of people with a similar national or cultural/ethnic background, but many international students find it hard to move beyond such groups to integrate with their course cohort. This tendency to remain with a culturally familiar group can perpetuate their lack of confidence with language, which may leave them nervous about speaking in class, and thus less likely to ask questions, or to feel equal in discussing academic work. Le et al. (2016) found that a good relationship with an advisor or mentor was vital to the adjustment process and sense of belonging for international students.

Racially minoritised students

A sense of belonging is particularly important for students from ethnic minority backgrounds; Just (1999) describes it as 'crucial to their persistence' in college, and Swail (2003) likewise identifies 'social and academic integration' as crucial for the retention of such students. Students from different ethnic groups may observe different or unfamiliar religious traditions and celebrate different feast days from the majority of the cohort. This can make them feel uncomfortable about having to explain or stand out as different, which may lead to stereotype threat. Another cause of anxiety can be the presence of alcohol at induction and welcome events: many ethnic minority students prefer to avoid alcohol for religious or cultural reasons.

It is important to note that the above factors are not mutually exclusive, and many students can identify with several such identities. For example, students who have undertaken a foundation course are often a little older and may thus live independently and commute to campus. Such students may also be in the first generation of their family to attend university, or be of a different ethnic origin from the majority. It can be hard for such students to identify and socialise with the white 18-year-olds who form the majority. Indeed, Hausmann, Ye et al. (2009) recognise how crucial it is that institutions foster a sense of belonging in students from all backgrounds, by considering the unique challenges faced by each different minority group.

STEM learning

In the light of the kinds of capital and stereotypes mentioned above, we consider the typical nature of, and the learning activities included in, a STEM course in higher education, in order to appreciate how different students may find some aspects of such a course challenging.

The right answer

STEM subjects are positivistic in nature, making the assumption that there is a single 'right answer' to how the universe behaves, and that the work of scientists is to determine this with ever-increasing accuracy through the interplay between controlled experiments and theoretical predictions. Undergraduate courses in STEM naturally reflect this assumption: students typically spend the first two years covering the currently accepted knowledge in the discipline, and are examined on their mastery and understanding of it. This means that most questions and assessments have a 'right' answer: a number, a definition, a routine procedure; if students do not fully know or understand it they feel unable to contribute anything. It is not meaningful to half-know an equation. At this level STEM is not about students' opinions or experiences, it is about knowledge. For this reason students' prior academic qualifications and science capital are crucial and can have a strong influence on their sense of belonging in the class.

Brilliance

A common stereotype is that to excel in science students need to be 'brilliant' and possess innate intellectual talent. Leslie et al. (2015) have shown that this stereotype significantly affects women and African Americans, both of whom are subject to stereotype threat and discrimination in this respect. This brilliance stereotype also influences students' self-efficacy, that is, one's belief in one's ability to succeed in a given task or domain, as defined by Bandura (1997). Nissen (2019) has studied self-efficacy in Californian high school students, and concluded that the masculine culture in physics, engineering and computer science correlates with decreases in women's self-efficacy in physics courses but not in mathematics, biology or chemistry courses, where women make up a much larger proportion of the class. Similar reduction in females' self-efficacy is found within engineering majors at university (Whitcomb et al., 2020).

Additionally, a cultural difference exists between school and university STEM subjects. Given the pervading stereotype that you need to be brilliant to do science, and the often competitive nature of admission to STEM programmes at university, students arriving on STEM programmes are likely to have been amongst the top performers in their school classes. Students who possess a high degree of self-efficacy can feel a strong sense of belonging in this environment. However, other students can lose confidence when they realise they are not as special as they previously thought. A related cultural difference is that the threshold for the top grade at university is 70 per cent, whereas at school it was likely to be 90 per cent; getting lower marks on the university scale can make students feel like a 'failure'.

The situation is further complicated for mature students, who may have had many years out of STEM education, and forgotten what they once knew. International students may not have studied some topics common to home students. And students admitted on a contextual offer, whereby lower grades are accepted because of the low socioeconomic status of the neighbourhood of their school, may also have less prior knowledge. This lack of academic scientific capital may mean that these students feel they start at a disadvantage, if this situation is not managed well by the university.

Investigation in physics

Methodology

To increase our understanding of the factors that affect students' sense of belonging, and their impact on subsequent engagement and academic success, we undertook a longitudinal study with first-year physics students as they transitioned into higher education. Students at the universities of Leeds, Glasgow and Bristol were surveyed at three key points in the year. The first survey was administered in September 2019 as students arrived to start their course; it sought to capture their initial feelings and expectations. The second survey took place in December 2019, at the end of the first semester, and aimed to compare students' lived experience with their prior expectations. The third was at the start of April 2020, and its object was to obtain information about the first set of exam results and find out how students felt about them. Although this third survey was technically released in the first few weeks of the Covid-19 lockdown, it referred to exams and results released before lockdown, and therefore data from these surveys was considered to pertain to activities that took place before the pandemic. Surveys were also run with the 2020–21 cohort, which was mostly taught remotely. This timing serendipitously allowed comparison of more traditional pre-pandemic induction activities and teaching with the largely remote experience necessitated by the Covid-19 pandemic.

To maximise the response rate, surveys were run in teaching or introductory sessions where possible, and by academic school staff to demonstrate the importance of and the value placed on the results. Responses were anonymous, but a unique code was used to facilitate longitudinal analysis of each student's responses through the year. This study was undertaken with ethical approval from the University of Leeds (MEEC 17-001). A total of 1,106 students responded to one or more of the surveys (641 in 2019–20 and 465 in 2020–21); this represented 80–90 per cent of the total cohort across the three universities.

Quantitative and qualitative questions were used to gain both a measure and an understanding of students' feelings of belonging, engagement and success. A summary of the main question areas is given in Table 3.1. Survey design and analysis were undertaken in conjunction with students via summer internships to ensure that the study focused on the issues that were of most importance to students.

Factors affecting sense of belonging

Students were asked to respond on a five-point Likert scale, from strongly agree (SA) to strongly disagree (SD), to the statement 'I feel I belong on my course'. This revealed that the great majority (72 per cent) of students agreed (A) or strongly agreed (SA) that they belonged at the start of their course. Twenty-three per cent admitted to feeling neutral about this, but 5 per cent disagreed (D) or strongly disagreed (SD). The group of students with negative sense of belonging included a slightly higher proportion (44 per cent) who said they were in the first generation of their family to attend university than the rest of the cohort (33 per cent). This negative-belonging group also reported feeling much less clued up about university (25 per cent) than the rest of the cohort (2 per cent). Additionally, 31 per cent of them felt much less confident about making friends, compared to only 9 per cent in the rest of the cohort. This suggests that first-generation students can be anxious from the start that they may be perceived as different from the majority of the cohort, and that they may thus find it hard to integrate, which may reduce their social capital.

Table 3.1 Summary of aspects explored in survey questions

Background	Belonging	Engagement	Success
Gender / LGBTQ+	I belong on my course	Clued up about uni	Achieved results hoped for
Nationality / ethnicity	I feel valued by staff	Confident with independent learning	How feel about results
Socioeconomic factors	Prepared academically	Technology is often a problem	How responded to results
First generation	Confident making friends	No quiet place to study	
Entry route / qualifications	My background makes me feel different	Nervous to speak in class	

Gender effects

So that we could investigate their academic science capital, we asked students to rate how they felt they compared to their peers with respect to preparedness for and ability to cope in core skills of maths and laboratory practice, using a five-point Likert scale ranging from 'a lot more prepared' to 'a lot less prepared'. In both study years the female students reported lower confidence than males in maths preparedness as they transitioned to university. This confirms the stereotype threat that females do not see themselves as equal participants in STEM, and especially physics, courses. However, after the spring exams, in both years, this gender difference, reported as ability to cope with maths, was no longer evident, the average female confidence having risen, and the average male confidence having fallen slightly. This suggests that feedback and exam results at university are a good way for students to evaluate how they are performing, and a powerful way to build the confidence of female students.

For laboratory skills a similar effect was seen: female students reported lower confidence than male students as they transitioned to university. This time, in 2019–20, after a semester of laboratory work, the confidence of both females and males had risen. However, in 2020–21 (during the Covid-19 pandemic), when there were few in-person laboratories and most lab skills were developed by remote activities, the confidence of males increased and that of females decreased. This highlights the power of in-person experience to build the confidence of female students, and the negative effect when this is absent.

This gender effect was also apparent in regard to the social aspect of forming friendships. In the pre-pandemic year, the gender gap in confidence about making friends as students arrived at university was not observed in December. However, in 2020–21 both genders reduced in confidence about friendships because of the significant lack of in-person activities that resulted from the pandemic.

These results reported here emphasise the lower self-efficacy of women entering physics courses, which broadly agrees with ideas widely discussed in the literature. For example, Cwik and Singh (2021) found a gender gap in self-efficacy at the beginning of the course that disadvantaged women. They attributed this to societal stereotypes and biases internalised by female students over their lifetime. But female students should not have to wait for feedback to realise their worth, and staff should do all they can to affirm the rightful place of women on STEM courses and to negate any adverse stereotypes.

Disadvantaged by background

To bring to the surface other factors that affect students' sense of belonging and engagement, the surveys asked if students felt disadvantaged by their background. This revealed a range of issues which can be categorised as related to social, cultural or academic capital. Socially, the issue of language was mentioned: for example, 'English is not my first language and sometimes I won't engage in a conversation because I'm not confident enough'. Cultural issues such as socioeconomic situation and class were raised: 'Financially I feel disadvantaged because many people get support from parents. I have to budget.' Academically, a range of issues relating to qualifications were mentioned: 'As I got into university with a contextual offer, I felt not as good as everyone else. I worked extra hard to prove I deserved to be there.' This last comment perhaps demonstrates the delicate balance that arises from supporting students from all backgrounds, whereby the very thing undertaken to 'level the playing field' for students from poorer neighbourhoods (for example a reduced-grades offer) inadvertently singles them out as disadvantaged and different.

Social interaction

The Covid-19 pandemic, with its remote teaching, provided an opportunity for great insight into the importance of social interaction in higher education. The 2020–21 surveys in December and April asked students about their feelings about, and ability to engage in, class activities. Asked to respond on a Likert scale to the statement 'I feel nervous to speak on the microphone in class' it was the female students and first-generation students who reported being the most nervous. This result again suggests that students need to have a certain amount of cultural capital in order to have the confidence or knowledge of how to speak in such an unfamiliar setting. The students reporting the most confidence to speak in remote classes were male. This is strongly related to the concept of social identity. According to Hofstede (1991), males are conditioned to be assertive, competitive and ego-oriented, whereas females are conditioned to be more modest and collaborative, and to care for weaker individuals.

Despite anxiety in speaking up in front of the whole class, it was clear from numerous responses that students highly value small-group interaction with peers or staff: 'The remote small group tutorials work well – it's nice to see other tutees. It is not just social contact they value, but also building relationships: "I really liked the fact that we have kept the same workshop groups throughout the full year."' The benefits of social interaction are well documented in the literature, which demonstrates that belonging and engagement can be enhanced through increased peer-to-peer conversations (Hilts et al., 2018; Thomas, 2012). Tinto (1997) reports that such academic socialising is linked to higher grades and better retention, and Tao et al. (2000) report that peers are 'the most important social agents' for students transitioning into university in China.

Success

Success is hard to quantify, as different students have different aspirations. Some are just happy to pass the exams, whilst others are disappointed if they do not get top marks. In 2019–20 the distribution of students' feelings about their results spanned the whole five-point scale, from 'really pleased' to 'very disappointed', but most students fell into the middle three categories, and there was no obvious correlation with feelings of belonging. However, by this third survey the response rate was lower, and it may be that students who felt demotivated, with poor sense of belonging, did not respond. This possibility gets at the very heart of the issue, how to engage the unengaged. And therefore it is important to get transition right, in order to help all students feel welcome and valued from the start, as Thomas et al. (2017) have noted.

In 2020–21 there was a stronger correlation between poor sense of belonging and dissatisfaction with exam results. Similar links between academic self-efficacy and academic performance have been reported by Freeman et al. (2007) and Chemers et al. (2001). In this way the pandemic has heightened our awareness of the consequences for students who have poor sense of belonging and become isolated:

> I've struggled with imposter syndrome and I think this is because I haven't witnessed anyone else struggling with difficult topics. I've felt lonely and haven't really spoken to anyone my age in quite a while. Conversation about my degree has been minimal. As a result of all this I stopped engaging for a while.

Lessons from the Covid-19 pandemic

No one wants a world pandemic at any time, especially in the middle of a research project. But the enforced pivot to remote teaching gave us a unique chance to understand what students need for their sense of belonging, engagement and success, by stripping back the learning experience to the bare minimum. The main benefit to emerge was the flexibility afforded by the fact that learning material was available online; students could view and re-view it when it suited them. The overwhelming downside to remote learning was the lack of social interaction, as discussed above; one student reported the situation as 'Far worse – meaningful connection is hard online.'

However, some students said they preferred remote study. A more detailed investigation revealed that these students comprise a high proportion of first-generation students and those not living in university accommodation, along with others such as those with a disability (physical or mental). This finding highlights the struggle that such students may have to attend university each day, and challenges institutions to find ways to support and include these students without adding a burden to their lives. A balance needs to be found, whereby such students can access material without undue discomfort or inconvenience, but can still engage with peers and staff to benefit from academic discussions, receive support and develop the social side of learning and professional communication.

Conclusions and recommendations

Students are unique in their feelings and situations and we cannot categorise, or assume that one size fits all. That being said, common factors have emerged from our research that provide a focus for the kind of support needed to enhance students' sense of belonging and engagement. These factors relate to students' background before they enter their STEM course at university, and are expressed in a framework of social, cultural and academic science capital, alongside concepts of social identity and stereotype threat.

Firstly, it is important to recognise the stereotype threat to female and other minority students within STEM. To counter this it is important that these students are not singled out for support. Rather, *all* students should be welcomed and told that we have admitted all of them because they have the qualifications and qualities to succeed. This builds a collective culture that acknowledges and celebrates everyone's diverse talents and prior experiences.

To build social identity, we suggest that small groups (for tutorials, workshops, labs, etc.) are formed, to ensure that all minoritised students have at least one similar person in their group, so all students can meet 'someone like me'. In this way students can bond and support each other to overcome any lack of social, cultural or science capital. Keeping the composition of these groups constant throughout the year can support students to overcome social barriers and build strong relationships with each other and with staff, so that they can admit their insecurities and support each other.

An additional consideration with group work is that neurodiverse students, or those with other specific learning preferences, can find this kind of social environment overwhelming (see also Leigh, Sarju and Slater, Chapter 14 in this volume). Care should thus be taken to provide some quiet activities, or ensure that everyone accepts it as normal if some students do not wish to speak or join in fully with group activities. Social events outside class can be wonderful for building a sense of belonging, but they need to be inclusive. Some students feel uncomfortable when alcohol is included. Students who do not live close to campus may have to commute and hence not be available after teaching hours. Not all students have appropriately aligned learning strategies or know how to approach staff or others for support. All new situations, activities and assessments should be clearly described and explained to everyone.

In summary, a sense of belonging is not something an individual student can create for themselves, but 'something that must be given, like a gift' (Nunn, 2021, p. 8). To provide this gift we have a collective responsibility to create a welcoming, accepting, supporting environment so that all students feel they belong, and accept that all others belong, so that all can thrive.

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References

Abraham, J. and Barker, K. (2020) Motivation and engagement with physics: A comparative study of females in single-sex and co-educational classrooms. *Research in Science Education*, 50(6), 2227–42. https://doi.org/10.1007/s11165-018-9770-3.

Adams, R. (2021) Girls overtake boys in A-level and GCSE maths, so are they 'smarter'? *The Guardian*, 13 August. https://www.theguardian.com/education/2021/aug/13/girls-overtake-boys-in-a-level-and-gcse-maths-so-are-they-smarter. Accessed 12 December 2023.

Archer, L., Dawson, E., DeWitt, J., Seakins, A. and Wong, B. (2015) 'Science capital': A conceptual, methodological, and empirical argument for extending Bourdieusian notions of capital beyond the arts. *Journal of Research in Science Teaching*, 52(7), 922–48. https://doi.org/10.1002/tea.21227.

Archer, L. and DeWitt, J. (2017) *Understanding Young People's Science Aspirations: How students form ideas about becoming a 'scientist'*. Abingdon: Routledge.

Archer, L., Moote, J., Francis, B., DeWitt, J. & Yeomans, L. (2017). The 'exceptional' physics girl: A sociological analysis of multimethod data from young women aged 10–16 to explore gendered patterns of post-16 participation. *American Educational Research Journal*, 54(1), 88–126. https://doi.org/10.3102/0002831216678379.

Astin, A. W. ([1984] 1999). Student involvement: A developmental theory for higher education. *Journal of College Student Development*, 40(5), 518–29.

Bandura, A. (1997) *Self-Efficacy: The exercise of control*. New York: W. H. Freeman,

Bourdieu, P. (1986). The forms of capital. In J. G. Richardson (ed.), *Handbook of Theory and Research for the Sociology of Education*, pp. 241–58. Westport, CT: Greenwood Press.

Broadfoot, P. (2012). Foreword. In L. Thomas, Building student engagement and belonging in higher education at a time of change: A summary of findings and recommendations from the What Works? Student Retention & Success programme, p. 1. Paul Hamlyn Foundation. https://web.archive.org/web/20240403110819/https://www.phf.org.uk/wp-content/uploads/2014/10/What-Works-Summary-report.pdf. Accessed 7 January 2024.

Carlone, H. B. and Johnson, A. (2007) Understanding the science experiences of successful women of colour: Science identity as an analytical lens. *Journal of Research in Science Teaching*, 44(8) 1187–1218. https://doi.org/10.1002/tea.20237.

Chemers, M. M., Hu, L.-t. & Garcia, B. F. (2001) Academic self-efficacy and first-year college student performance and adjustment. *Journal of Educational Psychology*, 93(1), 55–64. https://doi.org/10.1037//0022-0663.93.1.55.

Coates, H. (2014). Students' early departure intentions and the mitigating role of support. *Australian Universities' Review*, 56(2), 20–9.

Cwik, S. & Singh, C. (2021) Damage caused by societal stereotypes: Women have lower physics self-efficacy controlling for grade even in courses in which they outnumber men. *Physical Review Physics Education Research*, 17(2), 020138.

Erb, S. & Drysdale, M. T. B. (2017). Learning attributes, academic self-efficacy and sense of belonging amongst mature students at a Canadian university. *Studies in the Education of Adults*, 49(1), 62–74. https://doi.org/10.1080/02660830.2017.1283754.

Freeman, T. M., Anderman, L. H. & Jensen, J. M. (2007). Sense of belonging in college freshmen at the classroom and campus levels. *Journal of Experimental Education*, 75(3), 203–20. https://doi.org/10.3200/JEXE.75.3.203-220.

Gillen-O'Neel, C. (2021). Sense of belonging and student engagement: A daily study of first- and continuing-generation college students. *Research in Higher Education*, 62(1), 45–71. https://doi.org/10.1007/s11162-019-09570-y.

Goodenow, C. (1993). Classroom belonging among early adolescent students: Relationships to motivation and achievement. *Journal of Early Adolescence*, 13(1), 21–43. https://doi.org/10.1177/0272431693013001002.

Goodenow, C. & Grady, K. E. (1993). The relationship of school belonging and friends' values to academic motivation among urban adolescent students. *Journal of Experimental Education*, 62(1), 60–71. https://www.jstor.org/stable/20152398.

Hajovsky, D. B., Caemmerer, J. M. & Mason, B. A. (2022). Gender differences in children's social skills growth trajectories. *Applied Developmental Science*, 26(3), 488–503. https://doi.org/10.1080/10888691.2021.1890592.

Harper, S. R. (2008) Realizing the intended outcomes of Brown: High-achieving African American male undergraduates and social capital. *American Behavioral Scientist*, 51(7), 1030–53. https://doi.org/10.1177/0002764207312004.

Hausmann, L. R. M., Schofield, J. W. & Woods, R. L. (2007) Sense of belonging as a predictor of intentions to persist among African American and white first-year college students. *Research in Higher Education*, 48(7), 803–39. https://doi.org/10.1007/s11162-007-9052-9.

Hausmann, L. R. M., Ye, F., Schofield, J. W. & Woods, R. L. (2009) Sense of belonging and persistence in white and African American first-year students. *Research in Higher Education*, 50(7), 649–69. https://doi.org/10.1007/s11162-009-9137-8.

Hilts, A., Part, R. & Bernacki, M. L. (2018). The roles of social influences on student competence, relatedness, achievement, and retention in STEM. *Science Education*, 102(4), 744–70. https://doi.org/10.1002/sce.21449.
Hofstede, G. (1991). *Cultures and Organizations: Software of the mind*. London: McGraw-Hill.
Institute of Physics (2018). Students in UK physics departments. https://www.iop.org/sites/default/files/2020-07/Student-characteristics-2017-18.pdf. Accessed 13 December 2023.
Jackson, P. W. (1990). *Life in Classrooms*. New York: Teachers College Press. (Repr. First published 1968.)
Jones, K. L. and Hamer, J. M. M. (2022). Examining the relationship between parent/carer's attitudes, beliefs and their child's future participation in physics. *International Journal of Science Education*, 44(2), 201–22. https://doi.org/10.1080/09500693.2021.2021457.
Just, H. D. (1999). Minority retention in predominantly White universities and colleges: The importance of creating a good 'fit'. US Department of Education.
Kuh, G. D. (2009). What student affairs professionals need to know about student engagement. *Journal of College Student Development*, 50(6), 683–706. https://doi.org/10.1353/csd.0.0099.
Kuh, G. D., Kinzie, J., Buckley, J. A., Bridges, B. K. & Hayek, J. C. (2006). What matters to student success: A review of the literature. Commissioned report for the National Symposium on Postsecondary Student Success: Spearheading a Dialog on Student Success. https://nces.ed.gov/npec/pdf/kuh_team_report.pdf. Accessed 13 December 2023.
Lambert, N. M., Stillman, T. F., Hicks, J. A., Kamble, S., Baumeister, R. F. & Fincham, F. D. (2013). To belong is to matter: Sense of belonging enhances meaning in life. *Personality and Social Psychology Bulletin*, 39(11), 1418–27. https://doi.org/10.1177/0146167213499186.
Le, A. T., LaCost, B. Y. & Wismer, M. (2016). International female graduate students' experience at a Midwestern university: Sense of belonging and identity development. *Journal of International Students*, 6(1), 128–52. https://doi.org/10.32674/jis.v6i1.485.
Leslie, S.-J., Cimpian, A., Meyer, M. and Freeland, E. (2015). Expectations of brilliance underlie gender distributions across academic disciplines. *Science* 347(6219) 262–5. https://doi.org/10.1126/science.1261375.
Maslow, A. H. (1954). *Motivation and Personality*. New York: Harper & Row.
Maslow, A. H. (1968). *Toward a Psychology of Being*, 2nd edn. New York: D. Van Nostrand Company.
Nissen, J. M. (2019). Gender differences in self-efficacy states in high school physics. *Physical Review Physics Education Research*, 15(1), 013102.
Nunn, L. M. (2021). *College Belonging: How first-year and first-generation students navigate campus life*. New Brunswick, NJ: Rutgers University Press.
O'Sullivan, K., Bird, N., Robson, J. & Winters, N. (2019). Academic identity, confidence and belonging: The role of contextualised admissions and foundation years in higher education. *British Educational Research Journal*, 45(3), 554–75. https://doi.org/10.1002/berj.3513.
Pace, C. R. (1984). Measuring the quality of college student experiences: An account of the development and use of the College Student Experiences questionnaire. Higher Education Research Institute, University of California, Los Angeles.
Padgett, R. D., Johnson, M. P. & Pascarella, E. T. (2012). First-generation undergraduate students and the impacts of the first year of college: Additional evidence. *Journal of College Student Development*, 53(2), 243–66. https://doi.org/10.1353/csd.2012.0032.
Richardson, H. (2015) 'Girls outperform boys at school' despite inequality. BBC News, 22 January. https://www.bbc.co.uk/news/education-30933493. Accessed 13 December 2023.
Steele, C. M. & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology*, 69(5), 797–811. http://dx.doi.org/10.1037/0022-3514.69.5.797.
Swail, W. S. (2003). Retaining minority students in higher education: A framework for success. ASHE-ERIC Higher Education Report, 30(2). Jossey-Bass Higher and Adult Education Series. https://files.eric.ed.gov/fulltext/ED483024.pdf. Accessed 13 December 2023.
Tajfel, H. (1981). *Human Groups and Social Categories: Studies in social psychology*. Cambridge: Cambridge University Press.
Tao, S., Dong, Q., Pratt, M. W., Hunsberger, B. & Pancer, S. M. (2000). Social support: Relations to coping and adjustment during the transition to university in the People's Republic of China. *Journal of Adolescent Research*, 15(1), 123–44. http://dx.doi.org/10.1177/0743558400151007.

Thomas, L. (2012). Building student engagement and belonging in higher education at a time of change: Final report from the What Works? Student Retention & Success programme. Paul Hamlyn Foundation. https://web.archive.org/web/20220207011512/https://www.phf.org.uk/wp-content/uploads/2014/10/What-Works-report-final.pdf. Accessed 11 December 2023.

Thomas, L., Hill, M., O'Mahony, J. & Yorke, M. (2017). Supporting student success: Strategies for institutional change. Paul Hamlyn Foundation. https://web.archive.org/web/20240307082737/https://www.phf.org.uk/wp-content/uploads/2017/04/Full-report-Final.pdf. Accessed 13 December 2023.

Tinto, V. (1997). Classrooms as communities. *Journal of Higher Education*, 68(6), 599–623. https://doi.org/10.1080/00221546.1997.11779003.

Vaz, S., Falkmer, M., Parsons, R., Passmore, A. E., Parkin, T. & Falkmer, T. (2014). School belongingness and mental health functioning across the primary-secondary transition in a mainstream sample: Multi-group cross-lagged analyses. *PLoS ONE*, 9(6), e99576. https://doi.org/10.1371/journal.pone.0099576.

Whitcomb, K. M., Kalender, Z. Y., Nokes-Malach, T. J., Schunn, C. D. and Singh, C. (2020). Inconsistent gender differences in self-efficacy and performance for engineering majors in physics and other disciplines: A cause for alarm? In Y. Cao, S. Wolf & M. B. Bennett (eds), *2019 Physics Education Research Conference Proceedings*, pp. 639–44.

4

Is belonging always positive? Cultivating alternative and oppositional belonging at university

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Introduction

Student belonging is a hot topic in UK higher education, particularly since the beginning of the Covid-19 pandemic, given the significant disruption to face-to-face education (UPP Foundation, 2022; Wonkhe, 2022). While student belonging is often considered inherently positive, some students 'actively choose not to belong' (Gravett & Ajjawi, 2022, p. 1389), and indeed belonging might be harmful to some, particularly marginalised students (Guyotte et al., 2019), as highlighted by many chapters in this book. In this chapter we build on these discussions through an in-depth analysis of three students' experiences of not belonging – Katherine, Michelle and Khadija (all pseudonyms) – focusing on what we call 'oppositional' and 'alternative' forms of belonging. We ask: is belonging always positive in UK higher education or is it better not to belong in some instances?

Our three case studies are drawn from the Supporting the Identity Development of Underrepresented Students (SIDUS) project, which interviewed 110 'underrepresented' undergraduate students in science, technology, engineering and mathematics (STEM) at two pre-1992 elite UK universities. While most interviewees had relatively straightforward narratives of belonging being positive and not belonging being negative, our three case studies were of students who actively cultivated alternative or oppositional forms of belonging in response to exclusionary university, or disciplinary, cultures. The experiences of Katherine, Michelle and

Khadija require more complex understandings of belonging beyond a binary of positive belonging and negative not belonging. To examine their experiences, we draw on Gravett and Ajjawi's (2022, p. 1386) conceptualisation of student belonging as 'situated, relational and processual' and build on discussions of belonging not always being positive, especially for marginalised students (see also Kandiko Howson and Kingsbury, Chapter 1 in this volume).

Alongside this, we use sociological and intersectional understandings of belonging and marginality as dynamic processes actively navigated by people, rather than as fixed or deterministic (May, 2011, 2016; Yuval-Davis, 2006, 2011). We begin by defining 'belonging' and situating our work within the literature on student belonging in STEM, before discussing our methodology and analysis. We argue that there can be a *positive not belonging* when students actively reject dominant belonging discourses because of a difference in values or a refusal to hide or change parts of themselves in order to fit in, and conclude with suggestions for fostering a plurality of (not) belongings in UK higher education and beyond.

(Not) belonging as situated, relational, processual

Belonging is defined by sociologist Vanessa May (2011, p. 368) as 'a sense of ease with oneself and one's surroundings' in relation to other people and to 'more abstract notions of collectively held social norms, values and customs'. While belonging often involves dynamics of inclusion and exclusion – who belongs and who does not – it is not a binary, instead functioning as a multidimensional spectrum and intertwined with intersecting inequalities. For students, belonging might involve feeling at home at their university, on campus or in other university-related spaces (for example student accommodation), or it might be in relation to more specific groupings, such as their academic cohort or discipline.

Students experience a multiplicity of belongings and not belongings to different groups, spaces and ideas; they might feel like a physicist but not feel at home in their specific cohort or they might love their classmates on one course but feel out of place in their broader degree programme. Meehan and Howells (2019, pp. 1376–8) highlight that the idea of belonging at university brings up the question 'How do I fit in?', which is inextricably connected to questions of being – 'Who am I?' – and becoming – 'Who will I be?' And these are sometimes experienced differently in relation to different people, spaces and ideals, complicating monolithic ideas of the student and the student experience.

But, beyond this multiplicity of belonging, it is important to acknowledge that belonging is 'not inherently positive' (Guyotte et al., 2019, p. 556), particularly for students who may face exclusionary student communities or campus climates because they are from one or more marginalised groups. To belong in such a context might require changing oneself to fit in, flattening difference. As Mann (2005, p. 46) argues, 'the word "community" can be seen also to presuppose the idea of exclusion: for belonging and sharing in common imply not belonging and not sharing in common'. Similarly, Gravett and Ajjawi (2022, p. 1393) critique traditional understandings of student belonging as 'a universally positive, uniform experience, and as a fixed state of being' and highlight that some people choose not to belong. They ask: 'who can belong, how, and to where/whom?' (Gravett & Ajjawi, 2022, p. 1388), acknowledging the plurality of (not) belongings that students experience in relation to different groups, ideas and spaces, and helping to operationalise their understanding of belonging that is situated, relational and processual.

To better understand not belonging, we return to sociologist Vanessa May's (2016, p. 759) work, in which she describes not belonging as something relational and dialogic that is actively navigated by people. May draws on Cooley's (1902, p. 152) 'looking-glass self' metaphor to explain this relational and dialogic construction of self; Cooley uses the metaphor of a mirror to argue that the way we think of ourselves is impacted by how we imagine others perceive us, and relatedly how they judge us and the subsequent feelings we have about ourselves (May, 2016, p. 750). May (2016, p. 759) changes this metaphor to 'the looking-glass self-other', adding the question 'What do I think of other people?', and applies this to not belonging, explaining that not belonging can result from 'simultaneous rejection *by* others and rejection *of* others'. She discusses examples of not belonging in which people 'perform a counter-act of misrecognition, naming their own criteria against which they judge others', and so the dominant belonging group can be 'excluded from the person's "us"' (May, 2016, p. 760). In other words, people actively negotiate their (not) belonging in dialogue with their internal imagining of other people and may reject dominant modes of belonging through the construction of their own belonging groups. May (2011, pp. 374–5) argues that not belonging can provoke social change because, 'as a result of questioning who "we" are, people construct alternative identities and ways of life'.

We use May's work to inform our understanding of students' oppositional and alternative belonging narratives, which are part of their response to feeling excluded from dominant student belonging discourses in their contexts. Thus, not belonging is both a narrative about students' individual experiences and a way to understand the exclusionary contours of STEM in UK higher education, in which some people find it harder, or impossible, to belong. Their alternative modes of belonging help us reimagine what the university could be if it were genuinely inclusive of all students (see also Kandiko Howson and Kingsbury, Chapter 5 in this volume). We use these conceptualisations of (not) belonging as a situated and relational process that people actively navigate to consider the experiences of marginalised students in higher education, and specifically in STEM.

Sense of belonging in higher education is an enormous topic, as discussed throughout this book, which often highlights how being underrepresented and/or intersecting inequalities negatively impact on student belonging. For example, O'Keeffe (2013, p. 611) argues that first-generation, ethnic minority and disabled students may feel they have to assimilate and to compromise who they are in order to fit into campus cultural norms. While many students find belonging in extra-curricular activities, students who commute, are part-time or have caring responsibilities often struggle to participate in such activities (Winstone et al., 2020, p. 13) because they do not fit the typical student imagining of someone who is 'young, full-time and residential' (Thomas, 2015, p. 41). In terms of STEM, Rainey et al. (2018, p. 1) found that amongst US undergraduate STEM students white men were most likely to report a sense of belonging and women of colour were least likely. In an extensive literature review on women in STEM, Blackburn (2017, p. 247) found that women (particularly those from marginalised groups) often felt they did not belong in STEM because of sexism, stereotype threat, and concerns about fitting in, which negatively affected their likelihood of continuing in STEM careers (see also Smith, Chapter 9 in this volume).

Marginalised students often feel they have to conform to pre-existing campus cultures which are made by privileged groups and are hard to fit into, including the language and imagery that describe who a STEM student or professional is in their discipline. For example, Ong (2005, p. 593) explores the experiences of 10 women of colour who were studying physics in the US, arguing that their 'belonging and competence in science are questioned because their bodies do not conform to prevalent images of the "ordinary" white male physicist'. This results in the women of colour trying to 'pass' as belonging or as competent, which demonstrates how much effort is expended on performing as a physicist. Ong (2005, p. 595) argues that those women of colour who persevere can experience a high cost, with students having to 'compromise their identities as women, as minorities, or both', This tells us something about the structures of the university; Puwar (2004, pp. 153–5) argues that higher education is made by and for white upper/middle-class elite men and assimilation alone will not change these spaces. Puwar (2004, p. 8) describes the experience of being perceived as a 'space invader' in exclusionary spaces, such as universities, which are ordered by race, gender and class and thus position certain bodies as being against the 'somatic norm' of the institution. Thus, we examine what student (not) belonging narratives tell us about the university itself, alongside using an intersectional approach to student belonging which acknowledges the impact of multiple intersecting axes of structural inequalities.

Intersectionality means going beyond one axis of structural inequality to acknowledge how different forms of oppression are co-constitutive of each other; specifically, it concerns differences that matter, such as race and ethnicity, gender, class, sexuality, disability, nationality and citizenship status. 'Intersectionality' was coined by Kimberlé Crenshaw (1989) in her work on Black women's experiences falling through the cracks of anti-discrimination legislation in the US. However, similar ideas about the co-constitutive nature of privilege and marginality pre-date Crenshaw's work, including the Combahee River Collective's (1977) discussion of how different forms of oppression 'interlock' and are 'most often experienced simultaneously', which makes it difficult to separate them from each other. And, in STEM, the 'double bind' (Malcom et al., 1976) describes the experiences of women of colour of racism and sexism together; the two create specific forms of exclusion and devaluation (see also Al Arefi, Chapter 10 in this volume).

While intersectional analysis of belonging is uncommon in the STEM belonging literature, there are some notable examples. Rainey et al. (2018, pp. 2, 12) argue that many discussions of differences in the experiences of 'women' and 'men' are actually about white women and men; in their study of US-based undergraduate STEM students they highlight that, amongst men, not belonging was primarily experienced by men of colour. Additionally, Ong et al.'s (2011, p. 173) literature review of 40 years of research on women of colour in STEM (focusing on the US) emphasises that underrepresented minority women (African American, Chicana/Latina and Native American women) are more underrepresented than white and Asian American or Pacific Islander women. However, they argue that, despite Asian American women's proportionate overrepresentation in STEM degrees, they are the lowest-represented demographic group with academic tenure and almost completely absent at professorial level (Ong et al., 2011, p. 180). It is important to highlight these nuances in the different experiences of racially minoritised women over time, particularly since they can be glossed over and remain invisible if not disaggregated and considered across the whole lifecycle of a career in STEM.

To bring together intersectionality and our conceptualisation of (not) belonging, we use Yuval-Davis's (2011, pp. 12–18) three-layered explanation of socio-political belonging as consisting of:

1. *social locations* – gender, race and ethnicity, class, nationality/citizenship, sexuality, age, disability and so on, which can be understood as intersecting structural identities and hierarchical positions, namely differences that matter in particular times and places;
2. *identifications and emotional attachments* – narratives people tell about who they and others are, which are often attached to particular groupings or collectives and often implicitly construct boundaries between who is included and who is excluded;
3. *ethical and political values* – how different forms of belonging are 'assessed and valued by the self and others' (p. 18), which accounts for different understandings of the 'same' social location; for example, some women are feminists and others are not and so their conceptualisations and analysis of gender are likely to be very different.

While Yuval-Davis (2006, 2011) largely focuses on racialised citizenship and migration in her work, her conceptualisation of belonging and intersecting inequalities is helpful for our discussion, as she considers the complexity of how people narrate their identities, and the impact of ethical and political values. This approach acknowledges the impact of structural inequalities but does not consider identity and positioning as static or deterministic, which helps us to acknowledge the hugely varied experiences of marginalisation and their differential impact on student belonging narratives. And so, Yuval-Davis's work helps us to bring together intersectional and sociological understandings of (not) belonging to consider why some students in our SIDUS research project narrated not belonging in positive terms.

Methodology

The SIDUS Project (2020–22) analysed the experiences of 110 undergraduate students on STEM programmes at Imperial College London and the University of Reading. All participants self-identified as belonging to one or more 'underrepresented' groups in STEM or higher education in general; they included students marginalised on the basis of their gender, sexuality, race or ethnicity, disability or class, alongside those who were first generation to university, mature students (aged 21 or older upon entry to university) and international students (including EU students). Our overall research question was 'How does being underrepresented affect students' identities and career aspirations at university?' We focused on the following broad topics: sense of belonging; interviewee perceptions of the 'typical' and 'ideal' student in their discipline or degree programme and how far they fit into these ideas; future career planning and future professional selves; experiences of being 'underrepresented'; and how their identities and background impacted their student experience. Interviews were conducted via Microsoft Teams; we recorded in audio only, which was transcribed, and then thematically coded using NVivo data analysis software.

A key theme from the interviews was the difficulty of school-to-university transition for marginalised students, which was often described as very challenging, particularly by marginalised students who did not see 'people like them' amongst faculty or their student cohort (see also Voice, Purdy, Labrosse and Heath, Chapter 3 in this volume). Many interviewees discussed struggling with going from top of the class at school to getting average or below average grades at university; this was particularly difficult for those in very competitive cohorts, which were common at Imperial College London. Some students from multiple underrepresented groups felt less of a sense of belonging than other students, which negatively impacted their experience at university. Many students managed not belonging by finding belonging in specific student clubs and societies or in non-university spaces. Using our initial analysis, we wrote three articles based on the SIDUS data, which focused on: imposter syndrome (Murray et al., 2022); gendered hierarchies of STEM disciplines which position biology (a more gender-balanced discipline) as easier and less valuable than other disciplines (Wong et al. 2023); and the career trajectories of STEM students (Wong et al. 2022).

When we analysed the data on student belonging for this chapter, we initially examined three of our NVivo codes: 'Difficult sense of belonging or fitting in', 'Good sense of belonging or fitting in' and 'Unsure sense of belonging or fitting in'. While these large codes inevitably flatten complex belonging dynamics, particularly given the huge diversity of students we interviewed, they helped us to navigate the enormous amount of interview data. We discuss the broad student belonging findings in a separate article, currently under preparation, but this chapter focuses on in-depth analysis of three interviews with students who had a 'positive' sense of not belonging.

Most students discussed belonging as positive or not belonging as negative, but these three interviewees – Katherine, Michelle and Khadija – had an unusually positive response to not belonging. They did not feel they fitted into dominant belonging discourses in their contexts, but they had accepted this and narrated alternative or oppositional belonging positively. While their exclusion from dominant belonging discourses was not itself positive (and indeed tells us something about who can belong), we argue that their rejection of dominant modes of belonging is positive, constituting what May (2016, p. 760) calls a 'counter-act of misrecognition'. The three students actively rejected dominant belonging discourses that they could not fit into without changing or hiding parts of themselves or participating in something with which they disagreed (see also Smith, Chapter 9 in this volume). In short, these interviewees rejected the conditions placed on their sense of belonging at university and cultivated alternative or oppositional senses of belonging which helped them survive in exclusionary spaces. We take each student case study in turn, analysing their belonging journey at university through two questions: (1) why and how did they cultivate alternative or oppositional belonging discourses?, and (2) what does this tell us about dominant modes of belonging in their contexts?

Cultivating positive not belonging

Katherine: finding fellow 'outsiders'

Katherine was a final-year natural sciences student of mixed heritage – white British and brown South Asian – who moved around a lot when growing up (mostly between a South Asian country and Britain as a teenager) and described herself as middle-class. However, because her parents' income was in another country, her financial situation did not translate to a middle-class income in Britain, so she received a full bursary from her university. Katherine's sense of belonging at university was tied to her friendship group rather than to the university or her degree programme:

> I don't think I've ever felt a real sense of belonging with anything organised by [the university]. I felt belonging within my friendship group, but I felt like us as a group were kind of outsiders to the [university] experience. I think if you look at the … typical student. And I wouldn't say I'm one of them. … I think I just want a different life to a lot of people at [the university].

This characterisation of herself and her group of friends as 'outsiders' was a strong theme in her account of time at university. When asked to describe a specific time when she did not feel she belonged at her university, she said: 'I feel like I kind of had a constant sense of outsiderness throughout my whole degree. Yeah. I can't think of like a specific occasion … a general sense.'

Throughout her interview three key reasons seemed to contribute to this outsiderness: having different values and interests to many of her peers; being of mixed heritage; and being less wealthy than many fellow students at her university. Firstly, Katherine explained how her friendship group differed from other students: 'We value other things as well. Like our entire sort of sense of worth is not based solely on our academic performance.'

However, this was mixed with some imposter feelings, because Katherine did not feel she was on the same level as other students, whom she described as 'super-keen and getting really high marks and everything and sourcing out internships for every summer'. Alongside this, she reported a very competitive atmosphere across the university, which was mentioned by other interviewees. In contrast, Katherine described the importance of work–life balance, life beyond university and career planning, and the importance of music and politics in connecting her with her friendship group. When asked what created a sense of identity or belonging for her throughout her degree programme, she replied: 'Music definitely. And I think the people I ended up being friends with … had broader interests beyond science, maybe like philosophy or politics. And we were sort of happy to talk about bigger-picture things.'

Beyond these values and interests, which differed from those of her peers, Katherine discussed the impact of being marginalised on her sense of belonging, specifically this feeling of being in between worlds because of her mixed heritage and her complicated class position in Britain and in her elite university context. When describing the start of her first year Katherine explained: ‘I didn’t feel like I fitted in. … I was surrounded with people that I didn’t have a lot in common with. … A lot of the people in my halls were quite wealthy.’ These class differences were complicated by the dynamics of race and class across borders and how different types of schooling act as proxy measures for class. Katherine explained:

> Class or wealth made a big difference because … there are definitely a lot of private-school people at [the university] and a lot of rich international-school people. … And even though I was technically an international-school student … we never really, like, had a load of money … and there wasn’t really, like, a steady income. So I felt like I couldn’t really click with people who had kind of lived life with everything handed to them on a plate. And I feel, yeah, I think it was weird because I did feel quite international, but at the same time didn’t have that in common with a lot of the international students. So yeah, I think the friends that I ended up making were kind of a lot of people from Europe and from the UK who were not super-rich, who were a little bit more down to earth.

Her experiences demonstrate the importance of situated and relational understandings of how intersecting inequalities work in practice; in her home context she occupied a much more privileged position than she did in Britain and in her elite university. These contexts were centrally important to how she was classed and racialised and to her sense of belonging, which was complicated further by being of mixed heritage.

Katherine discussed a sense of being in between worlds after going to a student society event for people from her specific South Asian background but finding that she did not fit in with either the international students or the British South Asian students, because of her mixed heritage and a lack of connection to some of the cultural markers which she saw other students connecting over, such as food, music and dance. She described her experience of not ‘fitting in with either group’,which led to a ‘strange disconnect. … I’m kind of this weird mixture and those things [cultural markers like food, music and dance] aren’t the things that maybe create a sense of identity or belonging for me.’ This not belonging and sense of in-betweenness around her dual nationality and mixed heritage was in stark contrast to her very strong sense of belonging to her group of friends, the ‘outsiders’. It was significant that this friendship group was composed of other students from underrepresented groups, specifically working-class and less wealthy middle-class students who connected over a sense of class alienation from their peers.

Using Yuval-Davis's (2006, 2011) belonging framework to understand Katherine's account helps us to disentangle the different intersecting elements of structural positioning, from identifications and emotional attachments and values. Katherine cannot choose her mixed-heritage and class background, which strongly contribute to her not belonging at an elite university, but through finding friends who were also marginalised and understood this not belonging she was able to enact a 'counter-act of misrecognition' (May 2016, p. 760). Katherine and her friends collectively constructed a positive oppositional identity – the 'outsiders' – in response to the dominant belonging narrative at her university (see also Hyland, Chapter 2 in this volume). While this identity is partly rooted in their structural positioning, it is also about values and their specific academic context. As Chiu et al. (2021) argue, the academic culture of a university sets up external expectations of what constitutes the typical or ideal student. In Katherine's case, she discussed rejecting the values of the typical student in her elite university STEM environment: competitive and focused mainly on studying and high achievement at the expense of work–life balance.

Michelle: it's a degree, not my life

Michelle was a mature student who had started her degree at 22, after doing an access course at college. She was a white British student from a middle-class background and is autistic. When asked to describe her first week at university she recounted her experience during the start of the Covid-19 pandemic:

> I guess [I] didn't really feel like I was at university because it was all online and I was in my room. … I was definitely a bit overwhelmed by it all. Because obviously, even though we've got all the materials online, it does feel like I'm doing it on my own a bit. But it hasn't put me off. And I've got my group of friends and other things outside, so this isn't my whole life.

This experience impacted her ability to participate in a learning community on her course and subsequently her sense of belonging. When asked if there were any moments when she had felt a real sense of belonging on her course at university in general, she said: 'I haven't felt, like, a sense of belonging, but I don't think that's a bad thing. I think it's more just because it's online and I'm not in halls, but I'm not worried about that.' This acceptance was largely due to her being a mature student and having a different approach to university. She discussed being nervous about being a mature student, but said, 'I'm not going to university for the whole social life. I've got my friends at home. A lot of 18-year-olds will go to university to have the experience of parties and making new friends, which I've already done.'

Her sense of belonging with pre-existing friends and family at home meant that she was approaching university differently; the focus on studying rather than on the social life was similar to that of other mature student interviewees in our research. However, there was a complicating factor, as Michelle mentioned a few times in the interview that she felt nervous talking to other people or sometimes struggled with social interaction. She discussed how being autistic affected her experience of her degree:

> I don't put myself out there like other students do. And I do find it hard to talk in a group, so a lot of the times I'm just more of an observer rather than getting involved. I think in the past, especially at school, I've been excluded because I'm very quiet around people.

She described being told in her mid-teens that she might be autistic, but it took time to get an official diagnosis. She was receiving support from her university's disability support office for dyslexia, and they also knew she was autistic, but she had not talked to anyone else at university about being autistic. Her family and her closest friends knew, but she said being autistic was 'not really something I advertise out there because I just don't want to be seen as different'. Later in the interview, she brought up that being an autistic woman could be particularly difficult because of the lack of media representation of autistic women: 'It's mainly a male-viewed thing. I think [being an autistic woman] – that's something that is an extra struggle on top, that some people almost don't believe it.' Thus, Michelle's focus on the degree programme itself rather than on the social side of university life seemed to be due to a mixture of two aspects of her experience: being a mature student with an established adult social life beyond the university, and her navigation of being autistic at university, specifically her concerns about how others would respond to her neurodivergence.

Michelle's distinction between herself and other students draws on a stereotype of the sociable, neurotypical, partying student (see also Leigh et al., Chapter 14 in this volume). This feeling of not fitting into studenthood, and even not fitting into her own neurodivergence as an autistic woman, presents a double outsiderness, which was potentially exacerbated by online learning during the Covid-19 pandemic. It also demonstrates the importance of universities' promoting inclusive understandings of being a student and facilitating multiple modes of student socialising to build inclusive learning communities, including for neurodivergent students. Michelle genuinely seemed happy not to participate in the partying elements of student life, embracing a positive sense of not belonging as a mature student who had a more focused academic relationship to university. However, her sense of outsiderness on her courses did seem to bother her, and this academic outsiderness seemed to be a case of not *yet* belonging but wanting to belong. This was rooted in being marginalised as a neurodivergent student and the complex dynamics of creating learning community through online learning during the Covid-19 pandemic while not living in halls.

As Thomas (2015) says in relation to part-time mature students in UK higher education, they often create spaces of their own away from campus or university, which are essential, as they often do not fit into imaginings of the typical student, as young, full-time, and living in university accommodation. The typical student is also presumed to be neurotypical, and so, while Michelle has mostly described her not belonging in positive terms, it is important that universities appreciate the particular barriers to belonging experienced by mature and neurodivergent students to ensure that belonging remains an option for all students.

Khadija: no longer grateful

Khadija had a difficult sense of belonging at her university because she was hyper-underrepresented as one of very few Black Muslim students, as well as being first-generation and working-class. She described similar experiences at school; after going to her local state school she moved to a private sixth form. In the sixth form she initially felt like an outsider, describing feeling that 'this place really isn't made for you … and you're here but it isn't where you're meant to be'. When she started university, Khadija described being pleasantly surprised by the diversity of students on campus in comparison to school and finding comfort in recognising other students from her sixth form at the same university. However, these initial feelings changed over time:

> At the beginning I was kind of, because of where I'd come from, I was conditioned, I think, or I'd been led to believe that I should just

> accept anything. And there were a few that actually said oh yes, you should be grateful. Whereas now, I think I'm more angry about the situation. And I now think, well, I shouldn't have been made to accept that.

This shift from grateful to angry was informed by her beginning to reflect critically on her experiences at university. She highlighted the importance of universities going beyond widening participation efforts and considering how to support students' belonging and participation at university: 'I don't think [the university] is trying to change things, or, if they are, it's kind of trying to change things in name. … What are you doing so that when they [Black students] get here, they don't feel like they're out of place?'

Khadija sought out the Afro-Caribbean Society (ACS) and the Islamic Society on campus to find people like her. However, she said, 'On campus I'm much more aware of the fact that I'm a Black student, than I am of the fact that I'm Muslim', and because of this ACS was enormously important to her experience at university. She explained that she did not have a sense of belonging at university outside of ACS events, as they provided a sense of belonging that was hard to describe. She tried to explain, saying, 'It's just you talk about the same TV and the same cultures at home, similar food, similar styles of music.' These similar reference points were compared to a language barrier; Khadija did not have to translate herself for the white institution and non-Black peers while she was at ACS, and this was profoundly relieving.

Of course, ACS and Black students at her university were not a monolith; Khadija emphasised the intersection between race, class and nationality, and the importance of disaggregating categories to understand the plurality of Black student experiences. She explained that many Black British students were from working-class backgrounds and so their sense of exclusion was raced and classed, and this was complicated by other intersecting forms of marginality such as gender and religion.

The specificity of different racialised experiences within the 'BAME' category was particularly important; Khadija highlighted that Black staff were hyper-underrepresented even in comparison to other ethnically minoritised groups. Khadija described having had no Black women teachers and one Black man teacher, and the rare occasion when she had met a Black woman in her professional field outside of university. As she put it, 'Okay, cool, you've brought the ME [minority ethnic], but there is no B [Black]', calling attention to the issues associated with the abbreviations 'BME' or 'BAME' which conflate different experiences of being ethnically minoritised. Khadija explained that this category tended to hide the issues facing Black students specifically, and also the differences within the category of 'Black': a wealthy international student from Nigeria has a very different experience of race and class and nationality from that of a Black British working-class student with Ghanaian and Jamaican heritage. As Selvarajah et al. (2020) argue, the term 'BAME' is a governmental term that centres whiteness as the norm, homogenises non-white groups and avoids recognising the centrality of power and hierarchy in racialised categorisation. Thus, they advocate using specific, locally appropriate terminology to name groups, alongside using 'minoritised' as a helpful general term instead of 'BAME' to acknowledge the active processual and complex nature of intersectional forms of discrimination and power structures.

Khadija's (not) belonging changed over time as she became more critical of her highly racialised experiences of education. This demonstrates how processual belonging and narratives of belonging are, with emotional attachments to different belonging discourses sometimes changing over time. This process is reminiscent of Sobande's (2018, p. 96) 'accidental academic activism' concept, whereby 'To be Black and a woman in academia is often to be regarded as a political presence, before even having uttered a word', which prompts a more critical stance vis-à-vis the academy. Khadija's move from gratefulness to anger is particularly important, as anger is a highly policed emotion for Black women – with the disciplining spectre of the 'angry Black woman' stereotype (Ahmed, 2010, p. 68; Doharty, 2020) hovering over her student experience – and yet, as Audre Lorde ([1984] 2019, pp. 123, 120) argues, anger is 'an appropriate response' to racism and 'can become a powerful source of energy serving progress and change'. Khadija's anger is in response to the hyper-underrepresentation of Black students and her realisation that her white-majority sixth form school had primed her to accept rather than question her experiences of (not) belonging.

The importance of ACS cannot be overstated, both for Khadija and for others at her university, as it was described in similar ways by other Black student interviewees; this student-run, Black-majority space provided an alternative (and sometimes oppositional) space of belonging on campus where they did not need to translate themselves for non-Black students and staff. Lastly, Khadija's critique of the BAME umbrella category and the intra-categorical complexity of Black as a grouping provides an important reminder to researchers and universities to acknowledge the intersectional complexity and specificity of student experiences of (not) belonging.

Discussion

These three case studies complicate binary discussions of belonging that consider belonging to be inherently positive and not belonging inherently negative. They demonstrate how students actively negotiate university life, positioning themselves in relation to discipline- and university-specific cultures in which academic and social elements of studenthood are sometimes hard to disentangle. However, these negotiations are not fully or freely chosen, because university life is structured by and for dominant groups with associated imaginings of studenthood in mind; these can be exclusionary of those who do not fit in, positioning Others as 'space invaders' (Puwar, 2004; see also Hyland, Chapter 2 in this volume). The experiences of Katherine, Michelle and Khadija tell us something about their individual experiences and about the structure of elite higher education and STEM in the UK, highlighting who is assumed to be there, who fits in and who does not.

Katherine, Michelle and Khadija narrated their not-belonging experiences through what we call oppositional and alternative belonging. Both of these narratives involved not fitting into dominant modes of belonging, and while these narratives were slightly different from each other there were often shades of both in the three case studies. We conceptualise oppositional belonging as defining oneself against the dominant mode of belonging, often in ways that critique the dominant belonging narrative, for example Michelle's construction of mature students versus 'partying' non-mature students, or Katherine's friendship group seeing themselves as 'outsiders' because they opposed the high-achieving competitive academic culture of their university. Alternative belonging involves creating a separate positive space focused on an element of one's identity, background or interests that provides a sense of belonging.

The oppositional narrative of being 'outsiders' also provided this alternative belonging space for Katherine and her friends because of their focus on finding common ground through music, politics and being less wealthy than their peers. Similarly, ACS was important for Black students such as Khadija because it provided an alternative space of belonging that did not necessarily hinge on opposing dominant modes of belonging, but merely on acknowledging the significance of being hyper-underrepresented. However, Khadija's belonging narrative changed over time, becoming more critical of dominant modes of belonging, and of institutional anti-Blackness and other, intersecting exclusions, ultimately acknowledging the oppositional elements of her alternative belonging.

Michelle's oppositional and alternative belonging narratives were slightly more complicated, particularly given that she was a first-year student; perhaps she does not *yet* belong, and her narratives will change as she progresses through her degree; hence the importance of acknowledging the ongoing processual nature of belonging.

Alternative and oppositional belonging narratives were positive stories students told about their not belonging. This positive not belonging involved students responding to different forms of exclusion on multiple levels. Yuval-Davis's three-layer socio-political belonging framework helps to distinguish these dimensions: they experienced exclusion (and sometimes alternative spaces of belonging) based on their being underrepresented and/or marginalised because of class, race, age or neurodivergence; they rejected dominant modes of belonging, performing 'counter-acts of misrecognition' and identifying with alternative or oppositional belonging narratives, often connecting such disidentification with a broader ethical and political critique of their exclusion. These different responses to not belonging tells us something about the structure of universities. Who is presumed to be the student? In what ways is the university designed for them? And is it possible for the university to be redesigned for a multiplicity of students and studenthoods?

Conclusion: a pluralistic belonging model

In this chapter we have considered whether student belonging is always positive in UK higher education or if it is better for some students to embrace not belonging. Using in-depth analysis of three students' experiences, we identified some positive lack-of-belonging accounts in which students constructed alternative and/or oppositional belonging narratives in response to feeling excluded from, or disagreeing with, dominant belonging discourses in their context. Thus, we argue that for some students it would be damaging to their sense of self or betray their values if they were to attempt to fit into dominant belonging narratives. Our three students were unable to fit into dominant belonging discourses largely because they were marginalised and/or underrepresented as well as disagreeing with certain dominant ideas of 'the student' or 'studenthood' in their context. Their stories tell us something about university spaces, communities and ideas; belonging to the university is easier for some students than for others, as it is structured by inequality. However, the connection between inequality and belonging is not deterministic, as students can actively negotiate their contexts and reject dominant modes of studenthood and belonging to create new spaces of student (not-)belonging.

These alternative/oppositive belongings were most effective when they were collective, as in the case of Katherine's group of friends and their 'outsider' narrative or Khadija and her feeling of being at home in her university's Afro-Caribbean Society. For Michelle, while her life outside of university provided an alternative space of belonging, there was a sense that she was still looking for some academic belonging on her course, even though she rejected the dominant idea of the 'partying' non-mature student. Thus, positive not belonging is not always possible without sufficient support from others, whether informally from friends or family or institutionally through the structure of courses, academic cultures and student support services. Not belonging is an understandable response to exclusion and, rather than internalising it as an individual issue, we argue for collective and institutional responses.

Firstly, intersecting inequalities impact belonging, and so tackling forms of discrimination, bullying and harassment proactively is a crucial part of supporting student belonging. While university and STEM-specific equality, diversity and inclusion efforts are commonplace, they can often function as 'non-performative' (Ahmed, 2012); that is, they do not do what they say they do, but instead focus on being seen to do good rather than on tackling difficult issues like sexual harassment, racism and bullying. Additionally, competitive academic environments and disciplinary hierarchies that value some academic disciplines, forms of knowledge and knowers/learners over others are central to producing inequalities, particularly in elite universities and STEM environments. For instance, as we state in other articles based on the SIDUS project, competitive academic environments produce imposter feelings particularly in multiply marginalised students (Murray et al., 2022), and disciplinary stereotypes about the typical or ideal STEM student are often coded in gendered, racialised and classed ways, which contribute to exclusionary ideas about who can be in STEM (Wong et al., 2023).

Secondly, it is important for universities to provide more opportunities for students to connect with each other in order to support belonging. Wonkhe's (2022, p. 55) survey of student perceptions of belonging asked what would help students feel a greater sense of belonging at their university; across all demographics and modes of study, more and closer friendships and peer networks (such as getting to know more people on their course) were a central theme. Knowing this provides a helpful steer for university workers and student representatives interested in facilitating student belonging: they can create spaces for students to connect with each other to encourage more and deeper friendships and peer connections alongside proactively tackling barriers to connection. Such a step requires a rethink about university and students' union messaging concerning who is a student and who belongs, and increasing the variety of student societies and cohort-building social activities to accommodate students with different access needs, preferences, interests, schedules, housing and financial situations, and family and caring responsibilities.

Thirdly, some students may focus entirely on the academic aspects of university life, as demonstrated by Michelle's experience as a mature student. For these students, who may not feel they belong socially, it is still important that they feel they matter in the classroom and academically. Relational pedagogy, based on the principle of being intentional about building relationships which support student learning (Su & Wood, 2023), provides a helpful framework for thinking about supporting a plurality of student (not) belongings. It involves supporting their sense of mattering and of having positive interactions with staff and fellow students, and building this into the structure of academic courses. As Gravett et al. (2021) argue, there are opportunities to shift pedagogical practice in the everyday materiality of learning and teaching, through, for example: the co-creation of reading lists; the rearrangement of classroom spaces to decrease power imbalances and flatten hierarchies between teacher and learner; informal opportunities to connect with staff, particularly when teaching is online, which affords fewer opportunities to engage with staff in ad hoc ways; and the dispersal of assessment throughout modules and the inclusion of self- and peer-assessment. However, the facilitation of such pedagogies of mattering often requires more energy and time than staff have in UK higher education. Any discussions about changing curricula and pedagogical practices must be grounded in the material constraints of overworked and often precariously employed staff who are teaching increasing numbers of students in a cost-of-living crisis. Student belonging does not happen in a vacuum; it must be considered in the context of students dedicating more time to paid employment during their studies because of financial concerns along with a debt-based model of financing for many accessing UK higher education.

This chapter acknowledges the creative ways in which students respond to exclusionary cultures, carving out pockets of belonging at, or beyond, university as alternatives to, or in opposition to, dominant modes of belonging. The production of alternative or oppositional forms of (not) belonging tells us something about the exclusionary nature of UK higher education and the increased diversity of studenthoods. Universities need to continue to take responsibility for changing exclusionary cultures, supporting a multiplicity of (not) belongings, and making time and space for more relational pedagogical practices that allow for the diversity of student experiences and related learning needs.

References

Ahmed, S. (2010). *The Promise of Happiness*. Durham, NC: Duke University Press.

Ahmed, S. (2012). *On Being Included: Racism and diversity in institutional life*. Durham, NC: Duke University Press.

Blackburn, H. (2017). The status of women in STEM in higher education: A review of the literature 2007–2017. *Science & Technology Libraries*, 36(3), 235–73. https://doi.org/10.1080/0194262X.2017.1371658.

Chiu, Y.-L. T., Wong, B. & Charalambous, M. (2021). 'It's for others to judge': What influences students' construction of the ideal student? *Journal of Further and Higher Education*, 45(10), 1424–37. https://doi.org/10.1080/0309877X.2021.1945553.

Combahee River Collective (1977). The Combahee River Collective statement. BlackPast.org. https://www.blackpast.org/african-american-history/combahee-river-collective-statement-1977/. Accessed 14 December 2023.

Cooley, C. H. (1902). *Human Nature and the Social Order*. Charles Scribner's Sons.

Crenshaw, K. (1989). Demarginalizing the intersection of race and sex: A Black feminist critique of antidiscrimination doctrine, feminist theory and antiracist politics. *University of Chicago Legal Forum*, 1989(1), 139–67.

Doharty, N. (2020). The 'angry Black woman' as intellectual bondage: Being strategically emotional on the academic plantation. *Race Ethnicity and Education*, 23(4), 548–62. https://doi.org/10.1080/13613324.2019.1679751.

Gravett, K. & Ajjawi, R. (2022). Belonging as situated practice. *Studies in Higher Education*, 47(7), 1386–96. https://doi.org/10.1080/03075079.2021.1894118.

Gravett, K., Taylor, C. & Fairchild, N. (2021). Pedagogies of mattering: Re-conceptualising relational pedagogies in higher education. *Teaching in Higher Education*, 29(2), 388–403. https://doi.org/10.1080/13562517.2021.1989580.

Guyotte, K. W., Flint, M. A. & Latopolski, K. S. (2019). Cartographies of belonging: Mapping nomadic narratives of first-year students. *Critical Studies in Education*, 62(5), 543–58. https://doi.org/10.1080/17508487.2019.1657160.

Lorde, A. ([1984] 2019). *Sister Outsider*. London: Penguin Books.

Malcom, S. M., Hall, P. Q. & Brown, J. W. (1976). *The Double Bind: The price of being a minority woman in science*. Report of a conference of minority women scientists. Airlie House, Warrenton, VA, December 1975 Washington, DC: American Association for the Advancement of Science.

Mann, S. J. (2005). Alienation in the learning environment: A failure of community? *Studies in Higher Education*, 30(1), 43–55. https://doi.org/10.1080/0307507052000307786.

May, V. (2011). Self, belonging and social change. *Sociology*, 45(3), 363–78. https://doi.org/10.1177/0038038511399624.

May, V. (2016). When recognition fails: Mass Observation Project accounts of not belonging. *Sociology*, 50(4), 748–63. https://doi.org/10.1177/0038038515578991.

Meehan, C. & Howells, K. (2019). In search of the feeling of 'belonging' in higher education: Undergraduate students transition into higher education. *Journal of Further and Higher Education*, 43(10), 1376–90. https://doi.org/10.1080/0309877X.2018.1490702.

Murray, Ó. M., Chiu, Y.-L. T., Wong, B. & Horsburgh, J. (2022). Deindividualising imposter syndrome: Imposter work among marginalised STEMM undergraduates in the UK. *Sociology*, 57(4), 749–66. https://doi.org/10.1177/00380385221117380.

O'Keeffe, P. (2013). A sense of belonging: Improving student retention. *College Student Journal*, 47(4), 605–13.

Ong, M. (2005). Body projects of young women of color in physics: Intersections of gender, race, and science. *Social Problems*, 52(4), 593–617. https://doi.org/10.1525/sp.2005.52.4.593.

Ong, M., Wright, C., Espinosa, L. & Orfield, G. (2011). Inside the double bind: A synthesis of empirical research on undergraduate and graduate women of color in science, technology, engineering, and mathematics. *Harvard Educational Review*, 81(2), 172–209. https://doi.org/10.17763/haer.81.2.t022245n7x4752v2.

Puwar, N. (2004). *Space Invaders: Race, gender and bodies out of place*. Oxford: Berg.

Rainey, K., Dancy, M., Mickelson, R., Stearns, E, & Moller, S. (2018). Race and gender differences in how sense of belonging influences decisions to major in STEM. *International Journal of STEM Education*, 5, art. no. 10. https://doi.org/10.1186/s40594-018-0115-6.

Selvarajah, S., Deivanayagam, T. A., Lasco, G., Scafe, S., White, A., Zembe-Mkabile, W. & Devakumar, D. (2020). Categorisation and minoritisation. *BMJ Global Health*, 5(12), e004508. https://doi.org/10.1136/bmjgh-2020-004508.

Sobande, F. (2018). Accidental academic activism: Intersectional and (un)intentional feminist resistance. *Journal of Applied Social Theory*, 1(2), 83–101.

Su, F. & Wood, M. (2023). Relational pedagogy in higher education: What might it look like in practice and how do we develop it? *International Journal for Academic Development*, 28(4), 230–3. http://dx.doi.org/10.1080/1360144X.2023.2164859.

Thomas, K. (2015). Rethinking belonging through Bourdieu, diaspora and the spatial. *Widening Participation and Lifelong Learning*, 17(1), 37–49. https://doi.org/10.5456/WPLL.17.1.37.

UPP Foundation (2022). Turbocharging the future: The interim report of the UPP Foundation Student Futures Commission. UPP Foundation. https://upp-foundation.org/student-futures-commission/news/turbocharging-the-future/. Accessed 14 December 2023.

Winstone, N., Balloo, K., Gravett, K., Jacobs, D. & Keen, H. (2020). Who stands to benefit? Wellbeing, belonging and challenges to equity in engagement in extra-curricular activities at university. *Active Learning in Higher Education*, 23(2), 81–96. https://doi.org/10.1177/1469787420908209.

Wong, B., Chiu, Y.-L. T., Murray, Ó. M. & Horsburgh, J. (2022). End of the road? The career intentions of under-represented STEM students in higher education. *International Journal of STEM Education*, 9(51), 1–12. https://doi.org/10.1186/s40594-022-00366-8.

Wong, B., Chiu, Y.-L. T., Murray, Ó. M., Horsburgh, J. & Copsey-Blake, M. (2023). 'Biology is easy, physics is hard': Student perceptions of the ideal and the typical student across STEM higher education. *International Studies in Sociology of Education*, 32(1), 118–39. https://doi.org/10.1080/09620214.2022.2122532.

Wonkhe (2022). Students' perceptions of belonging and inclusion at university. Wonkhe. https://wonkhe.com/wp-content/wonkhe-uploads/2022/02/Belonging-and-inclusion-survey-Wonkhe-Pearson-Feb-22.pdf. Accessed 14 December 2023.

Yuval-Davis, N. (2006). Belonging and the politics of belonging. *Patterns of Prejudice*, 40(3), 197–214. https://doi.org/10.1080/00313220600769331.

Yuval-Davis, N. (2011). *The Politics of Belonging: Intersectional contestations*. London: SAGE.

5

Inclusive excellence in STEM higher education

Camille Kandiko Howson and Martyn Kingsbury

Introduction

Inclusive excellence is about more than widening participation, going beyond issues of outreach and access. It is more than changing who gets in, it is also about changing what they get into. To be truly inclusive in higher education we need to change who we teach, how we teach, what we teach and who teaches. Doing this well extends the principles of inclusion to redefining excellence: part of being excellent is to be inclusive, This chapter draws on research and evaluation of a strategic, institution-wide approach to embedding diversity and inclusion at Imperial College London, a research-intensive science, technology, engineering and mathematics (STEM) university. This chapter highlights the need to integrate identity and belonging in order to support inclusive excellence. It covers four case studies that support inclusive excellence through staff, students, the curriculum and the wider student experience. These case studies of institutionally funded research and evaluation projects provide insight into how inclusive excellence as an idea can be operationalised in practice.

The chapter challenges stereotypes in STEM fields and students' disciplinary identity. Similar beliefs exist about staff roles and responsibilities in STEM disciplines. The reality is much more complex, and there is a need to embrace wider views of who is part of STEM higher education, and how STEM communities can be more inclusive. Two of the case studies explore longitudinal approaches to researching belonging and identity in STEM higher education. Interviews with staff and research with students show that interactive pedagogies require a new focus on student identities and responsibilities, and on staff identities and roles. This focus brings prestige for educational expertise, new ways of staff and students coming together in disciplinary contexts, and fresh insights into intersectional identities. Two further case studies, one on lessons in belonging from sectors outside higher education and another on using a 'kitchen' model for introductory laboratory skills in chemistry, provide fresh insights and detail new pedagogical approaches to making STEM education more inclusive.

This research addresses more widely how belonging is an affective outcome of student and staff experiences, and not something that can be forced or imposed. Lessons are offered in how academics, teaching and professional services staff, as well as students, can create environments in which multiple identities can be supported and which offer opportunities for transformation for individuals within STEM fields. Experiences from sectors beyond higher education can provide insights into how such aims are realised. This chapter explores new and innovative pedagogies that integrate research and teaching, challenge what STEM is, and explore what it is to belong in a STEM environment and how belonging can be supported within institutions. This approach involves reconceptualising success in higher education, and incorporating wider indices which embed inclusion as an essential aspect of excellence.

From widening participation to inclusion

Selective higher education institutions have implemented a range of measures and initiatives to address calls to improve diversity and inclusion but, despite significant regulatory and market pressure, have struggled to achieve the impact expected given the level of investment and effort (Buitendijk et al., 2019; Millward, 2021). STEM fields have lagged behind, compounded by gender gaps in access and progression that have been managed successfully across higher education more broadly. With students from across the globe competing for entry, highly selective institutions have focused on cautiously diversifying intake (Tight, 2012), taking great care to mitigate any perceived or actual impact on standards and outcomes (Boliver, 2017). Older higher education institutions with historically established identities face an additional challenge, with cultural and historical inertia often resisting well-intentioned change (Boliver, 2015). These findings align with research suggesting that those who have benefited from higher education are hesitant about opening its possibilities to more of the population (Mountford-Zimdars & Sabbagh, 2013). In higher education, social inequalities have persisted, and many gaps have widened despite extensive policy rhetoric and institutional investment (Bathmaker et al., 2013; Dorling, 2015). Higher education needs to be seen as more than an instrumental good, incorporating the experience of attending higher education in addition to the degree credential it provides (Kromydas, 2017).

Recently, greater attention has been devoted to enhancing the experience of students already enrolled, with the aim of reducing progression gaps and improving outcomes and retention (Office for Students, 2018). Concurrently there has been a greater emphasis on improving mental well-being and addressing untalked-of problems such as an overly competitive culture among both students and staff (Atkinson 2021; Kerr, 2013). To stay competitive, higher education institutions must consider and invest in the wider student experience. How institutions retain their reputation and standards is an area of concern, especially as student, staff and regulatory definitions of what is excellent, and therefore what its various members expect from the institutions in question, continue to evolve in the light of the changing higher education landscape. Similarly, making STEM inclusive requires that both access and continuation be tackled, and addressing stereotypes that inhibit belonging and impact outcomes.

Inclusion and research on the student experience

With stereotypes abounding, it can be challenging for higher education institutions to get a sense of the student experience across the institution. This difficulty is compounded in devolved, research-intensive institutions where there are high levels of departmental autonomy and many staff and students' allegiance is to their discipline. However, increasing regulation and oversight of higher education, a strong feature in higher education in England, requires the student experience to be reported and evaluated at an institutional level.

Longitudinal research not only provides data to fulfil institutional reporting responsibilities; it can show, too, how the student experience is changing over time, in response to institutional initiatives and strategic plans. It can also provide insight into societal influences such as a cost-of-living crisis and global events like the Covid-19 pandemic, and how these impact on students. Such impacts disproportionately affect disadvantaged students, which provides a further incentive to understand how all students, not only the majority, are faring. Such institutional approaches can range from undertaking longitudinal qualitative projects to adding a few questions on belonging to existing institutional surveys (see Kandiko Howson and Kingsbury, Chapter 1 in this volume, for examples), or to analysing existing data through a belonging lens. The following case study provides an overview of several institution-wide research and evaluation projects that offer an institutional lens onto belonging and the students' experience.

Case study: longitudinal, institution-wide research on students' belonging

The Belonging, Engaging and Community (BEC) Project (Centre for Higher Education Research and Scholarship, 2023) started in 2019. It investigates how students understand and construct their own sense of belonging to, and engagement with, various potential communities. The project draws on multiple methodologies to explore students' belonging, including questionnaires and semi-structured, longitudinal interviews, as well as more innovative approaches to capture unique insights, such as walking interviews and vox pop interviews. Outputs from the project include reports on how students' sense of belonging is mediated through pedagogy and the curriculum (Cohen & Viola, 2022), and using civic scholarship as a lens into how students develop as global citizens in a multicultural institution. These findings challenge stereotypes and assumptions that STEM study is 'neutral', and show how students are impacted by societal and political events (Viola, 2021).

Two projects, including an annual survey and qualitative research, explicitly focus on the experiences of students who are in receipt of an institutional bursary. As well as enabling the institution to evaluate the bursary scheme, these give an opportunity to students predominantly from widening-participation backgrounds to express their views on their experience. Breaking down stereotypes, this research has demonstrated the resilience and self-efficacy of these students, but has also revealed some of the financial and social challenges. The BEC and bursary projects are complemented by an annual institution-wide Student Experience Survey, which gathers feedback on a range of College services and the Imperial College Union. Questions on belonging show departmental differences, which signifies the need to be sensitive to local cultures and structures when addressing institution-wide challenges.

These research and evaluation projects provide huge insight into students' experiences, their sense of belonging and the communities they feel part of – or excluded from. Going beyond a single data source, these findings can be brought together to target specific pockets of concern and to add nuance to debates about ways to address stereotypes of STEM students. Such research also provides data to enable evidence-informed institutional decision making. This was recently seen in the development of an institution-wide mental health and well-being strategy, which aims to help staff and students to feel part of a wider, single, integrated community.

Diversity and inclusion

In UK higher education, diversity became a key feature of New Labour's widening-participation drive (Department for Education and Skills, 2003). Archer (2007) argued that this embracing of student diversity conflates equality and social inclusion, obscuring economic rationales and broader social justice critiques of the sector. This widening participation policy shift focused on changing the attitudes and aspirations of those who do not participate in higher education (Reay et al., 2001) rather than on addressing institutional cultures and practices. Diversity and inclusion thus sit precariously within higher education, as a policy 'solution' and an institutional 'problem' to be addressed. Diversity and inclusion also began to emerge as a key pedagogical tool, focusing on meeting the learning needs of all students (Grace & Gravestock, 2008). Over the past two decades, equality, diversity and inclusion agendas have been both promoted and decried; current manifestations of the debate relate to culture wars, decolonisation and charges of 'wokeism'. The policy debate continues on notions of equality, equity, and how meritocracy is defined (Boliver & Powell, 2023).

Inclusive excellence has emerged as a key response to the cultural resistance exemplified by these manifestations. Inclusive excellence is an effort to redefine the standards that those in a higher education institution work towards by including an inclusive environment and culture as a dimension of excellence. This approach aims to broaden notions of quality and avoid the idea that there is a trade-off between quality and widening participation in higher education. In contrast, widening participation should be seen as a way of increasing quality through a diversity of inputs, talents and experience, and wider notions of success.

Inclusive excellence frameworks have been widely adopted as a way to embed equity, diversity and inclusion policies in universities in the US and the UK. 'Making excellence inclusive' is a guiding principle for the

Association of American Colleges & Universities (AAC&U, 2021), with an associated Equity Scorecard and Diversity Toolkit. Pursuing inclusive excellence means that inclusion is a requirement of excellence and of redefining notions and criteria of excellence. Beyond merely admitting students from a wider range of backgrounds, inclusive excellence is about creating an environment in which all students can thrive and exercise their diversity in a way that mutually benefits the whole community.

Stereotypes in STEM

Stereotypes about STEM impact staff and students' identity and sense of belonging, as well as progression and outcomes. Popular media representations of STEM professionals range 'from mad scientists to absent-minded professors to brilliant geniuses to maniacal villains to socially awkward loners to life-saving heroes' (Steinke, 2017, p. 1). Gender stereotypes about STEM are societally entrenched; the common perception is that boys are more interested than girls in engineering and computer science from as young as six (Master et al., 2021). In a study that covered 34 countries, over two-thirds of respondents associated science with men and boys (Nosek et al., 2009), although with noted differences across global regions, which demonstrates the importance of intersectionality. Gender stereotypes can be compounded by trait-based stereotypes, that people in STEM are socially awkward, unattractive, naturally intelligent geniuses (Cheryan et al., 2013; Ehrlinger et al., 2018). An integrative review found that 'social factors, such as stereotypes and self-representations about "belonging," are powerful contributors to observed gender differences in STEM interest and academic outcomes' (Master & Meltzoff, 2020, p. 152).

Alongside notions that STEM subjects are for naturally gifted brilliant geniuses, there is a conception that STEM, and mathematics in particular, is hard and not many people can do it. This links with stereotypes about the mathematical, logical and abstract ways of thinking that are foundational to STEM subjects. There is an expectation of struggle, the challenge being a rite of passage or initiation. The struggle is seen as an opportunity to prove resilience, a belief often perpetuated by those who have 'succeeded' in STEM fields. This belief can lead to those who do not achieve success blaming themselves and concluding 'I'm not a STEM person'.

For academic staff, stereotypes about STEM fields continue: there are inequalities in accessing jobs, obtaining grants and gaining promotion, across gender and ethnicity characteristics, as well as other factors.

Concentration of research funding and recognition supports a 'winner takes all' culture. Research-based reward schemes within academia lead to a devaluing of teaching and student support. Professionalising, defining and recognising teaching roles, and a wider conception of awards, which signal what is valued, can broaden notions of excellence. Similarly, rethinking teaching beyond producing the next generation of STEM academics can be more inclusive of the whole student population. Repositioning the 'struggle' of STEM fields as one of 'supported challenge' can help more students stay in STEM subjects and develop the confidence to continue. The following case study explores a unique approach to offering 'supported challenge' in the chemistry curriculum.

Case study: the Chemical Kitchen

The Chemical Kitchen was created by Roger Kneebone and Alan Spivey (Imperial College London) and renowned chef Jozef Youssef (Kitchen Theory), with experiments designed and run by Jakub Radzikowski and Luke Delmas (Imperial). The project started in 2019 as an Imperial College London Pedagogy Transformation Project, part of their Learning and Teaching Strategy, curriculum review and innovation process.

The 'skills gap' between school and university is widely acknowledged as a challenge (Smith, 2012). New undergraduate students often come ill-prepared for laboratory work, even if their school grades are outstanding. Many are fearful of displaying ignorance of subject knowledge or of disclosing inexperience of practical procedures, especially, but not only, those from widening-participation academic backgrounds.

By combining expertise from high-end kitchens and laboratory science, the Chemical Kitchen encourages chemistry undergraduates to focus on practical skills without their usual preoccupation with scientific facts. Students are introduced to the mindset and some fundamental skills needed in a laboratory through the less threatening parallel of cooking and work on the level and unfamiliar 'playing field' of the kitchen. The project aims to free up attentional capacity (Seery et al., 2019), which helps them to develop as craftspeople (Kneebone et al., 2018) in the laboratory.

The Chemical Kitchen is a face-to-face programme comprising three three-hour sessions in classes of 15 working in groups of three. The programme works at three levels: gaining basic practical skills (e.g., weighing, heating and mixing liquids and powders); acquiring more sophisticated skills (e.g., experimental design, collaborative team working, observation and note taking); and the essentials of 'scientific thinking' (e.g., exploration, creativity, critical thinking and innovation). Such activities empower tutors to communicate complex ideas in a simplified (but not simplistic) and challenging (but not threatening) manner, and students benefit from the changed perspective and reduced cognitive load. Students are able to reflect on practical work in their field and focus on the often omitted non-disciplinary aspects of their practice.

Evaluation reveals that students appreciate the fun and freedom of a challenge on an unfamiliar but level playing field, as illustrated by student feedback:

> Chemical Kitchen was a really fun and inventive way to help develop my confidence outside of a lab. As a first year it can be quite daunting stepping into a lab for the first time, but this preliminary step allowed me to try some lab techniques and work with peers in a creative environment as well as making some really tasty foods!
>
> The techniques used in the Chemical Kitchen practical such as suction filtration drew many parallels to those required in a normal synthesis. The 'kitchen' provided a much more relaxed and enjoyable method of learning these techniques, making our first real synthesis experiment less daunting.
>
> (Radzikowski et al., 2021, p.712)

The lessons learnt from the Chemical Kitchen informed the institutional response to the Covid-19 pandemic, particularly with respect to how a 'lab in a box' approach was used to send simplified but fundamental experiments that could be performed 'at home' to a distributed population of students (MacKay, 2022). The Chemical Kitchen informed institutional approaches to experimental, discovery-based learning more widely. This approach has led to the inception of bespoke 'laboratory kitchen' spaces and an extension of the concept to other experimental disciplines (Radzikowski et al., 2021).

Challenging stereotypes in STEM – those placed on students and those students have of their environment – is key to offering an inclusive environment. The Chemical Kitchen case study is a great example of giving students a safe space in which to develop their STEM identity, which offers a level playing field for students coming with a variety of previous experiences. This approach advances all students, and moves away from remedial education approaches targeted at disadvantaged students. The case study shows an inclusive approach, but one based on offering a high-quality education to all students rather than on attempting to mitigate a perceived deficit for a problematised minority.

Quality and excellence

Similarly to diversity and inclusion, quality and excellence are defined and measured by those with power. Excellence is a 'mark of distinction, describing something that is exceptional, meritocratic, outstanding and exceeding normal expectations. … If some provision is recognised as excellent, it implies that the majority of other providers are simply satisfying standards' (Brusoni et al., 2014, p. 20). Harvey and Green (1993) offer three notions of quality: a traditional notion of quality, linked with distinctiveness or something special; the view that quality means exceeding high standards, which is linked with an elitist notion that this is scarce; and quality as meaning checking standards, based on baseline thresholds to be met. Although excellence is assumed as a core value in higher education (Rostan & Vaira, 2011), it is also a contested, situated and dynamic concept (Gunn, 2018; Gunn & Fisk, 2013).

Higher education in the UK is highly stratified. There are persistent social class inequalities in access to elite institutions (Boliver, 2011) and research has shown that attendance at the most selective institutions is linked with entry to elite positions in the labour market (Wakeling & Savage, 2015). There is little movement in the hierarchy of institutions (Croxford & Raffe, 2015), and notions of excellence are reinforced through rankings and league tables (Hazelkorn, 2015). These rankings fuel global competition across and within institutions (Brankovic et al., 2018), even as their empirical basis is critiqued and debated.

Furthermore, in his article about seminal myths in higher education, Macfarlane (2020) concludes that they cannot be substantiated by empirical evidence. He tackles a dominant narrative of the perceived tension between excellence and inclusion, namely, that admitting a wider range of students necessarily means a lowering of standards. The 'moral panic' described by Macfarlane in reaction to such myths homes in on debates about quality in higher education, and what makes an institution 'excellent' (O'Connor & Barnard, 2021). Work to widen participation has been slowed by a hesitation to move away from the status quo in an effort to preserve standards and 'retain' excellence. Now, more than ever, higher education institutions need to be critical of discourses about inclusion, as these are used to examine, evaluate and predict student behaviour and the generalisations and stereotypes that are subscribed to by students.

Academic inclusion is a term used to specify how equitable access to skills and knowledge is. It functions as an evolving response to on-going societal problems, going beyond narrow demographic conceptions. Academic inclusion involves changing the nature of STEM disciplines: how roles are viewed, how contributions are valued and what success looks like. Culture plays a key part in how institutions put access and widening-participation policies into practice (Greenbank, 2007). What it means to be a student in higher education is changing, and at the same time students' expectations of their educational institutions are evolving beyond access to knowledge to include access to a community where they can belong, contribute and thrive (Maunder, 2018). Addressing the 'wicked problem' of how to diversify elite higher education requires new approaches and perspectives beyond the existing literature on higher education.

Looking outside higher education offers unique insights and recommendations to help higher education institutions capitalise on the potential of inclusive excellence. The study described below set out to explore inclusive excellence in other sectors in order to understand better what institutions outside of higher education are doing to widen participation and improve equality, diversity and inclusion (EDI), thereby providing a reflection on what the higher education sector can learn from others.

Case study: lessons from beyond, redefining inclusive excellence

Alejandro Luy, Imperial College London

How higher education institutions remain of high quality and diversify in a competitive post-pandemic future requires serious consideration as student, staff and regulatory definitions of what is excellent continue to evolve in the changing higher education landscape. This section reports on a case study that ventured beyond the higher education setting into other sectors with a similar focus on selectivity, competition and excellence, in search of insight and strategies for achieving inclusive excellence. Senior leaders from five sectors outside of higher education shared their reflections on diversifying their organisations while maintaining high performance, loyalty and well-being. Belonging emerged as key to building an inclusive and effective community by unlocking diversity. Exercised diversity, empowered to align with the mission of the community, was found to be the core mechanism through which excellence was achieved across the sectors studied.

Leaders from organisations outside of higher education in which belonging or inclusive excellence was a priority were interviewed on how they promote inclusion, and maintain excellence and a strong sense of identity, within their organisations. The semi-structured interviews were thematically analysed and, although the themes that emerged across the various sectors investigated were strong and well evidenced, the results must be interpreted in the light of the limited sample of participants explored across a wide range of sectors. The participants' positions and sectors were:

1. Senior leader in a religious organisation
2. HR executive in a large mining company
3. High-ranking officer/academic in the British Army
4. Senior leader in the Scout Association
5. Retired Team GB (Britain's Olympic team) coach
6. Recruiter for a UK Premier League football team
7. Staff leader in Team GB
8. People executive for a leading online vocational education provider

Inclusion and belonging: the bedrock of inclusive excellence

A phenomenon observed across all the sectors investigated was that, in every context, creating an environment in which those recruited would feel 'valued', 'accepted', 'cared for', 'known' and 'listened to' was described as the key to unlocking the power of diversity while maintaining excellence and remaining competitive. Such phrases are all strongly related to belonging. Some leaders went as far as saying that belonging was one of the most important factors determining success. Participants reflected on the importance of recognising and empowering individuality, and said that labels and categories used to address EDI issues can sometimes be a barrier to enabling diversity to manifest (cf. Read et al., 2003; Yorke, 2000).

The interviews suggest that belonging is the missing piece in the puzzle of inclusion, one that can help higher education institutions go beyond positive-discrimination measures and labels to enable individuals to exercise all dimensions of their diversity. If true belonging is the ideal state of a community and leads to enhanced performance, loyalty, well-being and exercised diversity, which the literature supports (Brooman & Darwent, 2014; Furrer & Skinner, 2003; Kuh et al., 2010; Osterman, 2000; Pittman & Richmond, 2008; Thomas, 2012), then the definition and understanding of what makes a community excellent must evolve to include it.

Three dimensions of inclusive excellence that emerge from belonging were identified by participants. The first was a clear mission and purpose with which all activities, recruitment, culture and objectives should align. Although most communities can identify their primary goal and purpose, care is needed to prevent them leading to unidimensional success criteria or forcing individuals to fit into a one-dimensional success identity. Thus, the second dimension was that inclusive excellence must be authentically multidimensional. In many cases participants suggested that softer aspects of their community, such as culture and belonging, had previously been underrecognised despite being integral to success and excellence, and that they are increasingly becoming the prime area of focus.

The third dimension of inclusive excellence was an emphasis on collective success. In all cases, the mission and purpose were greater than what could ever be achieved by an individual, with the individual's goals oriented towards the shared objective. The alignment between person and purpose is driven by, and drives, belonging. This summary of inclusive excellence was described by Participant D thus: 'What I do connects to what we do.'

Lessons

The three dimensions of inclusive excellence found in this research, together with the finding that a strong sense of belonging among the members of the community should be the bedrock upon which inclusive excellence is built, and the external setting within which these results were found, provide a helpful lens through which to reflect on higher education institutions. With a sense of belonging, competition and excellence can be framed as being positive and inclusive rather than as driving an 'us versus them' approach and limiting inclusion. Leaders adopted language that both reflects and shapes feelings of belonging, empowering members to exercise their uniqueness while ensuring that any competition was positioned to achieve common, collaborative goals. The rhetoric was not about 'protecting' excellence from diversity but rather about realising, reframing, enhancing and pursuing excellence through diversity.

Curriculum and culture change

Exploring an institution-wide, holistic approach that has embedding diversity and inclusion at its heart can offer insight into how to counter the 'more means less' myth Macfarlane (2020) identified. This research explores staff members' perception of their ability and of their sense of empowerment towards change, their perception of the prestige of research and teaching activities, and the impact of new teaching-based job roles. In the case study findings here, the focus is on aspects of equity, diversity and inclusion and how these are addressed in relation to institutional change.

Case study: inclusive curricula through new teaching roles

This case study reports on a research project that explores culture and curriculum change as part of a wider research and evaluation exercise of strategic reform at a UK-based research-intensive institution. The project utilises concept map-mediated semi-structured interviews to capture multiple data outputs through interviews with more than 50 members of staff over four years. As part of the wider project, interview data is analysed alongside the programme-level approach to the change process, drawing on discourse analysis of documentation of the process as well as programme-level and institutional-level evaluation indicators. This analysis of institutional change investigates an attempt to put inclusive excellence into practice. The approach draws on research on the prestige economy, which describes the beliefs, values and behaviours that characterise and express what a group of people prizes highly (English, 2005) and draws out 'pedagogical currency' metrics to support reward and recognition for high-quality educational work (Coate & Kandiko Howson, 2016).

Integrate identity and belonging to support inclusive excellence

A focus on active learning and interactive pedagogies in the curriculum review process has impacted staff and students. Students face new identities and new responsibilities for managing their educational experience. They become active agents in their education, not passive recipients of information. Innovative pedagogies integrating teaching and research have changed how staff holistically consider their academic role. Staff on teaching-only or teaching-intensive contracts have been developing credibility within their roles. Institutional support and development have professionalised teaching, and formal academic qualifications are now available. Prestige for educational expertise is being developed, with experts identified throughout the institution (Kandiko Howson & Kingsbury, 2023). 'I'm sorry, but excellent researchers don't necessarily make excellent teachers. I'll leave it at that, on that particular aspect of it. But so [the institution] is valuing teaching much more' (Thierry). There are emerging social identities of staff who are focused on STEM-based teaching: those with advanced qualifications and research experience who concentrate on teaching and have dual, but often not equal, discipline and pedagogical expertise. Such staff bring insights of inclusive education into their disciplinary contexts and 'translate' diversity to make it relevant for their departments.

> There's been a lot of focus on, and I feel that on the ground as well, like appreciating the diversity quite meaningfully and appreciating that [the institution] is, you know, a challenging place to be. You get quality, world-class education, but that also that different people approach it differently and by people, I mean students. (Shahrazad)

Laying the foundations through new staff roles has been a key part of the institutional journey towards inclusive excellence. However, changing the profile of staff and students is a long game. 'You know that we don't have a diversity problem. We have a huge diversity problem' (Noel). While demographic change takes time, staff on the ground reflected more on making the educational experience on offer more inclusive and more relevant to the student body, now and in the future.

Curriculum as the core delivery method

> At its core, the main ethos of [the institution] is excellence in learning and education. But it's really thinking about how can we deliver this for the next 10 years, the next cohort of students who have very different needs, very different demands, and also appreciating that the more global we get, the more difficult it will be to accommodate or appreciate this diversity within our student body, but also celebrate it. So it's not just about accommodating them but also celebrating, because I think there's an appreciation that this is the strength – that within that strategy that diversity is capitalised on the strength of that diversity. (Suki)

There was a strong sense among interviewees that successful inclusion required integration within the curriculum, not just activities or clubs outside of the academic experience. 'I think one of the best ways to measure [excellence] is the alignment between what's being delivered and what's being … adopted by the students. So it's the application of what they've learned, and that's from the educational or the excellence in scientific research and rigour' (Stef). In this way excellence is defined in the quality of teaching. For some staff, inclusion is seen holistically, rather than by splitting out different indices of diversity.

> And then I help plan the programmes with the leads and the administrators. And so working with the curriculum to see if we've got repetition, or if we're actually at the cutting edge, one is doing what it says on the tin or if it's cutting edge from a few years ago, making sure they're student-friendly, making sure they're inclusive, so that, as many people, say students with disabilities, or students coming from a different culture, are included and that they're able to access programmes properly. (Teo)

Equity, diversity and inclusion as incidental

For many staff, diversity did not feature in their discussions about curriculum change. This absence was echoed in documentary research, which featured little explicit mention of inclusion. However, a lot of changes were put in place that would support diverse learners. 'It is an EDI thing in that it is to do [with EDI] … not that it is what it was brought in for … it may not have been anybody saying "Ah, we need to do this for equality and inclusion reasons"' (Axel). Many staff mentioned wanting to support their students from different backgrounds, but they did not necessarily see this as supporting an inclusive environment. 'I haven't really implemented anything there. I think it's probably more that we try and be aware when we make, say, seminar groups, tutorial groups' (Narinder).

Many interviewees felt that there was little they could do to bring diversity into the curriculum content given the STEM nature of their disciplines. 'I'm not aware of anything particularly explicitly that I did. I tried, so one of the things that I do is talk about historical figures in the field as the various kind of relevant laws and things come up. They are almost universally white European, and there wasn't a lot I could do about it' (Harshit).

There is debate about whether making the education experience more supportive for the students at hand is true 'inclusion'. For many STEM staff, the goal was a curriculum that all students could access and succeed within. This signals a focus on academic inclusion, with notions of students' belonging being based on an understanding and a connection with the discipline and a logical, mathematical way of thinking, over socio-demographic definitions of diversity.

> We recognise that actually one of the big bits of feedback was that students are coming in from, so this is an EDI thing I guess, people from lots of different backgrounds with lots of different initial skills, and actually finding what the correct level was, without being assessed, was quite important. (Abady)

What emerged from this case study was a sense that diversity was supported at a high level within the institution, but that developing an inclusive environment stemmed from local activity and was delivered in the disciplinary context. The emerging STEM teaching-focused staff with dual discipline and pedagogical expertise were more explicitly aware that diversity in their active, discovery-based contexts enriched the learning experience for all, and were more likely to purposely position diversity in that context, rather than seeing it as a problem to be solved or managed. In one way this approach is more authentic and bottom-up, but it can be piecemeal and left to individual initiative.

Conclusion

This chapter highlights perceptions of the role of prestige in relation to research and teaching, the sense of empowerment towards change, and attitudes towards diversity and inclusion and the impact on staff's own academic identities. While the notion of 'inclusive excellence' can seem straightforward in theory, in practice it is a much trickier concept. It is challenging to apply inclusive practices to specific institutional and disciplinary contexts. Furthermore, how inclusion manifests in relation to the curriculum will be different in STEM than in the social sciences and humanities.

The examples from sectors beyond higher education shows the integral relationship between inclusion and belonging and how excellence can be achieved through wider and more expansive notions of belonging rather than through exclusion and 'othering', as noted by Hyland in Chapter 2 of this volume. The case study of the Chemical Kitchen showed how embedding activities into the disciplinary curriculum can help students to transition into new identities and to develop skills that help them to feel comfortable in their new environments. In many STEM subjects, it is in the delivery of the curriculum, rather than its content, that inclusion is operationalised. Thus, we see belonging as an affective outcome of staff and student experiences, not something that is forced or imposed. Similar examples from contexts beyond higher education were offered, which showed that belonging is situational and relational (Gravett & Ajjawi, 2022).

True inclusive excellence in STEM higher education is not about competing to be the best in a narrow field, but about broadening notions of success and working collaboratively with others. Inclusive excellence is about more than widening participation; going beyond issues of outreach and access we must transcend the fear that diversifying intake leads to perceived or actual erosion of standards and outcomes. The competitive nature of STEM fields, exacerbated in selective institutions, requires the reconceptualisation of success to incorporate wider indices, which embed inclusion as an essential aspect of excellence. Inclusive excellence entails reframing competition as collaborative and about striving to be the best that you can be rather than better than others, reframing difference as enriching the learning experience for all, and being pedagogically positive rather than seeing diversity as a problem to be solved. Cultural reframing is complex, and the case studies suggest that it requires top-down support and recognition and bottom-up embedded, integrated acceptance within disciplinary contexts to achieve lasting change.

As mentioned by interviewees in the research, inclusion is forward-looking, and entails developing STEM fields to have the capacity to deal with tomorrow's problems while not being confined by yesterday's standards.

References

AAC&U (2021). Making excellence inclusive. https://web.archive.org/web/20160319062209/https://www.aacu.org/making-excellence-inclusive. Accessed June 2021.

Archer, L. (2007). Diversity, equality and higher education: A critical reflection on the ab/uses of equity discourse within widening participation. *Teaching in Higher Education*, 12(5–6), 635–53. https://doi.org/10.1080/13562510701595325.

Atkinson, S. (2021). The toxic effects of subjective wellbeing and potential tonics. *Social Science & Medicine*, 288, 113098. https://doi.org/10.1016/j.socscimed.2020.113098.

Bathmaker, A.-M., Ingram, N. & Waller, R. (2013). Higher education, social class and the mobilisation of capitals: Recognising and playing the game. *British Journal of Sociology of Education*, 34(5–6), 723–43. https://doi.org/10.1080/01425692.2013.816041.

Boliver, V. (2011). Expansion, differentiation, and the persistence of social class inequalities in British higher education. *Higher Education*, 61(3), 229–42. https://doi.org/10.1007/s10734-010-9374-y.

Boliver, V. (2015). Lies, damned lies, and statistics on widening access to Russell Group universities. *Radical Statistics*, 113, 29–38.

Boliver, V. (2017). Misplaced optimism: How higher education reproduces rather than reduces social inequality. *British Journal of Sociology of Education*, 38(3), 423–32. https://doi.org/10.1080/01425692.2017.1281648.

Boliver, V. & Powell, M. (2023). Rethinking merit? The development of more progressive approaches to university admissions in England. *Widening Participation and Lifelong Learning*, 24(3), 33–55. https://doi.org/10.5456/wpll.24.3.33.

Brankovic, J., Ringel, L. & Werron, T. (2018). How rankings produce competition: The case of global university rankings. *Zeitschrift für Soziologie*, 47(4), 270–88. http://dx.doi.org/10.1515/zfsoz-2018-0118.

Brooman, S. & Darwent, S. (2014). Measuring the beginning: A quantitative study of the transition to higher education. *Studies in Higher Education* 39(9), 1523–41. https://doi.org/10.1080/03075079.2013.801428.

Brusoni, M., Damian, R., Grifoll Sauri, J., Jackson, S., Kömürcügil, H., Malmedy, M., Matveeva, O., Motova, G., Pisarz, S., Pol, P., Rostlund, A., Soboleva, E., Tavares, O. & Zobel, L. (2014). The concept of excellence in higher education. ENQA Occasional Papers 20. European Association for Quality Assurance in Higher Education, Brussels. https://www.enqa.eu/publications/the-concept-of-excellence-in-higher-education/. Accessed 15 December 2023.

Buitendijk, S., Curry, S. & Maes, K. (2019). Equality, diversity and inclusion at universities: The power of a systemic approach. LERU Position Paper. https://www.leru.org/files/LERU-EDI-paper_final.pdf. Accessed 15 December 2023.

Centre for Higher Education Research and Scholarship (2023). Belonging, Engagement, and Community. Imperial College London. https://www.imperial.ac.uk/education-research/our-work/sense-of-belonging/belonging-engagement-and-community-/. Accessed 15 December 2023.

Cheryan, S., Plaut, V. C., Handron, C. & Hudson, L. (2013). The stereotypical computer scientist: Gendered media representations as a barrier to inclusion for women. *Sex Roles*, 69, 58–71. https://doi.org/10.1007/S11199-013-0296-X.

Coate, K. & Kandiko Howson, C. 2016. Indicators of esteem: Gender and prestige in academic work. *British Journal of Sociology of Education*, 37(4), 567–85. https://doi.org/10.1080/01425692.2014.955082.

Cohen, E. & Viola, J. (2022). The role of pedagogy and the curriculum in university students' sense of belonging. *Journal of University Teaching & Learning Practice*, 19(4), art. no. 6.

Croxford, L. & Raffe, D. (2015). The iron law of hierarchy? Institutional differentiation in UK higher education. *Studies in Higher Education*, 40(9), 1625–40. https://doi.org/10.1080/03075079.2014.899342.

Department for Education and Skills (2003). The future of higher education. Cmd 5735 London: The Stationery Office.

Dorling, D. (2015). *Injustice: Why Social Inequality Still Persists* (rev. edn). Bristol: Policy Press.

Ehrlinger, J., Plant, E. A., Hartwig, M. K., Vossen, J. J., Columb, C. J. & Brewer, L. E. (2018). Do gender differences in perceived prototypical computer scientists and engineers contribute to gender gaps in computer science and engineering? *Sex Roles*, 78, 40–51. https://doi.org/10.1007/s11199-017-0763-x.

English, J. F. (2005). *The Economy of Prestige: Prizes, awards, and the circulation of cultural value*. Cambridge, MA: Harvard University Press.

Furrer, C. & Skinner, E. (2003). Sense of relatedness as a factor in children's academic engagement and performance. *Journal of Educational Psychology* 95(1), 148–62. https://doi.org/10.1037/0022-0663.95.1.148.

Grace, S. & Gravestock, P. (2008). *Inclusion and Diversity: Meeting the needs of all students*. Abingdon: Routledge.

Gravett, K. & Ajjawi, R. (2022). Belonging as situated practice. *Studies in Higher Education*, 47(7), 1386–96. https://doi.org/10.1080/03075079.2021.1894118.

Greenbank, P. (2007). Introducing widening participation policies in higher education: The influence of institutional culture. *Research in Post-Compulsory Education*, 12(2), 209–24. https://doi.org/10.1080/13596740701387494.

Gunn, A. (2018). Metrics and methodologies for measuring teaching quality in higher education: Developing the Teaching Excellence Framework (TEF). *Educational Review*, 70(2), 129–48. https://doi.org/10.1080/00131911.2017.1410106.

Gunn, V. & Fisk, A. (2013). Considering teaching excellence in higher education: 2007–2013: A literature review since the CHERI report 2007. https://eprints.gla.ac.uk/87987/1/87987.pdf. Accessed 16 December, 2023.

Harvey, L. & Green, D. (1993). Defining quality. *Assessment and Evaluation in Higher Education*, 18(1), 9–34. https://doi.org/10.1080/0260293930180102.

Hazelkorn, E. (2015). *Rankings and the Reshaping of Higher Education: The battle for world-class excellence*, 2nd edn. Basingstoke: Palgrave Macmillan.

Kandiko Howson, C. & Kingsbury, M. (2023). Educational expertise as prestige: Research-intensive curriculum change. *Teaching in Higher Education*, 1–18. https://doi.org/10.1080/13562517.2023.2215702.

Kerr, H. (2013). Mental distress survey overview. NUS Services Ltd/MRS Evidence Matters. https://web.archive.org/web/20180106134236/https://docplayer.net/28281501-Mental-distress-survey-overview-prepared-by-helen-kerr-research-officer.html#google_vignette.

Kneebone, R., Schlegel, C. & Spivey, A. (2018). Science in hand: How art and craft can boost reproducibility. *Nature*, 564, 188–9. https://doi.org/10.1038/d41586-018-07676-4.

Kromydas, T. (2017). Rethinking higher education and its relationship with social inequalities: Past knowledge, present state and future potential. *Palgrave Communications*, 3, art. no. 1, 1–12. https://doi.org/10.1057/s41599-017-0001-8.

Kuh, G. D., Kinzie, J., Schuh, J. H. & Whitt, E. J. (2010). *Student Success in College: Creating conditions that matter.* San Francisco, CA: Jossey-Bass.

Macfarlane, B. (2020). Myths about students in higher education: Separating fact from folklore. *Oxford Review of Education*, 46(5), 534–48. https://doi.org/10.1080/03054985.2020.1724086.

MacKay, M. (2022). Imperial education team wins prestigious Royal Society of Chemistry Prize. *Imperial College London News*, 22 November. https://www.imperial.ac.uk/news/241651/imperial-education-team-wins-prestigious-royal/. Accessed 16 December 2023.

Master, A. & Meltzoff, A. N. (2020). Cultural stereotypes and sense of belonging contribute to gender gaps in STEM. *International Journal of Gender, Science and Technology*, 12(1), 152–98. https://genderandset.open.ac.uk/index.php/genderandset/article/view/674. Accessed 16 December 2023.

Master, A., Meltzoff, A. N. & Cheryan, S. (2021). Gender stereotypes about interests start early and cause gender disparities in computer science and engineering. *Proceedings of the National Academy of Sciences*, 118(48), e2100030118. https://doi.org/10.1073/pnas.2100030118.

Maunder, R. E. (2018). Students' peer relationships and their contribution to university adjustment: The need to belong in the university community. *Journal of Further and Higher Education*, 42(6), 756–68. https://doi.org/10.1080/0309877X.2017.1311996.

Millward, C. (2021). Income is important for fair access, but so is place. Office for Students blog, 5 July. https://www.officeforstudents.org.uk/news-blog-and-events/blog/income-is-important-for-fair-access-but-so-is-place/.

Mountford-Zimdars, A. & Sabbagh, D. (2013). Fair access to higher education: A comparative perspective. *Comparative Education Review*, 57(3), 359–68.

Nosek, B. A., Smyth, F. L., Sriram, N., Lindner, N. M., Devos, T., Ayala, A., …, Greenwald, A. G. (2009). National differences in gender–science stereotypes predict national sex differences in science and math achievement. *Proceedings of the National Academy of Sciences*, 106(26), 10593–7. https://doi.org/10.1073/pnas.0809921106.

O'Connor, P. & Barnard, S. (2021). Problematising excellence as a legitimating discourse. In P. O'Connor & K. White (eds), *Gender, Power and Higher Education in a Globalised World*, pp. 47–69. Cham: Palgrave Macmillan.

Office for Students (2018). A new approach to regulating access and participation in English higher education: Consultation outcomes. OfS 2018.53. Office for Students.

Osterman, K. F. (2000). Students' need for belonging in the school community. *Review of Educational Research*, 70(3), 323–67. https://doi.org/10.3102/00346543070003323.

Pittman, L. & Richmond, A. (2008). University belonging, friendship quality, and psychological adjustment during the transition to college. *Journal of Experimental Education*, 76(4), 343–62. https://doi.org/10.3200/JEXE.76.4.343-362.

Radzikowski, J. L., Delmas, L. C., Spivey, A. C., Youssef, J. & Kneebone, R. (2021). The Chemical Kitchen: Toward remote delivery of an interdisciplinary practical course. *Journal of Chemical Education*, 98(3), 710–13. https://doi.org/10.1021/acs.jchemed.0c01047.

Read, B., Archer, L. & Leathwood, C. (2003). Challenging cultures? Student conceptions of 'belonging' and 'isolation' at a post-1992 university. *Studies in Higher Education*, 28(3), 261–77. https://doi.org/10.1080/03075070309290.

Reay, D., Davies, J. M., David, M. & Ball, S. J. (2001). Choices of degree or degrees of choice? Class, 'race' and the higher education choice process. *Sociology*, 35(4), 855–74. https://doi.org/10.1177/0038038501035004004.

Rostan, M. & Vaira, M. (2011). Questioning excellence in higher education: An introduction. In M. Rostan & M. Vaira (eds), *Questioning Excellence in Higher Education: Policies, experiences and challenges in national and comparative perspective*, pp. vii–xvii. Rotterdam: Sense Publishers.

Seery, M. K., Agustian, H. Y. & Zhang, X. (2019). A framework for learning in the chemistry laboratory. *Israel Journal of Chemistry*, 59(6–7), 546–53. https://doi.org/10.1002/ijch.201800093.

Smith, C. J. (2012). Improving the school-to-university transition: Using a problem-based approach to teach practical skills whilst simultaneously developing students' independent study skills. *Chemistry Education Research and Practice*, 13(4), 490–9. https://doi.org/10.1039/C2RP20096A.

Steinke, J. (2017). Adolescent girls' STEM identity formation and media images of STEM professionals: Considering the influence of contextual cues. *Frontiers in Psychology*, 8, art. no. 716, 1–15. https://doi.org/10.3389/fpsyg.2017.00716.

Thomas, L. (2012). Building student engagement and belonging in higher education at a time of change: Final report from the What Works? Student Retention & Success programme. Paul Hamlyn Foundation. https://web.archive.org/web/20220207011512/https://www.phf.org.uk/wp-content/uploads/2014/10/What-Works-report-final.pdf. Accessed 11 December 2023.

Tight, M. (2012). *Researching Higher Education*, 2nd edn. Maidenhead: Society for Research into Higher Education & Open University Press.

Viola, J. K. (2021). Belonging and global citizenship in a STEM university. *Education Sciences*, 11(12), art. no. 803. https://doi.org/10.3390/educsci11120803.

Wakeling, P. & Savage, M. (2015). Entry to elite positions and the stratification of higher education in Britain. *Sociological Review*, 63(2), 290–320. https://doi.org/10.1111/1467-954X.12284.

Yorke, M. (2000). The quality of the student experience: What can institutions learn from data relating to non-completion? *Quality in Higher Education* 6(1): 61–75. https://doi.org/10.1080/13538320050001072.

Part II
Identities and belonging in STEM

6

Understanding the sense of belonging and social identity among STEM students during the Covid-19 pandemic

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Introduction

Feeling a sense of belonging to the community of other human beings is essential, as we are social animals. Groups often provide us with a sense of social identity, of knowledge that we belong to certain social groups. How much we identify ourselves with the group represents the degree to which we see ourselves in terms of group membership and the degree of value and emotional attachment to the group. Students' sense of belonging to their study community in higher education seems to be strongly associated with study engagement and happiness. Our data on STEM students at the University of Helsinki shows that a sense of belonging was associated with how meaningful students found their studies and with perceived level of peer support and beneficial feedback from teachers. In addition, the stronger the sense of belonging was, the more the students believed that teachers had trust in their abilities. First-year students starting their studies during the Covid-19 pandemic had a weaker sense of belonging than students who started their studies before the pandemic did. Moreover, a small-scale study with respondents from two science courses revealed that, on average, students feel they belong to, and identify quite strongly with, their study community. The main source of social identity was positive interaction and collaboration with peers. How the sense of belonging could be supported among STEM students is discussed in the chapter.

It is a truth universally acknowledged that transition to higher education is a critical period for students, and that integration into the study community is essential for their future study success and well-being (Apriceno et al., 2020; Rainey et al., 2018; Tinto, 1975; see also Voice, Purdy, Labrosse & Heath, Chapter 3 in this volume). STEM students typically start their studies in big groups and, even if studies normally include small-group work in labs or as exercises, the Covid-19 pandemic forced first-year students to take most of their courses remotely, meaning that students missed the opportunity to interact with their peers. Positive social interactions in our everyday environment are crucial to our welfare (Baumeister & Leary, 1995). In general, research shows remote learning worsened university students' well-being (Allen et al., 2023; Browning et al., 2021; Heumann et al., 2023; Salmela-Aro et al., 2022). The aim of this chapter is to examine the relationship between sense of belonging and students' experiences of the teaching–learning environment among Finnish STEM students during the Covid-19 pandemic. With a mixed-methods approach we used quantitative data about sense of belonging and qualitatively explored students' thoughts about factors that enhance feelings of belonging and positive social identity in the study community.

Sense of belonging and social identity

Feeling accepted and supported by others (Goodenow, 1993) is a powerful motivation for human beings (Baumeister & Leary, 1995; Deci & Ryan, 2000). Sense of belonging consists of both affective and cognitive elements (Hurtado & Carter, 1997). The affective experience of fitting in is often studied (Good et al., 2012; Trujillo & Tanner, 2014; van Herpen et al., 2020), and the cognitive element is characterised through social identity, in other words, a cognitive representation of group membership. Social identity is the part of a person's self-concept that corresponds to group membership, and is based on the processes of categorisation and identification. Categorisation takes place when individuals define themselves as group members and identification occurs when individuals take on the qualities and characteristics of the group to which they belong (Turner & Reynolds, 2001).

Ahn and Davis (2020b; see also Kandiko Howson & Kingsbury, Chapter 1 in this volume) have suggested a four-domain model of students' sense of belonging to university: academic engagement, social engagement, surroundings and personal space. Academic engagement is associated with learning experiences and interaction with the staff. 'Social engagement' refers to positive social interaction with peers, ‘surroundings’ to such as living space and geographical and cultural location, and ‘personal space’ to more psychological aspects such as life satisfaction, identity and personal interests. Social engagement seems to be especially important for students in general (Meehan & Howells, 2019) and for those in STEM (Harben & Bix, 2020; Viola, 2021). In STEM fields, higher levels of sense of belonging in students have been produced by, for instance, using peer discussions with clicker questions, and group activities in a large introductory course (Harben & Bix, 2020), fostering a supportive student climate in computing (Sax et al., 2018) and using learning assistants in large biology courses (Clements et al., 2022).

Sense of belonging during undergraduate studies can operate at different levels: at the programme level, in the interdisciplinary learning environment, such as faculty, and in the intercultural global environment, such as the occupation they expect to follow (Araújo et al., 2014). Araújo and colleagues noticed that, while the importance of the study programme as a source of identity and sense of belonging stays at the same level through the three-year undergraduate course of study, the importance of belonging at the interdisciplinary and intercultural levels increases towards graduation.

Students’ sense of belonging to their study community in higher education seems to be strongly associated with their study engagement (Ahn & Davis, 2020b), happiness (Spiridon et al., 2021), well-being, academic motivation and reduced dropout intention (Suhlmann et al., 2018). For instance, in Rainey et al.’s (2018) study students who remained in STEM majors reported a stronger sense of belonging than those who left STEM, and sense of belonging (Xu & Lastrapes, 2022) and social identity (Chiu & So, 2022) predicted career interest in STEM. Students’ social identity and sense of belonging progressed through the first semester in data science (Jaiswal et al., 2022), so building a sense of belonging during the first study year is essential. Shared group membership and social identity also motivate pro-social behaviour, such as helping and social support, which increases the well-being of the group members (Haslam et al., 2009) and protects against loneliness (Haslam et al., 2022).

Sense of belonging and trust

Recent research in STEM fields has emphasised the impact of fixed or malleable ability beliefs on students’ sense of belonging (Lytle & Shin, 2020; see also Kandiko Howson & Kingsbury, Chapter 1 in this volume). We approach this question from the viewpoint of how students trust that teachers hold malleable beliefs of their ability. Sense of belonging, especially in the domain of social engagement – positive social interaction – requires trust, which is essential in forming group cohesion, the 'social glue' between group members. 'Trust' has different meanings but is often defined as 'a psychological state comprising the intention to accept vulnerability based upon positive expectations of the intentions or behavior of another' (Rousseau et al., 1998, p. 395). In other words, trust describes how much we believe in others' good intentions towards us. Trust is not widely studied in the context of higher education, at least trust between students and teachers, although it is shown to have positive effects on interaction between people. For example, several studies indicate that trust predicts team effectiveness and performance (De Jong et al., 2016; McNeese et al., 2021; Poort et al., 2022; Seppälä, 2012).

Teachers can demonstrate faith in students' abilities by their meta-lay theories about students' scientific potential. Meta-lay theories are people's fundamental beliefs and implicit theories about how fixed and uncontrollable intelligence and other human attributes are (Dweck & Legget, 1988). The so-called universal belief or meta-lay theory is the conviction that almost everyone has high intellectual potential, whereas the non-universal belief is that not everyone has high intellectual potential (Rattan et al., 2018). Rattan and her colleagues studied the impact of meta-lay theories in STEM fields and found that the universal belief was positively related to students' sense of belonging and reduced their social identity threat, particularly in minority students.

Good, Rattan and Dweck (2012) argued that learning environments that support the universal belief, that is, faith in students' potential, may promote the sense of belonging. The reason that universal belief promotes the sense of belonging is that belongingness depends more on commitment than on ability. They included trust as one component of the scale they used to measure students' sense of belonging to maths. Moreover, Ahn and Davis (2020a) observed that sense of belonging is related to trust through its close link to social capital, which typically includes components of trust, social networks and participation (Putnam, 1993). Trust is produced through communication and interaction between individuals and groups (de Lange & Wittek, 2022; Seppälä, 2012), and is especially required in situations that involve a lot of social uncertainty (Yamagishi, 2011). Hence, we can assume that starting one's university studies may be this kind of situation.

Teaching and learning environment

Sense of belonging and social identification are largely regulated by the social environment (see also McCrone, Chapter 13 in this volume). Previous research shows that in higher education, teaching and learning environments are vital for building sense of belonging and positive social identity (Ahn & Davis, 2020b; Hoffman et al., 2002; Tai et al., 2019). In the Enhancing Teaching–Learning Environments in Undergraduate Courses (ETL) model, Entwistle, McCune and Hounsell (2002) have identified four elements of the teaching and learning environment: course context, teaching and assessment of content, relationships between students and staff, and students and their cultures. Course contexts refer to aims of teaching and to course design, and teaching and assessment to teaching methods and assessment and feedback procedures. Staff–student relationship relates to guidance and support of learning. Lastly, students and students' cultures consist of both individual factors (abilities, knowledge and skills) and social factors (peer groups, relationships and students' beliefs and values). In Ahn and Davis's (2020b) four-domain model of students' sense of belonging, the first three elements (course context, teaching and assessment of content and student–staff relationships) relate to academic engagement. The last element can be linked to social engagement (peer groups and relationships) but also to the personal space domain (individual skills, beliefs and values).

The teaching and learning environment dramatically changed in March 2020 when the Covid-19 pandemic and the consequent lockdown of societies suddenly forced universities worldwide to transfer their education to online distance learning. University campuses, libraries and learning centres were forced to stop all face-to-face activities, and teachers and students began to work online, at home (Marinoni et al., 2020). Remote teaching impacted negatively on students in multiple ways: there were higher rates of study-related burnout and decreases in study engagement (Salmela-Aro et al., 2022), and students reported receiving less peer support and less constructive feedback from teachers than students in pre-Covid situations (Parpala et al., 2021). Liu et al. (2021) observed that social isolation was the most powerful negative predictor of students' well-being during the pandemic. Moreover, we noticed that science students found that the Covid-19 lockdown had negative effects on their studying, for example because studying independently was difficult, or because they were missing social contacts (Myyry, 2021). During the pandemic, STEM students appreciated flexible course and assessment policies, approachable instructors and online services (Pagoto et al., 2021). Thus, it is plausible that remote learning, with its lower interaction of students with peers and staff, during the Covid-19 pandemic, also has effects on sense of belonging.

Hence, our questions concerning students' sense of belonging and social identity were:

- To what degree do STEM students feel that they belong to their study community?
- Did the Covid-19 pandemic and the remote learning period affect students' sense of belonging?
- How was students' sense of belonging related to other aspects of learning, such as the students' trust in their teachers' belief in their abilities, and their experiences of the teaching and learning environment?

Methods

Our study is conducted in the Faculty of Science, University of Helsinki, which is the largest faculty of science in Finland. There are eight bachelor programmes: (1) physical sciences, (2) geosciences, (3) geography, (4) chemistry, (5) mathematical sciences, (6) computer science, (7) teaching in mathematics, physics and chemistry, and (8) a science programme in English. The faculty offers a broad variety of different study fields, including theoretical and more empirical study tracks. A student can specialise in a very narrow field of natural sciences, where classes are often small. Alternatively, there are multidisciplinary study programmes, which gather students from different campuses. Studies can include both laboratory and field courses, but students can also complete part of their studies in online courses.

The research procedures followed the principles for responsible research with human participants in Finland (Finnish Advisory Board on Research Integrity, 2012) that cover ethical standards of informed consent, benefit, not harm, and confidentiality. The studies did not involve elements requiring ethical review (Finnish National Board on Research Integrity TENK, 2019). The questionnaires included a section asking respondents for consent to use the answers for research purposes; the respondents were informed about the confidentiality of the study, and that it was voluntary to give permission to use the data for research purposes.

Data and procedure

Our study includes two types of data collection among STEM students: a large quantitative survey and a small-scale qualitative study from two science courses. The quantitative data was collected at the end of the first study year in April 2020 (n = 299) and in April 2021 (n = 307). Thus the first group did not experience the effects of the pandemic during their first year at the university, whereas the latter experienced them from the start of their studies. The data was gathered via an online questionnaire called HowULearn (Parpala & Lindblom-Ylänne, 2012). The HowULearn survey examines students' learning processes, their experiences of the teaching and learning environment, study-related burnout and general professional competences. The responses are used to give feedback to students about their learning as well as to develop teaching of the degree programmes. The HowULearn questionnaire adopted at the University of Helsinki includes a modified version of the Experiences of Teaching and Learning Questionnaire (ETLQ), which focuses on more general level of experiences in a study major (Parpala & Lindblom-Ylänne, 2012). The questionnaire was administered to students at the University of Helsinki three times as part of their bachelor's studies.

The scale to measure the experiences of the teaching–learning environment originated in the ETL Questionnaire (Entwistle et al., 2002). To select the scales, the starting point was that sense of belonging is demonstrated through academic and social engagement (Ahn & Davis, 2020b), and that it is related to motivation (Suhlmann et al., 2018). Consequently, we were especially interested in three of the scales: 'interest and relevance of studies' (e.g., 'I find most of what I learned in courses really interesting'), representing motivation; 'peer support' (e.g., 'Students support each other and try to give help when it is needed'); and 'constructive feedback from teachers' (three items, including 'The feedback given on my course exercises helps me to clarify things I hadn't fully understood'), representing the student–student and student–teacher interaction. All the scales were measured on a five-point Likert scale (1 = fully disagree; 5 = fully agree).

We added two questions to the basic HowULearn survey template, modified from the maths sense-of-belonging scale (Good et al., 2012): 'I consider myself a member of a community (e.g., class, study group, discipline-specific student association, degree programme, academic community) when studying' and 'I trust that teachers on the course have faith in my abilities'. Both questions were measured by a five-point Likert scale.

The qualitative data (n = 41) was collected from two science courses in the autumn term (September to November) in 2021 during the pandemic, via an online questionnaire. The first course was compulsory for MSc students and the second was compulsory for BSc students. The invitation to participate was sent to 78 students, and we received 41 responses, so the response rate was 53 per cent. The questionnaire examined students' sense of belonging to their study community by asking three open-ended questions as a part of a broader questionnaire. The questions were as follows:

1. What supports your sense of belonging to a degree programme? Give some concrete examples, if possible.
2. What decreases your sense of belonging to a degree programme? Give some concrete examples, if possible.
3. What supports your trust that teachers have faith in your abilities? Give some concrete examples, if possible.

To study respondents' thinking and to identify the main themes, the qualitative data was analysed following the general principles of empirically based qualitative content analysis (Patton, 2002; Yin, 2016). This meant reading the data several times through the students' answers to the questions. After that, we coded different descriptions regarding the questions from the data, and then classified similar types of descriptions into the categories. To underpin the trustworthiness of the qualitative content analysis, a confirmability criterion was used (Denzin & Lincoln, 2000; Lincoln & Guba, 1985; Yin, 2016). This means that the results are based on data rather than on the conceptions of the researchers. To strengthen the confirmability the authors classified a phase of the data separately and then compared and discussed the classification. The main findings were almost the same, so this kind of comparison increased the trustworthiness of the study. The qualitative data was analysed by question with the Atlas.ti program.

Quantitative results from the HowULearn questionnaire

To examine the relationship between sense of belonging and other variables, we recoded the sense-of-belonging item into three categories: 1 = low sense of belonging (totally disagree or disagree); 2 = moderate sense of belonging (neither disagree nor agree); and 3 = high sense of belonging (agree or totally agree). The number of respondents in each

Table 6.1. Sense of belonging in 2020 with no pandemic effect and 2021 with pandemic effect in frequencies (percentages in brackets)

	Sense of belonging			
	Low	Moderate	High	Total
2020, no pandemic effect	64 (22%)	64 (22%)	168 (57%)	296
2021, pandemic effect	148 (51%)	61 (21%)	81 (28%)	290

category is reported in Table 6.1. Consequently, first-year students in 2020 reported a significantly higher degree of sense of belonging than first-year students in 2021 ($\chi^2(2) = 63.70$, $p < 0.001$).

Sense of belonging and trust in teachers having faith in students' abilities correlated positively in both 2020 and 2021 ($r = 0.39$, $p < 0.01$ and $r = 0.37$, $p < 0.01$ respectively). Relationships between sense of belonging and trust in teachers are reported in Table 6.2. In both samples, students reporting low sense of belonging showed lower trust than students reporting high sense of belonging ($\chi^2(4) = 27.87$, $p < 0.001$ in 2020 and ($\chi^2(4) = 40.17$, $p < 0.001$ in 2021).

In addition, we examined if sense of belonging was related to the way students perceive the teaching and learning environment. We looked at the relationship between sense of belonging and how interesting and relevant they found their studies, and how satisfied they were with peer interaction and with feedback from teachers. In general, sense of belonging correlated positively with interest and relevance ($r = 0.24$ in 2020 and $r = 0.28$ in 2021), peer support ($r = 0.57$ in 2020 and $r = 0.54$ in 2021) and constructive feedback ($r = 0.28$ in 2020 and $r = 0.38$ in 2021): all associations were significant at the 0.01 level. Univariate analysis of variance (ANOVA) also showed that there was a significant main effect of the sense-of-belonging category on the interest and relevance of studies across the data ($F(5, 580) = 15.75$, $p < 0.001$, $\eta = 0.05$), for peer support ($F(5, 580) = 97.50$, $p < 0.001$, $\eta = 0.25$) and for constructive feedback ($F(5, 580) = 35.48$, $p < 0.001$, $\eta = 0.11$). Thus, as Figure 6.1 shows, students with low levels of sense of belonging perceived less interest and relevance, peer support and constructive feedback.

Results from qualitative data

Factors supporting students' sense of belonging

Next, we explored open-ended questions relating to students' sense of belonging. According to these university students, several factors

Table 6.2. Sense of belonging according to students' trust that teachers have faith in their abilities in 2020 and 2021, in frequencies (percentages in brackets)

2020, no pandemic effect	**Trust that teachers have faith in students' abilities**			
Sense of belonging	**Low**	**Moderate**	**High**	**Total**
Low	11 (17%)	23 (36%)	30 (47%)	64
Moderate	6 (9%)	20 (31%)	38 (58%)	64
High	7 (4%)	27 (16%)	134 (80%)	168
Total	24	70	202	296
2021, pandemic effect				
Low	29 (20%)	73 (49%)	46 (31%)	148
Moderate	2 (3%)	29 (48%)	30 (49%)	61
High	4 (5%)	20 (25%)	57 (70%)	81
Total	35	122	133	290

Source: Authors

support students' sense of belonging to a degree programme. We reduced these factors to the following five main categories: (1) programme-led communality, (2) student-based communality, (3) cooperation, (4) similarity among students and (5) programme communication.

The first category, programme-led communality, is the biggest of the five and includes comments relating to weekly meetings or tutor activities in the programme. Students had felt that the activities organised by their degree programme supported their sense of belonging. By attending those activities, they were also able to meet their course mates. The second-biggest category, student-led communality, explains students' own communality, such as studying together or having lunch together, as an important factor that supported their sense of belonging to a degree programme. This category included mentions of the meaning of study organisations, student boiler suits and all kinds of joint activities with fellow students. These boiler suits are overalls worn by university students in some Nordic countries, especially for parties. They show which university the student is from and which degree he or she is studying for. Students on a particular degree programme order the same overalls for all, which contributes to a sense of belonging.

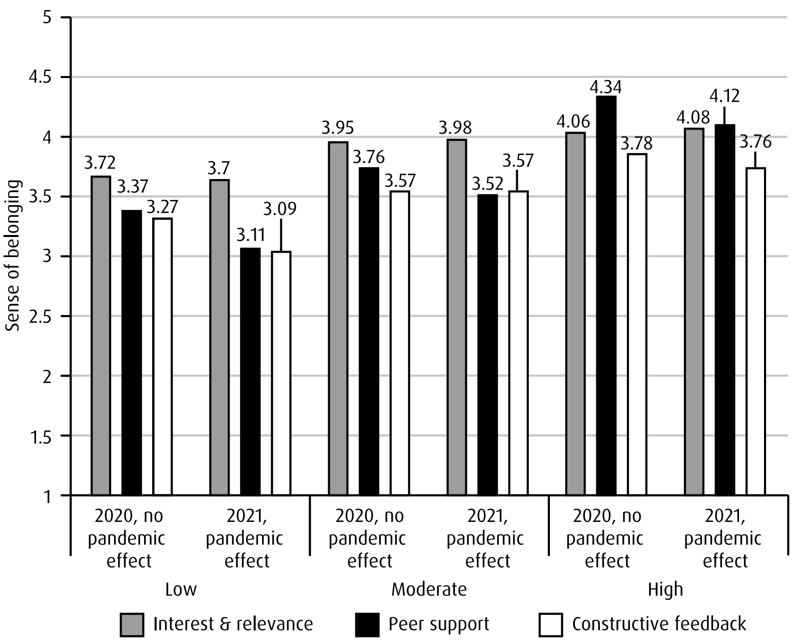

Figure 6.1 Perceived interest and relevance of studies, peer support and constructive feedback according to sense of belonging in 2020 and 2021. © Authors.

The last three factors focus on aspects such as cooperation, similarity among students, and programme communication. For instance, one student mentioned group work as a factor that supports one's sense of belonging. The student stressed that, in particular, 'a meaningful group work where things are done really together and not just as independent work that is combined before submitting for grading' increases one's sense of belonging (Student 22). Another student explained the significance of similarity for one's sense of belonging by talking about 'like-minded people with the same kind of interests'.

Factors that decrease students' sense of belonging

The factors that decrease university students' sense of belonging to a degree programme were reduced to three main categories: (1) online teaching and learning, (2) no friends/studying alone and (3) study difficulties. Online teaching with no real-time online lectures but only videos proved to be the most unwanted and largest factor that decreased students' sense of belonging. Lack of friends and studying alone were other factors that decreased students' sense of belonging. In some cases, the whole course seemed to be reduced to watching old video recordings about the learning environment on one's own, which made it impossible to get to know other students. In addition, there were personal study challenges, such as difficulties in understanding the content of the course, uncertainty about whether they were in the right field of study, and health problems that decreased respondents' sense of belonging to a degree programme. For example, one student characterised their uncertainty as follows: 'I am not 100 per cent sure about whether this is the programme for me' (Student 27).

Factors that supported students' trust

The last open-ended question dealt with students' trust that teachers had faith in their abilities. Here the following three categories were found: (1) teachers' encouraging feedback or support, (2) teachers' answering students' questions and (3) teachers' enabling students to try hard. Teachers' encouraging feedback was found to be a signal of their faith in students' abilities. A teacher could for example reassure a student performing a difficult task by saying that understanding is only a matter of time. Teachers' patient interaction with students' questions was thought to confirm their trust in students' abilities. STEM students experienced teachers' demands positively. When teachers gave challenging tasks, students felt encouraged to try hard, and their belief that the teachers

Table 6.3. Examples of responses to the three open-ended questions

Topic	Original quotation	Main category
Factors supporting students' sense of belonging	We have weekly meetings with the programme's coordinators and all other students within the programmes. (Student 14)	Programme-led communality (n = 10)
	There is a really vibrant and active community for the chemistry exchange students led by some great tutors which has been essential in helping me settle in. (Student 18)	
	Lectures on campus, having lunch with other students in Unicafe, studying together …. (Student 6)	Student-based communality (n = 9)
	Student organisation, group chats, boiler suits. (Student 23)	
Factors decreasing students' sense of belonging	According to remote study, not many contact meetings with teachers. And the course based on videos even without any online lectures make me less belongings. (Student 7)	Online teaching and learning (n = 11)
	Distance learning classes. (Student 31)	
Factors supporting students' trust	Feedback throughout the course, for instance during discussion on the lectures. (Student 4)	Teachers' encouraging feedback or support (n = 12)
	When I'm being told 'you will understand it in due time' for a course and then eventually I do, makes me believe what I was going through was normal and the teachers were reassuring me in a truthful manner. (Student 38)	

had faith in their abilities increased: 'They do not hesitate to give complex tasks and some rarely show concern about the level of challenge; therefore they must believe that I am capable of completing the said tasks without problems' (Student 36). Table 6.3 includes examples of findings from each open-ended question.

Discussion

In this chapter we have examined the relationship between sense of belonging and Finnish STEM students' experiences of the teaching and learning environment during the Covid-19 pandemic. We have also looked at students' thoughts about factors that enhance feelings of belonging and positive social identity in the study community. For students who started their studies in September 2019, the restrictions of the Covid-19 pandemic had just begun when they answered the HowULearn survey in April 2020. Students starting in September 2020 had to study almost completely remotely in their first academic year. Consequently, sense of belonging was significantly lower for the first-year students in the second cohort than for the students starting before Covid-19, in September 2019. This result is in line with findings about the negative effects of the Covid-19 pandemic on students' well-being (Allen et al., 2023; Browning et al., 2021; Heumann et al., 2023; Salmela-Aro et al., 2022). Social isolation in particular seems to be harmful for students (Liu et al., 2021).

In the teaching and learning environment, lower sense of belonging was related to finding studies less interesting and relevant, lower peer support and less constructive feedback from teachers. These results are in line with Tai et al.'s (2019) findings that students' perceptions of study engagement – feeling acknowledged and included – are influenced by relevant tasks and by feedback from teachers and peers. We do not know whether sense of belonging affects perception of the relevance of studies or whether it is the other way round. However, if there is a relationship between these two, organising teaching that offers relevant tasks, constructive feedback and opportunities to interact might facilitate both, as several studies indicate (Lahdenperä & Nieminen, 2020; Parpala et al., 2021; Tai et al., 2019).

Students' trust in teachers' belief in their abilities, the so-called universal belief (Rattan et al., 2018), was related to the sense of belonging. Students with high sense of belonging had high trust. This confirms the earlier finding that trust is closely linked to sense of belonging (Ahn & Davis, 2020a; Good et al., 2012; Haslam et al., 2009), and indicates that not only students' own ability beliefs (Lytle & Shin, 2020) but also how far they trust in teachers' universal belief are significant. Building trust seems to be an important factor in students' engagement in their studies in STEM fields (Rainey et al., 2018; Rattan et al., 2018), and the role of interaction in trust-building activities seems to be essential (de Lange & Wittek, 2022; Seppälä, 2012).

The importance of interaction was also found in the qualitative data, where both organised opportunities for communication (such as regular meetings within study programmes and with tutors, and student organisation events) and spontaneous ones (such as having lunch with peers) were mentioned as supporting students' sense of belonging. The former are related to the belonging levels of Araújo et al. (2014): study programme and faculty environment. In addition, similarities between students and their wearing similar boiler suits were mentioned, which refer to categorisation and identification processes of social identity, i.e., defining oneself as a member of a student group and taking on the qualities of the group (Turner & Reynolds, 2001). Online teaching and learning, and loneliness, on the other hand, were mentioned as decreasing sense of belonging, which corresponds to Liu et al.'s (2021) finding of the social isolation effect during the pandemic.

Overall, these findings fit with earlier research on the importance of positive social interaction with peers and staff to students' sense of belonging (Ahn & Davis, 2020b; Araújo et al., 2014; Harben & Bix, 2020; Meehan & Howells, 2019; Viola, 2021). Thus, our results do not endorse the stereotype sometimes found, that STEM students avoid communication and teamwork (see Kandiko Howson & Kingsbury, Chapter 1 in this volume). They also confirm that remote teaching during the Covid-19 pandemic has been harmful to students' well-being (Allen et al., 2023; Browning et al., 2021; Heumann et al., 2023; Salmela-Aro et al., 2022). As for students' belief that teachers have faith in their abilities, students mentioned teachers giving feedback, answering students' questions and offering proper challenges that encourage students to try hard. These can be situations where students feel social uncertainty, and a lot of trust is needed on the students' side. These findings thus support Yamagishi's earlier research (2011). In addition, teachers' showing trust in students' potential by expecting them to try hard fits with Rattan et al.'s (2018) universal belief.

Thus, our quantitative and qualitative results support each other. STEM students' sense of belonging and positive social identity are built by teachers' facilitating group work and collaboration. This is reinforced through positive social student–staff interaction that demonstrates trust in students' skills and knowledge. Positive social interaction does not necessarily demand big changes in teaching practices; practices can include, for instance, using group discussions before answering questions, which Harben and Bix (2020) noticed in a large introductory STEM course, and which our respondents commented on in the qualitative data. In addition, offering opportunities to students to interact (Hoffman et al., 2002) and encouraging comments and feedback (Lahdenperä & Nieminen, 2020) can help.

Sense of belonging and social identity are fundamental elements of motivation (Haslam et al., 2009; Suhlmann et al., 2018), related to experiences of the teaching and learning environment, dropout intentions (Rainey et al., 2018; Suhlmann et al., 2018) and the well-being of students (Spiridon et al., 2021). Therefore it is crucial to create a learning environment where students can find groups they can fit into. At the faculty level, it is important to encourage degree programmes to organise opportunities for teacher–student communication and to consider if teachers have time to answer students' questions and provide feedback to them so as to demonstrate their faith in students' abilities. While remote teaching decreases sense of belonging, as is apparent from our data, it is a challenge to design courses, especially remote ones, that maintain positive social engagement. Teachers' digital competence to support students' remote learning seems to be limited (Amhag et al., 2019; Bond et al., 2018; Myyry et al., 2022), but online learning is efficient only when it enables social presence. Social presence refers to opportunities to identify with the study community and have meaningful interaction in a trusting environment for students (Conrad et al., 2022; Garrison et al., 2010).

The first study year is crucial for developing students' sense of belonging, especially as students progress through the first semester (Jaiswal et al., 2022). One opportunity to support the development of a sense of belonging at the very beginning of studies would be to organise the students in a degree programme into small groups that last throughout the first year, as building group cohesion usually takes time (Nijstad & Van Knippenberg, 2012). For instance, the group instruction sessions and exercises that are typical in STEM education could support the creation of a sense of belonging better if students had time to get to know each other. Knowing each other can also build trust, which is essential for the cognitive engagement of students (Poort et al., 2022). Specific to STEM education is the on-site hands-on laboratory courses that maintained a sense of community before the Covid-19 pandemic.

In the post-pandemic period, universities may struggle to adapt to new ways of teaching which are based on the lessons learned from the Covid-19 lockdown. Blended or hybrid remote teaching, as well as purely online courses such as MOOCs, is expected to be more common in the future (Guppy et al., 2022), although digitalisation of teaching started before the pandemic. For instance, in 2017 the University of Helsinki made digital learning one of its most important strategic goals.

In sum, new teaching methods and pedagogy that support learning and positive social interaction are needed to ensure quality learning and students' sense of belonging to the study community in the future.

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References

Ahn, M. Y. & Davis, H. H. (2020a). Sense of belonging as an indicator of social capital. *International Journal of Sociology and Social Policy*, 40(7/8), 627–42. https://doi.org/10.1108/IJSSP-12-2019-0258.

Ahn, M. Y. & Davis, H. H. (2020b). Students' sense of belonging and their socio-economic status in higher education: A quantitative approach. *Teaching in Higher Education*, 28(1), 136–49. https://doi.org/10.1080/13562517.2020.1778664.

Allen, R., Kannangara, C., Vyas, M. & Carson, J. (2023). European university students' mental health during Covid-19: Exploring attitudes towards Covid-19 and governmental response. *Current Psychology*, 42(23), 20165–78. https://doi.org/10.1007/s12144-022-02854-0.

Amhag, L., Hellström, L. & Stigmar, M. (2019). Teacher educators' use of digital tools and needs for digital competence in higher education. *Journal of Digital Learning and Education*, 35(4), 203–20. https://doi.org/10.1080/21532974.2019.1646169.

Apriceno, M. B., Levy, S. R. & London, B. (2020). Mentorship during college transition predicts academic self-efficacy and sense of belonging among STEM students. *Journal of College Student Development*, 61(5), 643–8. https://doi.org/10.1353/csd.2020.0061.

Araújo, N., Carlin, D., Clarke, B., Morieson, L., Lukas, K. & Wilson, R. (2014). Belonging in the first year: A creative discipline cohort case study. *International Journal of the First Year in Higher Education*, 5(2), 21–31. https://doi.org/10.5204/intjfyhe.v5i2.240.

Baumeister, R. F. & Leary, M. R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin, 117*(3), 497–529. http://dx.doi.org/10.1037/0033-2909.117.3.497.

Bond, M., Marín, V. I., Dolch, C., Bedenlier, S. & Zawacki-Richter, O. (2018). Digital transformation in German higher education: Student and teacher perceptions and usage of digital media. *International Journal of Educational Technology in Higher Education*, 15, art. no. 48. http://dx.doi.org/10.1186/s41239-018-0130-1.

Browning, M. H. E. M., Larson, L. R., Sharaievska, I., Rigolon, A., McAnirlin, O., Mullenbach, L., et al. (2021). Psychological impacts from COVID-19 among university students: Risk factors across seven states in the United States. *PLoS ONE* 17(8): e0273938. https://doi.org/10.1371/journal.pone.0273938.

Chiu, S. W. K. & So, W. W. M. (2022). STEM career aspiration: Does students' social identity matter? *Asia Pacific Journal of Education*. https://doi.org/10.1080/02188791.2022.2108758.

Clements, T. P., Friedman, K. L., Johnson, H. J., Meier, C. J., Watkins, J., Brockman, A. J. & Brame, C. J. (2022). 'It made me feel like a bigger part of the STEM community': Incorporation of learning assistants enhances students' sense of belonging in a large introductory biology course. *CBE – Life Sciences Education*, 21(2). https://doi.org/10.1187/cbe.21-09-0287.

Conrad, C., Deng, Q., Caron, I., Shkurska, O., Skerrett, P. & Sundararajan, B. (2022). How student perceptions about online learning difficulty influenced their satisfaction during Canada's Covid-19 response. *British Journal of Educational Technology*, 53(3), 534–57. https://doi.org/10.1111/bjet.13206.

Deci, E. L. & Ryan, R. M. (2000). The 'what' and 'why' of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry*, 11(4), 227–68. https://doi.org/10.1207/S15327965PLI1104_01.

De Jong, B. A., Dirks, K. T. & Gillespie, N. (2016). Trust and team performance: A meta-analysis of main effects, moderators and covariates. *Journal of Applied Psychology*, 101(8), 1134–50. https://doi.org/10.1037/apl0000110.

de Lange, T. & Wittek, A. L. (2022). Analysing the constitution of trust in peer-based teacher mentoring groups – a sociocultural perspective. *Teaching in Higher Education*, 27(3), 337–51. https://doi.org/10.1080/13562517.2020.1724936.

Denzin, N. K. & Lincoln, Y. S. (2000). Introduction: The discipline and practice of qualitative research. In N. K. Denzin & Y. S. Lincoln (eds), *Handbook of Qualitative Research*, 2nd edn, pp. 1–29. Thousand Oaks, CA, and London: Sage.

Dweck, C. S. & Legget, E. L. (1988). A social-cognitive approach to motivation and personality. *Psychological Review*, 95(2), 256–73.

Entwistle, N., McCune, V. & Hounsell, J. (2002). Approaches to studying and perceptions of university teaching-learning environments: Concepts, measures and preliminary findings. Occasional Report 1, ETL Project. https://www.etl.tla.ed.ac.uk/docs/ETLreport1.pdf. Accessed 17 December 2023.

Finnish Advisory Board on Research Integrity (2012). Responsible conduct of research and procedures for handling allegations of misconduct in Finland. https://tenk.fi/sites/tenk.fi/files/HTK_ohje_2012.pdf. Accessed 20 March 2024.

Finnish National Board on Research Integrity TENK (2019). The ethical principles of research with human participants and ethical review in the human sciences in Finland: Finnish National Board on Research Integrity TENK guidelines 2019. https://tenk.fi/sites/default/files/2021-01/Ethical_review_in_human_sciences_2020.pdf. Accessed 17 December 2023.

Garrison, D. R., Cleveland-Innes, M. & Fung, T. S. (2010). Exploring causal relationships among teaching, cognitive and social presence: Student perceptions of the community of inquiry framework. *Internet and Higher Education*, 13(1–2), 31–6. https://doi.org/10.1016/j.iheduc.2009.10.002.

Good, C., Rattan, A. & Dweck, C. S. (2012). Why do women opt out? Sense of belonging and women's representation in mathematics. *Journal of Personality and Social Psychology*, 102(4), 700–17. https://doi.org/10.1037/a0026659.

Goodenow, C. (1993). The psychological sense of school membership among adolescents: Scale development and educational correlates. *Psychology in the Schools*, 30(1), 79–90. https://doi.org/10.1002/1520-6807(199301)30:1%3C79::AID-PITS2310300113%3E3.0.CO;2-X.

Guppy, N., Verpoorten, D., Boud, D., Lin, L., Tai, J. & Bartolic, S. (2022). The post-COVID-19 future of digital learning in higher education: Views from educators, students, and other professionals in six countries. *British Journal of Educational Technology*, 53(6), 1750–65. https://doi.org/10.1111/bjet.13212.

Harben, A. & Bix, L. (2020). Student sense of belonging in a large, introductory STEM course. *NACTA Journal*, 64(1), 288–96.

Haslam, S. A., Haslam, C., Cruwys, T., Jetten, J., Bentley, S. V., Fong, P. & Steffens, N. K. (2022). Social identity makes group-based social connection possible: Implications for loneliness and mental health. *Current Opinion in Psychology*, 43, 161–5. https://doi.org/10.1016/j.copsyc.2021.07.013.

Haslam, S. A., Jetten, J., Postmes, T. & Haslam, C. (2009). Social identity, health and well-being: An emerging agenda for applied psychology. *Applied Psychology*, 58, 1–23. https://doi.org/10.1111/j.1464-0597.2008.00379.x.

Heumann, E., Helmer, S. M., Busse, H., Negash, S., Horn, J., Pischke, C. R., Niephaus, Y. & Stock, C. (2023). Anxiety and depressive symptoms of German university students 20 months after the COVID-19 outbreak: A cross-sectional study. *Journal of Affective Disorders*, 320, 568–75. https://doi.org/10.1016/j.jad.2022.09.158.

Hoffman, M., Richmond, J., Morrow, J. & Salomone, K. (2002). Investigating 'sense of belonging' in first-year college students. *Journal of College Student Retention*, 4(3), 227–56. https://doi.org/10.2190/DRYC-CXQ9-JQ8V-HT4V.

Hurtado, S. & Carter, D. F. (1997). Effects of college transition and perceptions of the campus racial climate on Latino college students' sense of belonging. *Sociology of Education*, 70(4), 324–45. https://doi.org/10.2307/2673270.

Jaiswal, A., Magana, A. J. & Ward, M. D. (2022). Characterizing the identity formation and sense of belonging of the students enrolled in a data science learning community. *Education Sciences*, 12(10), art. no. 731. https://doi.org/10.3390/educsci12100731.

Lahdenperä, J. & Nieminen, J. H. (2020). How does a mathematician fit in? A mixed-methods analysis of university students' sense of belonging in mathematics. *International Journal of Research of Undergraduate Mathematics Education*, 6(3), 475–94. https://doi.org/10.1007/s40753-020-00118-5.

Lincoln, Y. S. & Guba, E. G. (1985). *Naturalistic inquiry*. Newbury Park, CA: Sage.

Liu, C., McCabe, M., Dawson, A., Cyrzon, C., Shankar, S., Gerges, N., Kellett-Renzella, S., Chye, Y. & Cornish, K. (2021). Identifying predictors of university students' wellbeing during the COVID-19 pandemic: A data-driven approach. *International Journal of Environmental Research and Public Health*, 18(13), art. no. 6730. https://doi.org/10.3390/ijerph18136730.

Lytle, A.& Shin, J. E. (2020). Incremental beliefs, STEM efficacy and STEM interest among first-year undergraduate students. *Journal of Science Education and Technology*, 29(2), 272–81. https://doi.org/10.1007/s10956-020-09813-z.

Marinoni, G., van't Land, H. & Jensen, T. (2020). *The Impact of Covid-19 on Higher Education Around the World: IAU global survey report*. Paris: International Association of Universities. https://www.iau-aiu.net/IMG/pdf/iau_covid19_and_he_survey_report_final_may_2020.pdf. Accessed 17 December, 2023.

McNeese, N. J., Demir, M., Chiou, E. K. & Cooke, N. J. (2021). Trust and team performance in human–autonomy teaming. *International Journal of Electronic Commerce*, 25(1), 51–72. https://doi.org/10.1080/10864415.2021.1846854.

Meehan, C. & Howells, K. (2019). In search of the feeling of 'belonging' in higher education: Undergraduate students transition into higher education. *Journal of Further and Higher Education*, 43(10), 1376–90. DOI: https://doi.org/10.1080/0309877X.2018.1490702.

Myyry, L. (2021). Study-related well-being and the effect of Covid-19 lockdown among science students. Paper presented at the online conference of the European Association for Research in Adult Development, 24 April, University of Jönköping.

Myyry, L., Kallunki, V., Katajavuori, N., Repo, S., Tuononen, T., Anttila, H., Kinnunen, P. A., Haarala-Muhonen, A. & Pyörälä, E. (2022). COVID-19 accelerating academic teachers' digital competence in distance teaching. *Frontiers in Education*, 7, art. no. 770094. https://doi.org/doi: 10.3389/feduc.2022.770094.

Nijstad, B. & van Knippenberg, D. (2012). Group dynamics. In M. Hewstone, W. Stroebe & K. Jonas (eds), *An Introduction to Social Psychology*, 5th edn, pp. 387–413. Chichester: BPS Blackwell.

Pagoto, S., Lewis, K. A., Groshon, L., Palmer, L., Waring, M. E., Workman, D., De Luna, N. & Brown, N. P. (2021). STEM undergraduates' perspectives of instructor and university responses to the COVID-19 pandemic in Spring 2020. *PLoS ONE*, 16(8), e0256213. https://doi.org/10.1371/journal.pone.0256213.

Parpala, A., Katajavuori, N., Haarala-Muhonen, A. & Asikainen, H. (2021). How did students with different learning profiles experience 'normal' and online teaching situation during COVID-19 spring? *Social Sciences*, 10(9), art. no. 337. https://doi.org/10.3390/socsci10090337.

Parpala, A. & Lindblom-Ylänne, S. (2012). Using a research instrument for developing quality at the university. *Quality in Higher Education*, 18(3), 313–28, https://doi.org/10.1080/13538322.2012.733493.

Patton, M. Q. (2002). *Qualitative Research & Evaluation Methods.* Thousand Oaks, CA, and London: Sage.

Poort, I., Jansen, E. & Hofman, A. (2022). Does the group matter? Effects of trust, cultural diversity, and group formation on engagement in group work in higher education. *Higher Education Research & Development*, 41(2), 511–26, https://doi.org/10.1080/07294360.2020.1839024.

Putnam, R. D. (1993). The prosperous community: Social capital and public life. *The American Prospect*, 4(13), 35–42.
Rainey, K., Dancy, M., Mickelson, R., Stearns, E. & Moller, S. (2018). Race and gender differences in how sense of belonging influences decisions to major in STEM. *International Journal of STEM Education*, 5, art. no. 10. https://doi.org/10.1186/s40594-018-0115-6.
Rattan, A., Savani, K., Komarraju, M., Morrison, M. M., Boggs, C. & Ambady, N. (2018). Meta-lay theories of scientific potential drive underrepresented students' sense of belonging to science, technology, engineering, and mathematics (STEM). *Journal of Personality and Social Psychology*, 115(1), 54–75. https://doi.org/10.1037/pspi0000130.
Rousseau, D. M., Sitkin, S. B., Burt, R. S. & Camerer, C. (1998). Not so different after all: A cross-discipline view of trust. *Academy of Management Review*, 23(3), 393–404. http://dx.doi.org/10.5465/AMR.1998.926617.
Salmela-Aro, K., Upadyaya, K., Ronkainen, I. & Hietajärvi, L. (2022). Study burnout and engagement during COVID-19 among university students: The role of demands, resources, and psychological needs. *Journal of Happiness Studies*, 23(6), 2685–702. https://doi.org/10.1007/s10902-022-00518-1.
Sax, L. J., Blaney, J. M., Lehman, K. J., Rodriguez, S. L., George, K. L. & Zavala, C. (2018). Sense of belonging in computing: The role of introductory courses for women and underrepresented minority students. *Social Sciences*, 7(8), art. no. 122. http://dx.doi.org/10.3390/socsci7080122.
Seppälä, T. (2012). *Trust Building and Cooperation in Supervisor–Subordinate Relationships and Work Units*. Publications of the Department of Social Research 2012:14, University of Helsinki.
Spiridon, E., Davies, J., Kaye, L. K., Nicolson, R. I., Tang, B. W. X., Tan, A. J. Y. & Ransom, H. J. (2021). Exploring the impact of group identity at university on psychological and behavioural outcomes. *Journal of Further and Higher Education*, 45(7), 932–42. https://doi.org/10.1080/0309877X.2020.1831450.
Suhlmann, M., Sassenberg, K., Nagengast, B. & Trautwein, U. (2018). Belonging mediates effects of student–university fit on well-being, motivation, and dropout intention. *Social Psychology*, 49(1), 16–28. https://doi.org/10.1027/1864-9335/a000325.
Tai, J. H.-M., Bellingham, R., Lang, J. & Dawson, D. (2019). Student perspectives of engagement in learning in contemporary and digital contexts. *Higher Education Research & Development*, 38(5), 1075–89. https://doi.org/10.1080/07294360.2019.1598338.
Tinto, V. (1975). Dropout from higher education: A theoretical synthesis of recent research. *Review of Educational Research*, 45(1), 89–125. Dropout from higher education: A theoretical synthesis of recent research.
Trujillo, G. & Tanner, K. D. (2014). Considering the role of affect in learning: Monitoring students' self-efficacy, sense of belonging, and science identity. *CBE – Life Science Education*, 13(1), 6–15. https://doi.org/10.1187%2Fcbe.13-12-0241.
Turner, J. & Reynolds, K. J. (2001). The social identity perspective in intergroup relations: Theories, themes, and controversies. In R. Brown and S. L. Gaertner (eds), *Blackwell Handbook of Social Psychology: Intergroup processes*, pp. 133–52. Malden, MA: Blackwell.
van Herpen, S. G. A., Meeuwisse, M., Hofman, W. H. A. & Severiens, S. E. (2020). A head start in higher education: The effect of a transition intervention on interaction, sense of belonging, and academic performance. *Studies in Higher Education*, 45(4), 862–77. https://doi.org/10.1080/03075079.2019.1572088.
Viola, J. K. (2021). Belonging and global citizenship in a STEM University. *Education Sciences*, 11(12), art. no. 803. https://doi.org/10.3390/educsci11120803.
Xu, C. & Lastrapes, R. E. (2022). Impact of STEM sense of belonging on career interest: The role of STEM attitudes. *Journal of Career Development*, 49(6), 1215–29. https://doi.org/10.1177/08948453211033025.
Yamagishi, T. (2011). *Trust: The Evolutionary Game of Mind and Society.* Tokyo: Springer.
Yin, R. K. (2016). *Qualitative Research from Start to Finish*, 2nd edn. New York: Guilford Press.

7

Inside(r) out(sider): building belonging and identity in the non-disciplinary classroom

Elizabeth Hauke

Introduction

This chapter presents an ethnographic case study exploring belonging and identity in the author's own classroom(s). Within the following chapter you will find an enhanced ethnography (Humphreys & Watson, 2009, p. 43) in the form of passages of narrative storytelling, reported dialogue that has been reconstructed from peri-contemporaneous field notes (recorded immediately after each class), email communications and theoretical reflections. While the ethnography is faithful to the data, 'Indubitable cognition is not part of the ethnographer's luck; her certainty is established on a much wider basis of experience which … transforms the nature of the objects studied' (Hastrup, 2005, p. 169). So, while this is the truest account that can be put forward, the very construction of the telling, along with the meaning that is drawn from it, is a (re)creation.

Institutional context

Imperial College London is an elite specialist university focused on science, engineering, maths, medicine and business at an undergraduate level. The Change Makers programme offers students from all undergraduate degrees at Imperial the opportunity to take interdisciplinary modules that have been designed using our Live, Love, Learn approach (Hauke, 2017). These modules can be integrated for degree credit in one year of study and taken as non-credit or extra-credit in the other years. Currently, between 200 and 300 students take these modules each year, and even including the optional non-credit and extra-credit students who may withdraw at any time from the module with no penalty, we enjoy the highest retention rates in the wider programme of more traditional study.

The modules equip students to address global challenges such as climate change, human rights, poverty and conflict (Kelly, 2008; Tennant, 1999) using active (Astin, 1984; Chickering & Gamson, 1987), student-centred (Kember, 1997) partnership pedagogy (Cook-Sather, Bovill & Felten, 2014). The Change Makers approach (Hauke, 2017) ensures that every single classroom activity addresses our three pillars:

- Live: prior learning, individual and collective experiences are valued as a foundation for new knowledge and understanding of the lived world;
- Love: empathic engagement with others critically anchors learning to the real, messy, intricate needs of individuals and communities around the world;
- Learn: challenging, active learning is vitally pursued to create independent, critical thinkers who approach complexity with confidence and self-awareness.

Critically, we are working to help students experience and harness their whole personhood within their study and in their engagement with the world and with others. We want to empower students to think and act with confidence and care (hooks, 1994; Noddings, 1986), developing the necessary mindset and skill set (Hauke, 2022b) to accomplish this.

The modules are necessarily interdisciplinary and person-centred (Baxter Magolda, 1999), and have a holistic focus on process and praxis (Grundy, 1987), privileging a divergent, dynamic and personalised sense of knowledge (Freire, 1970), rather than product and a more static, reified and convergent conceptualisation of knowledge (Hauke, 2019).

I am a practitioner researcher (Menter et al., 2011), using ethnography (Britzman, 1995) and autoethnography (Delamont, 2009; Ellis, 2004; Reed-Danahay, 2009) to share insights from my classroom. I practise a form of participant ethnography (Etherington, 2004) in which I simultaneously inhabit the roles of teacher and researcher (Hauke, 2021). With over 10 years' experience of teaching and evolving these modules, and several years of ethnographic observation under my belt, I am well positioned as an insider (Murray & Kalayji, 2018) to the specifics of these learning encounters. My position as both naive newcomer to the individual encounter and experienced teacher and ethnographer allows me to guard against the seduction of familiarity and expectation (Hammersley & Atkinson, 2007) while affording me the sensitivity and experiential luggage (Rudie, 1994) to notice, interrogate and reflect on the nuances of what might be happening for us as we work together (Becker, 1971; Delamont & Atkinson, 2004; Mills, 1959).

The nature of my teaching creates a lot of 'teaching data'. Students reflect frequently on their learning and their experiences, and I keep detailed teaching notes to facilitate intricate attention to both individuals and the group, while dynamically navigating and driving the curriculum according to the contemporaneous needs of students. The nature of this teaching and learning 'observation' is explicitly discussed with the students at the start of the module and they formally consent to learn in this way. Accordingly, while the module is in progress, I am primarily present as the teacher, although my focus and gaze within the class and my note keeping will be ethnographically enhanced. Once the teaching has ended, the data is secondarily used for research purposes and the students provide consent for this research use at this point, when the data that is already collected moves from being a teaching artefact to an object of interrogation. No data is collected that is not a part of the learning and teaching process, and the only data that is collected is what would occur in the normal process of teaching whether research was taking place or not. The only difference from the perspective of the student is the secondary use of that data.

Ethical approval for this and other similar studies has been granted by Imperial's Educational Ethics Review Process (EERP) (Imperial College, 2023). The students' identities are protected by the use of pseudonyms. The consent process makes students aware that they may be identifiable by other members of their own class within the research, but where specific characteristics of a student may make them identifiable more widely, an individual conversation is initiated with the student in which they provide initial consent to explore whether this characteristic may be used or could be substituted. Example characteristics include things like neurodivergence, physical difference or disability, and sexuality or gender identity. To date, all students who have given enhanced consent in this way have wanted to share their experiences and have the specifics of their identity included in the research.

Before we begin the Beguine

I have been at Imperial for over a decade, completing an MEd and a PhD in post. I have developed a programme of study. Grown a team. Worked with thousands of students. Won prizes and awards. And yet. Do I belong? To whom? To what? Where? At Imperial? Within the wider field of higher education? As an educator? Teacher?

This is the starting point for my understanding of belonging. In many ways, on a daily basis, I do not belong. And yet I stay. I work and engage. And that work generates its own belonging. I do not belong because of my role or discipline. I do not belong because of longevity or seniority. I belong, in my own small way, thanks to the myriad moments of engagement and coming together. With colleagues and students.

I am sure we all agree that we want our students to feel as though they belong at university. Within their institution, discipline, year group, learning and friendship circles. But the transient nature of (most) students within higher education means that they risk being treated or feeling like visitors, at best guests, at worst interlopers. While considering various models of belonging (Ahn & Davis, 2020; Goodenow, 1993), my action-oriented mind always comes back to three needs in terms of identity and belonging that I see in my students and that, unless addressed, compromise my ability to provide the best experience for my students (see also Hyland, Chapter 2 in this volume).

Students need (and I can provide):

- confirmation (or validation) of their right to be at university, to be learning in my classroom and to participate,
- curiosity about who they are, how they see the world, and how they feel about learning and their experiences with us, and
- care for their well-being, their needs as learners and as people.

And we can provide these three Cs at an intellectual level, by telling and asking, and at an affective level by modelling, showing and celebrating.

So what of belonging in my classroom(s)? Within the ecosystem of my university, I do not belong to a degree programme, or to a department. I sit outside the educational and research structure of the institution; my work is oriented alongside service providers like the library service, the disability service and the careers service. And yet I am not a service provider. I am an educator. And my classes form a part of the degree studies of our students. Part of their formal education. And yet I teach from the outside, from a space that is very different to the standard educational spaces within departments. From my non-departmental position, I offer a (perhaps) unusual perspective.

I operate in a space where everybody belongs, yet nobody belongs. A space where there is nothing that holds my students and me together. We do not share common ground intellectually or pragmatically.

My work is interdisciplinary and my students' varying STEM disciplines train them to think and work in different ways to me and to each other. Our timetables subject us to differing demands and shape our working weeks with different rhythms. My students are geographically located in different buildings. Their departments have different structures for pastoral and social interaction. Individually, we come from different backgrounds, cultures and countries. As an institution we have just under 12,000 undergraduate students, with more than half of our students joining us from 125 different countries outside the UK.

And, being a non-departmental entity, I do not come with real estate. I teach my classes in borrowed classrooms, often moving from building to building as the weeks of a module pass by. I have no base, no physical symbol of my identity, place or belonging within the institution. Each classroom I occupy is a constructed foil for what I want to take place there.

But perhaps, within my classes, we belong because of the equality of our non-belonging. Perhaps, as others have proposed, there are benefits and opportunities gained by un-belonging (Murray, Chiu & Horsburgh, 2022), a liberation from conforming, from losing or supressing important parts of ourselves to 'fit in'.

But the work that takes place in my classrooms – messy, risky, experimental, exploratory and experiential – cannot take place in a belonging vacuum. Something needs to draw us together, to offer us comfort and reassurance as we experience vulnerability and become exposed in our learning. To inspire us to move forward individually and together with new ways of communicating, working and 'being' in the world (Barnett, 1997).

Boom! Shake, shake, shake the room ...

> [A]ny radical pedagogy must insist that everyone's presence is acknowledged. That insistence cannot be simply stated. It has to be demonstrated through pedagogical practices. … Often before this process can begin there has to be some deconstruction of the traditional notion that only the professor is responsible for classroom dynamics.
>
> (hooks, 1994, p. 8)

The first session of the year, with brand-new, first-year students,three weeks into their higher education experience. Perhaps just a month away from home, from their familiar surroundings and home comforts.

The entrance is at the top of the lecture theatre, a very steeply raked and cramped space. There is row upon row of seats, with only a single access point to each row, down the side of the lecture theatre. It is an oppressive space, not suited to active learning like group work, whole-class discussion or kinaesthetic work. But even

> in lecture halls … teachers possess the power to create conditions that can help students learn a great deal – or keep them from learning much at all. Teaching is the intentional act of creating those conditions, and good teaching requires that we understand the inner sources of both the intent and the act. (Palmer, 2007, p. 7)

The first tentative head peers through the open doorway, and looks aghast at the steep steps, the rows and rows of seat choices and then at me, tiny and yet huge at the bottom of the room. As more students file in, the rows begin to fill.

The bubbling anticipation of those first entrants to the space becomes overtaken by a reverential hush. Students are taking their places, but they are sitting in silence, uniformly looking forward, conforming to some unspoken ideal. And my welcoming ministrations fall into the depths of the silence within the room.

This room dictates the action that will occur within it (Jacklin, 2000; Sennett, 2018). Those rows of seats, facing forward towards the big projector screen, tell the students to sit facing forward and direct their attention to the screen. The rake of the lecture theatre means that their gaze naturally extends to the screen. It is an effort, an active disruption to the ergonomic of the room, to look down at the row in front of you, or up to the row behind. Even looking at the student in the neighbouring seat requires effort: you are so closely situated that for comfortable conversation you need to lean away from each other to be able to see and interact at a more normal distance. This room is not about making connections. It is not about communication, collaboration or participation. In this room, the students are not important. In this room, content is king.

To create active learning in this space, the invisible conforming forces of the room need to be subverted. While initially horrified by this room allocation just a few days previously, I have been busy developing an activity to take our experience beyond this room and set up some values that I want to shape our experiences together. The students will be split into groups of 10 and allocated one of the United Nations Sustainable Development Goals (SDGs) to research and present. Each team will receive a Change Maker Kit package that contains background information on their allocated SDG along with the kit components.

I quickly demonstrate the kit: each team has two pairs of glow-in-the-dark glasses (for fearless vision), a coin (for timely decision making), Love Hearts sweets (for passion and energy), coloured pens (for creativity), stones to put in their shoes (for discomfort) and team tethers (to tie their team together so that no one will get left behind). I am confronted by a sea of disbelieving and sceptical faces until I take off my own shoes and shake out the stones I have been (painfully) walking around on all afternoon. After that there is a scrabble for the kits, the students are ripping them open and distributing the contents, before spilling happily out of the lecture theatre to start working together.

Their task is to create a poster detailing their allocated SDG and a *tableau vivant* (a living picture or static scene containing people, models or props that communicates a concept or action) that represents their SDG. They must return in an hour, at which point we will transform the two images into a GIF and use it to populate our reimagining of the SDG poster. It will be a scintillating mass of images, switching between poster and tableau in each little square. Rather than endless presentations, all the posters will be visible at once. The students can browse them, discuss them and offer some peer review. And then there will be a vote for prizes.

As the students leave the room with more energy than they had brought in, I am relieved. I have a niggling worry about losing these new-to-me students as they spill out into the early darkness of a winter afternoon, dissolving into the shadows between buildings. Luckily, I had the foresight to ask the students to tie themselves together and gave them glow-in-the-dark glasses, which are amazingly effective in helping me keep track of my own students in the heaving mass of a busy campus full of people.

I wander between teams, not wanting to stray too far from the room, but wanting to see how the activity is progressing and offer support where needed. I come across a team huddled beneath a staircase.

Me: How are you doing?

Angela: We're getting on fine. I'm taking the lead on the poster, and Michele is taking the lead on the tableau.

Me: It's great that you're taking the lead. Do you like drawing? (*Seeing a brilliant drawing emerging on the poster*)

Angela: I'm not normally very confident at these things, but I've got the glasses on, and they're so bright! I love all the teams with the glasses on …

Me: Yes, they're a lot brighter than I thought they'd be!

Angela: They're so cool. Can we take them home?

So now we are free and at large. Free to be active, move, communicate and make connections. But have we lost something by leaving our lecture theatre? Have we lost our biggest connection? In those first moments of the class, we were strangers, brought together at the start of an as yet uncertain experience. We were not from the same discipline, part of campus or personal background. We had nothing in common apart from signing up for this class at this time on this day. And yet we had the lecture theatre to contain us, inform us and guide us. Goffman (1959) suggests that we are constantly performing, especially when our interactions and behaviours can be observed by others; we put on a 'front' (p. 32). While the students might have been physically uncomfortable in the lecture theatre, the conformity that it prompted offered a psychic comfort. They were able to (safely) belong by performing and conforming within the lecture theatre. And that has now been lost.

So how has this activity intersected with this potential desire to conform? We have moved from the safety of a defined and confined 'place', into the more nebulous 'space' of the rest of campus (Ingold, 2011, p. 145). Whereas Ingold describes a place as a container, a comfortable known, space is rather trickier. It is nebulous, indefinite, incalculable. But is our moving from place to space problematic? I have certainly imposed no limits on where the students go; I have not even limited them to campus. For all I know, they might have hopped on public transport and be miles away. But I have asked them to be back in an hour. So there is a limit, even if I have gone for a temporal rather than spatial limit.

And perhaps I have enabled the students to begin constructing their own 'places' and conforming ideals? They are finding containment by tying themselves together in teams with their shoelace tethers, physically defining and delimiting their belonging within their team. They are huddled around their posters, they are physically contorting themselves to create their tableaux. They are occupying nooks and crannies, café tables, pavements and porches. They are not lost in space: rather they are suspended in a solution of activity that has gently flowed outwards, but is still connected by the activity (and, of course, the glow-in-the-dark glasses). The teams somehow look alike but different. Act alike but differently. As the students have ventured off undertaking mini acts of 'world building' in their teams (Goffman, 1961), we have somehow networked new micro-places within space.

This task, with its glasses and tethers, provides a scaffolded step to breaking with conformity. The glasses and tethers provide props and a mask or costume that protects the students, or, in Goffman's terms, the 'performers' (1959, p. 28). In fact, the items go one step further and represent a 'uniform', because all the teams have identical masks or costumes. The 'front' is the performance of ourselves that we present when in the continued presence of a group of observers (in this case other students and the teacher). While in performance mode, we are curating a version of ourselves that we want others to see and believe. But we hide our vulnerabilities and aspects of our true selves that we are not ready or happy to share. However, when we have a mask, a costume or, as in this case, a uniform, it provides a conformity and an acquired identity to hide within, a relief from being entirely responsible for our actions or behaviours. And, in this way, this built-in excuse provides a little safe space to share something of ourselves that we might not otherwise be confident to do. If it goes wrong, or people judge us, we can excuse the moment as being due to the uniform. We see Angela in this example, perhaps feeling more confident to try leading and sharing her drawing because she is wearing the glasses. She is secure within her tethered team and with her networked identity as a glasses-wearer. She can take the risk of exposing a little of her individuality under cover of her conforming uniform.

So, by subverting the implicit forces of the lecture theatre, we have liberated communication, creativity, movement, social interaction and individual experience, under the cover of some new mechanisms of conformity: masks and uniform, team identities and networked identities across the teams.

Normalising struggle, failure and difference

Buoyed by the success of this task, the following week we double-down on breaking and remaking our learning space. Again allocated to an inappropriate (and slightly depressing) lecture theatre, we begin a task that will introduce more values and opportunities to build our community. We start by reviewing photos from the first week: seeing themselves on screen helps the students appreciate their achievements.

With some prompting to link what they see on the screen with learning, skill development and the Change Maker mindset, the students begin to value the (crazy) activities that we do together, their own contributions and each other.

This week, the students have to work in teams of about 60 students. A near-impossible task. And they have to create physical timelines in the lecture theatre, using rope, luggage tags, and an assortment of craft materials. This means incorporating the fixed furniture into their constructions. They have to pick themes, develop areas of interest and divide themselves into subteams by the end of the session. It is a hot, overwhelming and busy task. Having a full-capacity lecture theatre of people all up on their feet, moving around, trying to organise physical tasks in their own ways, is chaotic, to say the least. We talk about this chaos at the start. I tell the students that the task might be impossible. I tell them that I cannot see a way for them to accomplish the task, but I believe that they can do it. They must try.

Because together we will be able to think of things that we cannot imagine individually. Together, we can achieve more. The students might make mistakes, get things wrong or make bad decisions. But, by trying, we will learn from every moment, every action. We will take the task as far as we can. I reassure them that not everyone needs to be a leader. Not everyone needs to have a loud voice or be in the middle of the mêlée. There is space for people to support their team more peripherally. For people to move to the edges. And, of course, if anyone has concerns or is struggling they can take a breather or ask for help.

As the task progresses, leaders emerge in one team. I interrupt the class and point out the amazing practices that I see happening in that group. The other teams incorporate those ideas in their work. Another group has an amazing method of keeping everyone in the team together and differentiated from the other teams in the class. I interrupt and point out this amazing phenomenon, jump up and down in excited admiration, and again the other teams adopt some of this idea into their own process. And so the class proceeds. Frequent interruptions from me nudge the class towards good practice, successful strategies and inclusive working.

When I see students who have 'fallen out' of their team's orbit, I pull a fistful of feathers out of my back pocket and given them the special task of making sure that each of their team members uses a feather to designate something (of their own invention) on their timeline. And those students are back in the game.

Another student who is clearly struggling with the nature of the activity becomes our honorary photographer, taking my phone to capture the best bits of the action around the room. And so on.

I roam the room, tucking people back in where appropriate and finding them safe respite where needed. But every single person is needed and critical to our success.

The following week, we reconvene and celebrate our new-found confidence in being able to tackle anything. This task was so difficult (and we have the pictures to prove it) that we now know we are made of strong stuff. We can problem-solve on a huge scale. We can work together. We can look after each other. We can lead and be led. We can contribute, collaborate and concentrate. In the least ideal of conditions. And we really do celebrate. Cheers and applause for our favourite moments. All the while linking these recollections to the learning, skills and mindset goals we have as a class.

In our final session of the term, after seven varied but successful sessions, we find ourselves back in that first lecture theatre again. But this time the room does not provide the dominant influence on our coming together. As the students file in from that top door, they are chatting and joking, teasing each other about what might be about to happen. Would Jason end up in a big tangle of rope? Would I (the crazy teacher) end up tying Dominic to Yeye? Would I cover the students in stickers, or colour in their faces? The students file into the rows, but do not sit facing forward. They stand, they sit backwards on the bench tables, they leapfrog the rows precariously. They instinctively put their bags and coats out of the way. They have seen the front bench covered in crafting treasure. Their anticipation is immense.

And I do have a crazy task for them. One that even I worry might be a step too far. I want them to make hats that represent possible futures. And then, when they have made and are wearing their hats, I want to turn the rows and columns of seats in the lecture theatre into a giant graph, plotting each student (wearing their hat) into our graph of the future. I anticipate rolling eyes, sighs and attempts to avoid the task, especially from some of the students who have been at pains to emphasise their 'seriousness' to me over the weeks, the ones who do the tasks that I set, but let it be known that they could have learned these skills in a more 'traditional' way. But this does not happen. There is a mad scramble for the best pipe-cleaners, card, pens and glue. Hat construction is fully under way.

And by the end of the class, every student has stood at the front of the whole class to present their hat and be 'plotted' into the graph, even the students who have told me over the weeks that they are scared to speak in front of others, or are not confident in their language or communication skills. I am prepared to step in and help present the hats, I am prepared with alternative strategies to allow these students to participate without speaking, but I am not needed. Each student gets a raucous cheer and rapturous applause as they speak and get plotted into our graph. And each student walks proudly out of the class at the end wearing their hat.

And now for something completely different (and yet subtly the same)

> Teaching is a performative act. And it is that aspect of our work that offers the space for change, invention, spontaneous shifts, that can serve as a catalyst drawing out the unique elements in each classroom.
>
> (hooks, 1994, p. 11)

Moving on from this first-year scaffolded and highly supported module, we will drop into a final-year module. A completely different experience for all involved.

Final-year students have more established disciplinary and institutional identities. They have usually found their place as students, and they carry a confidence and assuredness that is not possible for first-year students. They are generally able to make their own connections within the classroom, which as soon as the students start arriving comes alive with noise and energy.

This module uses an adapted team-based learning structure, so the students are already sitting and working in the teams that they will stay in for the whole module. They will explore historical disasters and must curate their own reading and research. They will create annotated bibliographies that reflect the content of the material chosen, alongside their critique and experience of accessing the source. They will create a synthesised knowledge base that could inform an intelligent adult about the disaster. And they will ask and answer questions in persuasive prose.

They will not be given specific guidance about how this should be completed, but they will get frequent and copious feedback, which will enable them to develop their own feel for how to present information, and for tricky questions like 'How much is enough?'. As well as seeing their own feedback, the students know that all work within the class is public, meaning each team will review the work and feedback of the other teams. This drives forward their learning, allowing them to leapfrog the missteps of others and reach dizzying heights very quickly. The containing structures of the work cycle and the teams are put in place, but it is up to the students to navigate the relationship building and learning for themselves.

The session is going well, the students are drawing maps of the working processes they will adopt and are discussing strategies for effective team working. Riding on the coat-tails of these great discussions, I introduce the Class Spirit Quiz. It asks students to comment on their own, each other's and my identity. They need to consider different aspects of each person's identity. The process is adapted from Gee (2000); the students must choose natural (a physical trait), institutional (student or teacher), discursive (how the person is known) and affiliative (a sense of belonging valued by the individual) identity characteristics. If they do not know, they must guess, but mark the guesses with an asterisk. Finally, if they are brave enough, they try to get points by showing their guess to the person concerned. They get two points if their answer matches the person's own answer for themselves, one point if it is different but the person is not offended, and lose a point if the answer is very wrong or the person is offended. They get no points if they choose not to share their guesses.

As often happens, the students are cheating a bit, collaborating on the answers. This enhances the learning from the task, the aims of which are to help the students get to know each other, allow the students to construct their persona within their team, and consider themselves and each other as multifaceted.

Garrett, who was proving to be a very vocal member of the class, wanted to test his responses about my identity. Although most of his 'guesses' were designed to flatter me ('funny', 'clever', 'a teacher that loves teaching'), he most notably identified me as 'not from Imperial', while everyone else on his list was noted as 'from Imperial'.

Garrett had already expressed disappointment that this would not be a lecture-based module, even though this was clear in the module description. He wanted to be taught the facts of history rather than take a critical view of our construction of history and conduct his own research. At the end of this first class he declared that he had not learned anything all afternoon, and that he was disappointed. The class was not good enough. We agreed to continue the discussion if he returned the following week, and – spoiler alert – he did and we did. At length.

Another team were struggling a bit with the Class Spirit Quiz. Team Ali's Crew were a friendly bunch, sitting right at the front of the class. They had seemed to be getting along very well, but there was one team member, Jackson, who looked dejected and somehow isolated within the friendly group. I managed to catch his eye and sidled up for a chat.

Me: Hi, you're Jackson, aren't you?

Jackson: Yes. I'm slightly scared that you know that as we've never met.

Me: Well, I looked at your team chart, and I've been with you nearly two hours …

Jackson: It doesn't matter, I don't know if I will stay in this module …

Me: That's a shame, I was looking forward to getting to know you. Is there something in particular that you don't like or you are worried about? It seems like you have a really lovely team here …

Jackson: That's the problem. They're all really happy, and I am a really miserable person. It's not a problem, I don't need help. I'm just not like them. I'm moody, sometimes I don't want to do my work, and I'm just not friendly.

Me: You haven't said anything there that means you couldn't work with this team – I'm not worried. We're all different people, we have different moods and different temperaments. And we don't always want to do our work. That sounds pretty okay to me. Perhaps we can find a way to make it okay with your team, I'm sure they will understand if we talk to them.

Jackson: No, they're all really happy positive people. I don't want to bring them down. And we just wouldn't work together. We wouldn't gel.

Walter: I'm sorry, I couldn't help overhearing. Jackson, you don't need to worry. We'll all be able to work together. We'll find a way – just tell us what you need. We don't need you to be happy, we'd still like you to be in our team.

Me: Thank you Walter, that is so kind of you. (*Turning to Jackson*) You see? Jackson, they really want you to be in their team …

Jackson: I would like to believe that it would work, but I just won't gel. I will ruin the team.

Me: Oh, wow. (*Turning to Walter, and then the rest of the team, who are listening by now*) I think Jackson has just thrown down a challenge. He doesn't believe that he can be 'gelled' into this team. What can we do to change his mind?

Charles: Well, let's start now. Jackson, what are you doing straight after class?

Jackson: Going out to eat. On my own.

Charles: We'll all come with you – won't we!

Jackson: You won't like it. It is my kind of food. You wouldn't like it.

Charles: Oh, I love trying new things. Even if I don't like it, I would love to find out what you like. This is going to be so much fun.

Me: Okay, everyone, we need to pack up now. Remember, if you do go out, take it easy. Jackson might be happy to share, but he might also just need time on his own. You can't kidnap him and force him to be gelled into your team.

Charles: We'll make it work. We won't do anything illegal, but we will show Jackson that he can be a member of our team however he wants to be. He doesn't have to be cheerful all the time. He doesn't have to do the same work as everyone else. We just want him to be part of our team.

With that, the students packed up and left. I was amazed by this team, but slightly worried about Jackson. Firstly, I was worried about his well-being and, secondly, I was worried that, by trying to be kind, Ali's Crew might actually do more harm than good.

However, I should not have worried. I had just got home from work when my email pinged and a photo popped up on my phone of Ali's Crew in a restaurant, all crammed together in a booth, arms around shoulders. And in the centre, grimacing theatrically, was Jackson.

The following week, Jackson began developing his class persona. He was the perpetual grump, loudly and frequently denying that he had been gelled (soon to become a running joke). At Christmas, when the team were preparing a special performative presentation, he declared that the team could not use a Christmas theme as he was an established Scrooge. Fast-forward an hour, and the team are performing a rendition of *A Christmas Carol* with Jackson as Scrooge, explaining the basis of a natural disaster in Venezuela via the ghosts of nature past, present and future.

Garrett, too, did not immediately settle into this class. He continued to express disappointment in the way he was being expected to learn. He did not like doing his own research, he emailed me frequently between classes to complain, and then he and his team struggled with the first assignment. In many ways, this was a great outcome. I was able to show him why he needed to complete the tasks as he had been asked, and not second-guess what he needed to learn. He had also refused to get formative feedback during the first cycle, but when he saw his poor grade he began to understand that learning is not just about accumulating facts and was very keen to engage in this (strange) way of learning for the second cycle.

Throughout his complaints, he had been carefully positioning himself and his team as the experienced Imperial-ites. The students who know what learning is know how to learn and know the 'Imperial' way. His declaring of me as 'not from Imperial' in the Class Spirit Quiz was the first step of this tussle. In fact, I had been at Imperial longer than Garrett. By far. But this was not my argument, so I did not need to state my case.

As Garrett began to engage, he continued to position me as outsider and himself, his team and the rest of the class as insiders. He would take his team off to another room, and then email me during class.

> **Subject: Location, Location, Location**
>
> **Date: Thursday, 22 November 2018 at 17:38:23**
>
> **From: Garrett**
>
> **To: Elizabeth**
>
> Dear Elizabeth,
>
> Just to let you know we're in SAFB 164, should you want to pop in
>
> Best,
>
> Garrett

These emails were provocative. The subject line alone required deep breaths. Anzaldúa (2015) describes a state of wilful disengagement or wilful ignorance (*desconocimientos*) that we use to distance ourselves from knowledge, ideas and experience in unfamiliar settings. But Garrett was learning something. He was working something through, and I could not fault his commitment to his team. And as the weeks passed, the emails got a little more polite. He started addressing me by my title, and asking for help rather than suggesting it might be a nice activity to help me pass the time. And, as Garrett and his team got better results, he began to let go of his animosity. Garrett began to value me as someone who could help him learn. He did not quite understand how this was happening, and it was a gradual process, but Garrett gradually began to trust that I was working to help and not hinder him, uncomfortable as it might be for both of us.

In one whole-class (admittedly slightly strange drama-based) activity, he tried to cheat the task to 'prove' that I was a fraud, did not know what I was doing and that I was, in fact, wasting the students' time. His cheat backfired, because it demonstrated the exact value that I had hoped the students would gain from the activity. But rather than hiding his embarrassment, he declared it to the class.

He raised his hand to ask a question and, when I called on him, he admitted to the class what he had done, declaring that he had wanted to prove that what we were doing was nonsense. After cheating on the activity, he declared, 'This isn't nonsense at all. It was so powerful, I just have to tell everyone in case anyone else thought that it was nonsense. It's real, guys. This is really real. I don't know what's happening, but it is definitely real.'

He later admitted that he was learning a lot in the module, and that it was so surprising and confusing to him that he had talked to his dad about it. 'I taught myself about Chernobyl and the LA Riots. But I learned other things at the same time. And I can't describe it. We do all these things together, and we work all backwards and sideways, never learning the thing we are learning. But learning all these other things.'

Garrett's journey in this module began with his declaring his belonging to his team, and to Imperial, while 'othering' the aspects of the class that he found confusing and uncomfortable. He extended this by taking on the role of 'gatekeeper' for the rest of the class, assuming that they shared his misgivings and providing an alternative locus of belonging for them.

Going back to Ali's Crew, we see almost the opposite. After that first restaurant photo, I started to get weekly photo updates from the team's social activities, usually one after the class, and often another one later in the week from some other activity. And if a team member was absent for any reason, they would be photoshopped into the image. I also found myself photoshopped into these images.

So, where Garrett's membership of the class initially required me to be pushed out, Ali's Crew pulled me in. We had many amazing discussions in class. I stepped into some pretty heated arguments (good-natured, but heated) ,and I shared their joy at their progress and the work they produced. But that was not enough. I also belonged in their experiences of the class that did not directly involve me, that did not occur in the classroom. As Ingold (2011) puts it, 'lives are led not inside places but through, around, to and from them, from and to places elsewhere' (p. 148). This constant motion or wayfaring is characterised by knots and meshwork formed when people come together.

In the same way that Ali's Crew wayfared in and out of the classroom, taking me along to dinners in pictorial form, Garrett's experience moved beyond our classroom sessions. His frequent complaining emails from the first few weeks morphed into emails letting me know that he would be 'leaving for class soon', or emails after the class to ask whether I had picked up the random item that he managed to leave in the classroom at the end of each session. He even emailed me television recommendations at one point. Just as I constructed the curriculum and the classroom, and curated our in-class communications and relationships to help the students find their feet, belong and thrive in the classes, the students were constructing their own extensions of these experiences, showing me how I belonged to their own conceptions of their learning and our time together. We might consider that this wayfaring takes us to spaces

> where ties are severed or [postmodern culture] can provide the occasion for new and varied forms of bonding. To some extent, ruptures, surfaces, contextuality, and a host of other happenings create gaps that make space for oppositional practices which no longer require intellectuals to be confined by narrow separate spheres with no meaningful connection to the world of the everyday. … [A] space is there for critical exchange. … [T]his may very well be 'the' central future location of resistance struggle, a meeting place where new and radical happenings can occur. (hooks, 1990, p. 31)

Embrace the mess

Both in the more linear and teacher-constructed approach I take with my first-year students, and in the anti-linear and student-constructed approach I facilitate with my final-year students, I have found that supporting belonging is not a tick-box exercise. No single action will 'solve' belonging for every student. Different students will be ready to take different steps and respond to different cues at different times. And the complexity of human experience will ensure that even the same student may feel differently about their place in my classroom on different days. hooks's (1994) engaged pedagogy urges us to take a deconstructive approach to seeing the teacher as solely responsible for classroom dynamics. However, she also reminds us that as teachers we must be active in sharing this role, which might look different in every classroom, and with each successive cohort. We must see each classroom as different, each student as an individual with changing needs. We must be prepared to change our strategies, adapt, be spontaneous. We must look beyond our expectation and try to make sense of each moment of interaction or non-interaction.

My curricula provide me with a palate of activities that approach the learning outcomes from a range of perspectives and with varying trajectories. I can tailor the activities in the room and adjust to my students on a week-by-week basis, drawing out more engagement with topics or skills that will help each group of students achieve the learning outcomes in the most meaningful ways for them. But I cannot do this alone: this is a collaborative and shared process.

The students need to be engaged with this co-development process (see also Kinchin and Gravatt, Chapter 17 in this volume). They need space to understand, misunderstand, resist, observe, hide, step forward, share, worry and grow. And this means that they need to be supported and cared for, their enthusiasms encouraged, their anxieties acknowledged and contained, their missteps acknowledged, contextualised and transformed into valid stepping stones to success. And their successes? They need celebrating loudly and clearly. My own identity and belonging with these students is infused with radical, critical, feminist and relational pedagogies from hooks (1994) to Anzaldúa (2015), from Palmer (2007) to Ingold (2023). And I hope to scaffold and support the development of the students' own identity and belonging in dynamic and multifarious ways, containing within them elements of auto-criticality in the sense of Barnett's (1997) 'critical being', liberating them in the spirit of Freire (1970) and empowering them to move forward with care and (com)passion à la Noddings (1986).

Working with both the linear and anti-linear arcs described above, the teacher can support and facilitate the process of establishing fluid and evolving states of identity and belonging, but they cannot do this alone. It is a constant negotiation between the teacher and the students.

This ethnography has explored a very particular classroom context. But what if your classroom looks nothing like this? What if you don't have the control to make large-scale changes to learning activities or assessments? Go back to those first principles: think about what students need (and you can provide):

- confirmation (or validation) of their right to be at university, to be learning in your classroom and to participate,
- curiosity about who they are, how they see the world, and how they feel about learning and their experiences with you, and
- care for their well-being, their needs as learners and as people.

Find explicit, out-loud ways to celebrate the students' presence in your classroom; enjoy learning about them while they learn how to navigate your classroom space and the learning material you are providing. Find ways to show them that you care about them as people, and remember

– this is a negotiation. If you're not sure how to establish these practices, ask the best resource in the room: the students. Let them design, alongside you, how you will create your sense of belonging, together.

References

Ahn, M. Y. & Davis, H. H. (2020). Four domains of students' sense of belonging to university. *Studies in Higher Education*, 45(3), 622–34. https://doi.org/10.1080/03075079.2018.1564902.

Anzaldúa, G. E. (2015). *Light in the Dark / Luz en lo oscuro: Rewriting identity, spirituality, reality*, ed. A. Keating. Durham, NC, and London: Duke University Press.

Astin, A. W. (1984). Student involvement: A developmental theory for higher education. *Journal of College Student Personnel*, 25, 297–308.

Barnett, R. (1997). *Higher Education: A critical business*. Buckingham: Society for Research into Higher Education & the Open University Press.

Baxter Magolda, M. B. (1999). *Creating Contexts for Learning and Self-Authorship. Constructive-developmental pedagogy*. Nashville, TN: Vanderbilt University Press.

Becker, H. S. (1971). Footnote to M. Wax and R. Wax, 'Great tradition, little tradition and formal education'. In M. L. Wax, S. Diamond and F. O. Gearing (eds), *Anthropological Perspectives on Education*, pp. 3–27. New York: Basic Books.

Britzman, D. P. (1995). 'The question of belief': Writing poststructural ethnography. *International Journal of Qualitative Studies in Education*, 8(3), 229–38. https://doi.org/10.1080/0951839950080302.

Chickering, A. W. & Gamson, Z. F. (1987). Seven principles for good practice in undergraduate education. *AAHE Bulletin*, 39(7), 3–7.

Cook-Sather, A., Bovill, C. & Felten, P. (2014). *Engaging Students as Partners in Teaching and Learning: A guide for faculty*. San Francisco, CA: Jossey-Bass.

Delamont, S. (2009). The only honest thing: Autoethnography, reflexivity and small crises in fieldwork. *Ethnography and Education*, 4(1), 51–63. https://doi.org/10.1080/17457820802703507.

Delamont, S. & Atkinson, P. (2004). Qualitative research and the postmodern turn. In M. Hardy and A. Bryman (eds), *Handbook of Data Analysis*, pp. 667–82. London: Sage Publications.

Ellis, C. (2004). *The Ethnographic I: A methodological novel about autoethnography*. Walnut Creek, CA, and Oxford: AltaMira Press.

Etherington, K. (2004). *Becoming a Reflexive Researcher: Using our selves in research*. London: Jessica Kingsley Publishers.

Freire, P. (1970). *Pedagogy of the Oppressed* (trans. M. B. Ramos). New York: Seabury Press.

Gee, J. P. (2000). Identity as an analytic lens for research in education. *Review of Research in Education*, 25(1), 99–125. https://doi.org/10.3102/0091732X025001099.

Goffman, E. (1959). *The Presentation of Self in Everyday Life*. Garden City, NY: Doubleday.

Goffman, E. (1961). *Encounters: Two studies in the sociology of interaction*. Indianapolis: Bobbs-Merrill.

Goodenow, C. (1993). Classroom belonging among early adolescent students: Relationships to motivation and achievement. *Journal of Early Adolescence*, 13(1): 21–43. https://doi.org/10.1177/0272431693013001002.

Grundy, S. (1987). *Curriculum: Product or praxis?* London: Falmer.

Hammersley, M. & Atkinson, P. (2007). *Ethnography: Principles in practice*, 3rd edn. Abingdon: Routledge.

Hastrup, K. (2005). Anthropological knowledge incorporated: Discussion. In K. Hastrup and P. Hervik (eds), *Social Experience and Anthropological Knowledge*, pp. 168–80. London: Routledge.

Hauke, E. (2016). The world today: A space for disorientation, self-reflection and reorientation towards a future ripe for transformation. MEd dissertation, Imperial College London.

Hauke, E. (2017). *Live, Love, Learn*. http://www.livelovelearn.education. Accessed 19 December 2023.

Hauke, E. (2019). Understanding the world today: The roles of knowledge and knowing in higher education. *Teaching in Higher Education,* 24(3), 378–93. https://doi.org/10.1080/13562517.2018.1544122.

Hauke, E. (2021). Who's looking at who, looking at who? In J. Huisman and M. Tight (eds), *Theory and Method in Higher Education Research*, vol. 7, pp. 75–92. Bingley: Emerald Publishing.

Hauke, E. (2022a). Evoke (y)our authentic: An (auto)ethnographic exploration of my higher education classroom(s). PhD thesis, Imperial College London. https://spiral.imperial.ac.uk/handle/10044/1/94953. Accessed 19 December 2023.

Hauke, E. (2022b). What is a Change Maker? Change Makers: (More than a) handbook. http://changemakerslearning.com/wordpress/2022/08/25/change-maker-what-is/. Accessed 19 December 2023.

hooks, b. (1990). *Yearning: Race, gender, and cultural politics*. Boston, MA: South End Press.

hooks, b. (1994). *Teaching to Transgress: Education as the practice of freedom*. New York, Routledge.

Humphreys, M. and Watson, T. (2009). Ethnographic practices: From 'writing-up ethnographic research' to 'writing ethnography'. In S. Ybema, D. Yanow, H. Wels and F. Kamsteeg (eds), *Organizational Ethnography: Studying the complexities of everyday life*, pp. 40–55. London: SAGE Publications.

Imperial College (2023). The EERP Process. Imperial College London. https://www.imperial.ac.uk/research-and-innovation/support-for-staff/education-ethics/the-eerp-process/. Accessed 19 December 2023.

Ingold, T. (2011). *Being Alive: Essays on movement, knowledge and description*. Abingdon: Routledge.

Ingold, T. (2023). Introduction: Knowing from the inside. In T. Ingold (ed.), *Knowing from the Inside: Cross-disciplinary experiments with matters of pedagogy*, pp. 1–20. London: Bloomsbury Academic.

Jacklin, H. (2000). Locating pedagogy. Paper presented at the British Sociological Association annual conference, York University, April.

Kelly, P. (2008). *Towards Globo Sapiens: Transforming learners in higher education.* Rotterdam: Sense Publishers.

Kember, D. (1997). A reconceptualisation of the research into university academics' conceptions of teaching. *Learning and Instruction*, 7(3), 255–75. https://doi.org/10.1016/S0959-4752(96)00028-X.

Menter, I., Elliot, D., Hulme, M., Lewin, J. & Lowden, K. (2011). *A Guide to Practitioner Research in Education.* London: Sage.

Mills, C. W. (1959). *The Sociological Imagination*. New York: Oxford University Press.

Murray, Ó. M., Chiu, Y.-L. T. & Horsburgh, J. (2022). Is belonging always positive? Cultivating alternative belonging at university. Imperial College, London. *Festival of Learning and Teaching*. https://www.imperial.ac.uk/media/imperial-college/staff/education-development-unit/public/Is-Belonging-Always-Positive-Cultivating-Alternative.pdf. Accessed 19 December 2023.

Murray, Ó. M. & Kalayji, L. (2018). Forging queer feminist futures through discomfort: Vulnerability and authority in the classroom. *Journal of Applied Social Theory*, 1(2), 12–34.

Noddings, N. (1986). *Caring: A relational approach to ethics and moral education*, 2nd edn. Berkeley and Los Angeles: University of California Press.

Palmer, P. J. (2007) *The Courage to Teach: Exploring the inner landscape of a teacher's life*, 10th anniversary edn. San Francisco, CA: Jossey-Bass.

Reed-Danahay, D. (2009). Anthropologists, education, and autoethnography. *Reviews in Anthropology*, 38(1), 28–47. https://doi.org/10.1080/00938150802672931.

Rudie, I. (1994). Making sense of new experiences. In K. Hastrup & P. Hervik (eds), *Social Experience and Anthropological Knowledge*, pp. 28–44. London: Routledge.

Sennett, R. (2018). *Building and Dwelling: Ethics for the city*. New York: Farrar, Straus and Giroux.

Tennant, M. (1999). Is learning transferable? In D. Boud and J. Garrick (eds), *Understanding Learning at Work*, pp. 165–79. London: Routle

8

Barriers to belonging for racially minoritised students in STEM higher education

Billy Wong, Meggie Copsey-Blake and Reham El Morally

Introduction

In university settings, racism is structurally embedded and can materialise as racial microaggression, racial stereotypes, social exclusion and marginalisation. In science, technology, engineering and mathematics (STEM) disciplines, racism can hinder the belonging of students from minoritised ethnic backgrounds at university. This chapter explores the views and experiences of 42 racially minoritised undergraduate students in STEM higher education. Informed by critical race theory (Crenshaw, 1989; Gillborn, 2018), we explore the barriers that appear to undermine student belonging. We discuss prominent issues, including regular experiences of racism and unwelcoming environments. We also discuss the perpetuation of whiteness and the lack of diversities and 'people like me' in STEM, including amongst student and staff populations and on the STEM curriculum.

In university contexts, these issues can cause students to feel ostracised, isolated and demoralised, dampening their feelings of belonging, including in STEM disciplines. By highlighting the lived experiences and challenges of racially minoritised students, we make suggestions for policy and practice to mitigate these existing barriers, and revisualise STEM education and the university as spaces where belonging can be experienced by everyone. In the UK, the decolonisation agenda aims to address racial inequalities and support the belonging of racially minoritised students in higher education. This involves being critical in relation to whose knowledge is recognised and represented, what is taught in universities, and which pedagogical approaches are used and why some forms of knowledge are privileged over others (Schucan Bird & Pitman, 2020). As we argue in this chapter, universities require a long-term, cultural and institutional shift towards decolonising their systems, behaviours and practices. However, immediate changes are also needed to address racism and support the belonging of racially minoritised students, including in STEM higher education.

The STEM context

There are concerns that a greater proportion of students from racially minoritised backgrounds are dropping out of STEM education compared to their white counterparts (Advance HE, 2020; Elias et al., 2006). Recent research indicates that the reasons for this 'leaky pipeline' lie in various factors and social inequalities.

In the UK, and similar Western countries, one of the main challenges for racially minoritised students in STEM education is that these fields are historically (but also presently) dominated by white people, especially white men. Underrepresentation and marginalisation can create feelings of isolation and disconnection amongst students, including racial and ethnic minorities, women and gender minorities, and individuals with disabilities. A lack of representation can perpetuate racist stereotypes and biases, and fewer opportunities for racially minoritised students to develop belonging and identity, which leads to further feelings of exclusion and marginalisation (Ong et al., 2018).

Furthermore, it is important that racially minoritised people are represented on the staff, as positive role models, mentors and academic support networks can be a powerful source of inspiration and facilitate career progression amongst marginalised students in STEM, especially Black women (Inyang & Wright, 2022). However, people from minoritised ethnic backgrounds are underrepresented as professors in higher education. This is especially true of women, of whom most are in the social sciences, as the lack of diversity in STEM is marked (HESA, 2022). For instance, the Royal Society of Chemistry (2022; Ghosh 2022) reported just one Black chemistry professor in the UK last year. This has implications, as racial and ethnic diversity can affect belonging, motivation and achievement (Graham et al., 2022).

Existing studies have also found that students with underrepresented identities, including students from minoritised ethnic backgrounds, are more likely than other students to experience feelings of being an imposter at university (Murray et al., 2022), where they do not feel as though they belong or can succeed in STEM fields. More specifically, the culture of most STEM fields is often different from that of other, non-STEM disciplines. STEM disciplines tend to be highly focused on research and discovery, typically underpinned by a positivist approach and objective mindset which tends to assume scientific knowledge is universal or value-free. This approach tends to be uncritical of the factors that shape scientific knowledge, overlooking its vast global implications, perspectives and histories (Smith, 2021), and highlighting unique challenges and assumptions about decolonising the STEM curriculum in the UK.

Consequently, racially minoritised students may struggle to identify with or align their values with how certain ideas or knowledges are presented to them in STEM contexts. Positivist and objective approaches to learning are often used in STEM, but these may not appeal to students who are more accustomed to collaborative or interpretive approaches to learning. For example, STEM degrees, especially those with lab work, often require students to work in isolation or in small groups, or for long hours, which can make it difficult for some students to develop social connections and a sense of community, especially those with other commitments, or those with few or no peers from similar backgrounds in their classes (Keller, 1992; Ong et al., 2018).

Moreover, racism and racial inequalities persist as an everyday reality for students from minoritised ethnic backgrounds in higher education, manifesting in various forms across time and space, in different contexts and disciplines (Wong, Chiu et al. 2023; Wong, El Morally, Copsey-Blake et al., 2021). Whilst this is a collective problem that requires institutional change and long-term collective action, immediate action is also needed, as the consequences of racism are current and ongoing, and damage the belonging of students in university settings. Whilst belonging is inevitably nuanced and context-specific, the experiences of racially minoritised students in STEM disciplines are underresearched in UK literature.

Student belonging and racial inequality in higher education

Although scholarly definitions are widely contested and varied, the concept of *belonging* can be understood as feeling accepted, affirmed and valued by a group or community, and is often associated with the basic human need to connect with others and feel included. Yet racism, even when manifested in its most subtle or implicit forms, presents significant barriers to belonging for racially minoritised students in higher education.

In education research, *belonging* is typically 'measured' in terms of a sense of group membership, and of the extent of academic engagement and social integration in university settings, which includes utilisation of support provisions and resources (Ahn & Davis, 2020). According to Gravett and Ajjawi (2022), belonging is situated, relational and processual. Student belonging is often positively associated with different aspects of student experiences, including well-being and academic achievement (Read et al., 2003). Research on student belonging fills an important gap in the understanding of students' experiences and outcomes. However, few studies have unpacked how structural inequalities and manifestations of racism affect the belonging of racially minoritised students. We use the lens of critical race theory to focus on the barriers that seem to inhibit student belonging in STEM higher education.

To elaborate, the underrepresentation and apparent underachievement of minority ethnic students suggests that the current higher education system in the UK privileges and favours the belonging of White British students (Bunce et al., 2021). However, existing research appears to underplay ethnic differences, and not to acknowledge the potential barriers for students who may struggle to feel socially accepted or valued by their institutions, especially when there is evidence that racism exists as an everyday lived reality for students in UK universities (Equality and Human Rights Commission, 2019). This assertion is supported by an extensive range of case studies of education-to-work trajectories that highlight the intersections of race and ethnicity (Arday & Mirza, 2018; see also Al Arefi, Chapter 10 in this volume).

In university settings, racism is often disguised by being covert, implicit or subtle. For example, racial microaggressions have long been the focal point of scholarship on the racialised experiences of minority ethnic students (Singh, 2009). The consensus is that these subtle forms of racism serve to marginalise and negate the identities of racially minoritised students, typically in ways that are normalised in society, which makes them harder to identify or call out. Though microaggressions are often tolerated by bystanders, or at least by the majority, evidence suggests that they can prompt isolation, perplexity and low self-esteem (Harris, 2017), and can be more damaging than explicit forms of racism, such as overtly racist comments (Jeyasingham & Morton, 2019).

A recent inquiry into racial harassment in UK universities (with 845 student responses) found that 24 per cent of students from minoritised ethnic backgrounds reported experiences of racial harassment, whilst 56 per cent had been subjected to racist name-calling, insults and 'jokes' (EHRC, 2019). For these students, higher education is a journey of racial challenges and inequalities; this is further evidenced by the ethnicity degree-awarding gap, that is, the percentage of 'good' degrees (class 2:1 or above) awarded to the white majority and to racially minoritised students, even when prior attainment and entry grades are controlled (Universities UK/National Union of Students, 2019; Wong, El Morally & Copsey-Blake, 2021).

The growth in the number of students from minoritised ethnic backgrounds in higher education has enabled the disruption of these previously normalised discourses, institutionalised cultures and pervasive ways of thinking. Student-led initiatives such as the 'Why isn't my professor black?' (Jahi, 2014) and 'Why is my curriculum white?' events (Peters, 2015) have illustrated that whiteness is perpetuated by the university curricula and the underrepresentation of Black academic staff. The decolonisation agenda has been strengthened through such campaigns, which draw attention to the colonial histories and structures of higher education, and the existence of white supremacy and racial hierarchies. Universities therefore require a long, collective process of unlearning and undoing centuries of colonial ideas, practices, behaviours and systems (Bhambra et al., 2018).

The intersection of race and ethnicity is therefore key in research that attempts to understand student belonging. For instance, a recent study of the experiences of Black students in STEM higher education in the UK found that they often feel unwelcome at university because they are underrepresented in student and staff populations. The researchers suggest that students can benefit from a greater diversity of teaching and assessment approaches in STEM disciplines, and from moving away from traditional lectures and towards smaller teaching groups (Greaves et al., 2022).

McClain (2014) suggests, from a small qualitative study of Black mathematics undergraduates, that an absence of Black peers caused them to feel like outsiders, and that experiences of racism and negative racialised stereotypes served to other and isolate them further. These factors have serious implications for the belonging of those who are underrepresented in their degrees, and, more broadly, within high-tariff universities with poor ethnic representation (Advance HE, 2020, p. 138; see also Hyland, Chapter 2 in this volume).

Critical race theory

A key lens to interpret the experiences of racially minoritised groups is critical race theory (CRT), which acknowledges and accepts that racism exists and is central to social inequalities. CRT is a useful theoretical framework, as it effectively destabilises notions of race and racism, and challenges normative or dominant institutional discourses (Solórzano, 1998). There are several key commentaries that conceptualise the central tenets of CRT similarly (e.g., Crenshaw, 1989; Crenshaw et al., 1995). A key perspective is the notion that racism is structurally embedded and ingrained in society and exists as a product of social thought and colonial imagination. However, as Gillborn (2018) notes, racism is fluid and cannot be solely understood as a depersonalised system, as it operates on the beliefs, actions and fears of individual actors. The barriers to belonging for racially minoritised students must therefore be contextualised if any intentional or meaningful change is to be actioned.

Relatedly, intersectionality theory – coined by Kimberlé Crenshaw to challenge single-axis anti-discrimination doctrine in the US – was developed to acknowledge the unique racialised and gendered experiences of Black women (Crenshaw, 1989). Over time, intersectionality has become a popular lens through which to examine the interconnectedness of different social inequalities and identities in Western contexts, especially in education and social science research. For instance, an intersectional feminist approach recognises that students can experience multiple axes of oppression based on race, ethnicity, gender, class, disability, sexuality and more. However, these inequalities are often siloed, and the unique complexities of intersectional experiences can be overlooked in the literature. Similarly, the centrality of racism and white supremacy as deeply rooted in global inequalities can be absent in studies that adopt intersectional frameworks without deeper insight into their origins in CRT and Black feminism. Within intersections of race and ethnicity, there are interconnected inequalities between ethnic groups, which merit closer insight.

Our focus is on the barriers to belonging for racially minoritised students in STEM higher education. We suggest that racism manifests as unwelcoming university environments, social exclusion and marginalisation, and a lack of 'people like me' in STEM. We aim to expand our knowledge of these challenges by providing deeper empirical insights into the lived experiences of racially minoritised students at university.

Study details

Data in this chapter comes from a three-year (2018–21) qualitative project that investigated the lived experiences of racially minoritised students in STEM undergraduate degrees. The project aims to improve understanding of their views, experiences, opportunities and challenges at university. According to Advance HE (2020, Table 3.6), around 24.3 per cent of all UK-domiciled university students self-identified as being from a minoritised ethnic background, with 25.6 per cent in STEM and 23.1 per cent in non-STEM degrees. In other words, racially minoritised students appear better represented in STEM disciplines, at least in terms of access statistics. This chapter contributes to a growing literature base that appreciates the lived experiences of racially minoritised students in higher education, and our boundary is within STEM degrees, where students from minoritised ethnic backgrounds are seemingly better represented.

Our project is based at an English university with a student composition that broadly reflects the national population. The project received ethical approval to carry out the project by the university's ethics committee and began in Autumn 2018 with a call for participants in any STEM undergraduate degrees, with an emphasis on those who consider themselves to be from a minoritised ethnic background. Using our own contacts as well as department websites, we set out to recruit UK-domiciled undergraduates from minoritised ethnic backgrounds. We approached over 100 staff to seek permission and support to promote recruitment; the promotion included over 60 short presentations to students about the project at the beginning or end of a subject lecture. Further details were disseminated through students' virtual learning environment. Data was collected over three years and a small number of students continued with us over the course of the project, providing longitudinal qualitative data, which we explore separately.

We draw on semi-structured interviews conducted with 42 undergraduate students from minoritised ethnic backgrounds. Most students self-identified as women (n = 32), but a range of racially minoritised groups were recruited, including Black, East Asian, Middle Eastern, Mixed, South Asian and White European. Although our target was UK-domiciled undergraduate students from minoritised ethnic backgrounds, we also accepted interest and participation from those who self-identified as White British (n = 15), which provided us with comparison data. Given that the scope and focus of this chapter is the experiences of racially minoritised students, any comparison with White British students would be inappropriate. Therefore, they are excluded in this chapter.

For context, the degrees that our students studied include biological science, biomedical science, computer science, mathematics, pharmacy and psychological science. We have chosen to extend our definition of STEM to include 'non-traditional' disciplines that involve scientific inquiry and positivist approaches to scientific knowledge. Whilst students' experiences are inevitably nuanced and context-dependent, a closer examination of the views of marginalised students in different STEM (and non-STEM) contexts can highlight the persistence of racism and intersectional inequalities across university settings, as well as within disciplines.

For instance, disciplinary hierarchies can also exist within STEM fields (Wong, Chiu et al., 2023). They can affect the belonging of racially minoritised students, as well as students with other marginalised and intersecting social identities, as the white, male (able-bodied, cis-hetero) majority is overrepresented in the physical sciences, which are stereotypically elitist compared to the life sciences, which tend to be more diverse and in which minoritised students and staff are better represented.

The interviews lasted an hour on average; students were asked questions about their experience in higher education. Students were invited to share their experiences of and stories about race and racism in higher education, in domains which included accommodation, teaching and learning content and practices, and the study/university environment. The interviews were audio-recorded and transcribed verbatim, with sensitive details removed. For confidentiality purposes, data was anonymised and participants were given pseudonyms.

For the reader's information, the authors all have a social science background with no associations or interactions with participants outside of the project. We are ethnically diverse, with heritages including British East Asian, White British and Middle Eastern. At the time of data collection, Wong was an academic staff member with a departmental role that championed equality, diversity and inclusion, Copsey-Blake was completing an undergraduate degree and went on to do a master's, and El Morally was a doctoral student.

Data analysis was informed by a social constructionist perspective, which understands social phenomena as socially constructed and discursively produced (Burr, 2003). Interview transcripts were imported into NVivo, a qualitative data analysis software package, for initial data arrangement; we created provisional codes as we moved back and forth between the data and analyses in an iterative process, through which the dimensions of concepts and themes were refined or expanded as we compared the data (Corbin & Strauss, 2014). A coding framework was developed with a guided list of definitions for each code, and discussed between the team members. Each author independently coded five interview transcripts by relevant themes; we compared and reflected on these as a team, and debated any differences on the application of codes until a consensus was reached. We also wrote summary reflections about each interview and overall reflections on our experiences of working on the project. In the 'Findings' section below, we focus on the challenges of racially minoritised students as they navigate unwelcoming environments, deal with social exclusion and marginalisation, and cope with the many difficulties related to a lack of diversities and 'people like me' in STEM higher education.

Findings

Unwelcoming environments

As a result of racism, racially minoritised students in STEM have had experiences of feeling unwelcome in university settings and learning environments, especially in the form of racial microaggressions and racial stereotypes, and different levels of marginalisation. When subjected to racist remarks, most students, such as Pakiza (South Asian woman, studying psychology), opt to 'laugh it off at the time, but then it just sort of niggles at the back of your head … that wasn't funny … it was kind of scary'. Although some students said they were already accustomed to racially charged comments or questions from strangers in public, Pakiza said that similar experiences have happened at university, especially in student halls of residence, which have made her more aware of racial differences when interacting with White British students.

The embeddedness of institutional racism in the UK was described by Shanika (Black woman, biomedical science), who expressed a low sense of belonging and a general disconnect with unwelcoming environments, in university settings and in society more broadly. She said, 'A lot of people [are] naive [because they] don't understand Britain

[is] built on racism.' She added, 'It makes me feel uncomfortable that I live here. … I can't believe that this is sort of the place I live.' Mabel (Black woman, biomedical science) suggested her peers were ignorant of and oblivious to the damage caused by racial microaggression, which she attributed to a lack of education about Black British history. She said:

> People that do these microaggressions, they don't understand why it's so offensive. … I think a lot of it is to do – because of Black history in schools. … No one really knows about the Black British pioneers, what happened here, and not just to the Black British people but other ethnicities too who were also prejudiced against when they came here.

Unwelcoming environments have affected how racially minoritised students engage with their STEM degrees and learning environments. For instance, Lutah (South Asian man, psychology) observed that students of similar Asian background are 'more likely to stay in' and isolate themselves from groups to avoid negative interactions with their peers and others. Others, particularly Black students, suggested that racialised stereotypes and stereotype threat can cause marginalisation in academic settings (Gillborn, 2018).

In the same way, Tamu (Black woman, psychology) suggested that, because of racialised stereotypes, she has to be mindful of how she interacts with white students, as her tone and use of language can be ridiculed or policed by her classmates. She explained:

> Sometimes, in terms of communication, there comes a clash in understanding how people communicate. People from my background are considered loud, harsh and rude. For us, we don't see that as being loud, we're just very expressive. … There are some things that you should be mindful of how you say it. I learned that a lot from my British friend because she will tell me, 'Oh, no, you don't say that to someone.' That's a challenge as well.

Similarly, Carol (Black woman, biomedical science) recalled her limited engagement with a lecturer who 'had given me zero for something that I'd actually done correct, so I emailed her to complain about that and she never replied'. Carol did not pursue the matter because 'I didn't want to escalate the issue … [and] I kind of don't want to be the one to cause trouble, so I guess that's why I kind of just left it'. Here, her reluctance reflects a fear of being labelled, and perhaps stereotyped, as troublesome, even when the act against her was unjust. For Black students such as Carol, these instances are often racialised, with negative consequences for well-being, attainment, and even safety. Cecilia (Black woman, pharmacy) described the harm that is caused by racial stereotypes, particularly for Black women like herself (Crenshaw, 1989), who are particularly underrepresented in STEM disciplines. She said:

> It's just sad. You take into account, firstly, matters like Black Lives Matter. And for some people, it's kind of a performative stunt to just be like, 'Oh yeah, Black Lives Matter'. And then next thing you know, they're back to their normal lives. But for some people, it's a daily struggle. … Narratives that are shaped by media or narratives that are perpetuated by certain groups of individuals, like the 'angry black woman', they are very harmful because at the end of the day, you are having to make yourself kind of inferior at hands of other people.

Students sometimes spoke of their 'incompatibility' with the popular, dominant student lifestyle and culture in the UK, which typically involves alcohol. Whilst not a concern specific to racially minoritised students in STEM, it is certainly a prominent issue that can exclude students and contribute to unwelcoming university environments across academic and non-academic contexts (see also Voice, Purdy, Labrosse & Heath, Chapter 3 in this volume). Many of our students said they avoided societies or activities, as the popular drinking culture does not match their cultural or religious values and principles. Thus, very few students in our study were current or active members of university clubs or societies, thereby increasing their sense of exclusion and isolation, which can affect their overall sense of belonging in STEM higher education.

As Ying (East Asian woman, pharmacy) said, 'Most of them, they like to go clubbing … [but] the way we have our amusement time can be go to cinema, watch a movie, shopping, travel and karaoke.' Students who chose not to engage in the dominant, partying culture described feelings of isolation from and loneliness within the white majority who lived with them or nearby The problems include incidents such as disruptive social gatherings, and excessive noise during exam periods or at unsocial hours; these often result in confrontation, racial insults and alienation. More generally, our data suggests that student accommodation plays a role in building student belonging and the formation of friendships at university, especially for first-year campus students.

In short, the perpetuation of whiteness within university systems and cultures can create unwelcoming environments and affect the belonging of racially minoritised students in STEM. Therefore, it seems reasonable to suggest that, as a result of racial microaggression, racial stereotyping and dominant sociocultural norms, the university may be an unwelcoming, or even hostile, environment for students, including in STEM settings.

Social exclusion and marginalisation

In addition to unwelcoming learning environments, challenges of underrepresentation, social exclusion and marginalisation create barriers to belonging for racially minoritised students. Tasu (South Asian woman, biological science) was critical of the university for not trying harder to 'get everyone together', especially those from diverse and minoritised backgrounds.

According to Andri (East Asian woman, mathematics), it is common to find ethnic groupings in lecture halls and classrooms, with racially similar groups often in their own clusters. While students like Shu (East Asian man, pharmacy) admitted that it is just easier to surround himself with 'people like me', especially those who understand his culture and home language, Disha (South Asian woman, mathematics) and others confessed, 'I don't have white friends', and felt that her white peers 'don't want to be my friend because of my culture, maybe how I talk, maybe how I think'. Unfortunately, Disha's concerns were sometimes reflected in our interviews with White British students (see Wong, El Morally & Copsey-Blake, 2021).

Some students said they made concerted efforts to broaden their social networks, but there were still challenges of acceptance by the white majority. Ying (East Asian woman, pharmacy) said she even tried to 'adopt a British accent' and therefore assimilate her ethnic and linguistic identity to fit in. Others, such as Chang (East Asian woman, pharmacy), described feeling like an outcast on her degree programme. She said, 'I think a lot before I speak because I don't want to offend anyone. ... Because I know that I'm a foreigner to them … and I just feel like they are probably more comfortable with … their own people.'

A lack of 'people like me' can thus lead to feelings of isolation and loneliness in STEM higher education, which tends to be pathologised in mainstream public discourse (Davis & Ernst, 2019; see also Hyland, Chapter 2 in this volume). The worry is that white students and staff are not able to recognise or empathise with the struggles and inequalities experienced by racially minoritised people. This has implications for underrepresented students in STEM: a lack of understanding about racism amongst students and staff can trigger feelings of self-doubt and confusion, especially in racially minoritised students, through fear of invalidation or retribution, or of denial and rejection from the white majority (Davis & Ernst, 2019). For example, Sachini (South Asian woman, biological science) said:

> Any time I walk in a room, I sort of try and not make direct contact with anyone. I don't know if they automatically just look at me because I look different, or whether you would automatically sort of look at anyone who would walk in a room.

Students also raised concerns that the teaching and learning in their degrees are rather homogeneous in terms of student and staff composition. Chang (East Asian woman, psychology) said that the limited visibilities of ethnically diverse peers and lecturers can be 'demoralising', as her cohort is predominantly White British. Furthermore, Tenner (Black man, biological science) felt that the lack of Black students in his course was unsettling, especially because of his fears of being stereotyped as the 'Black, ignorant [or] aggressive' man. Kevin's (Black man, biomedical science) awareness of racial stereotyping was shared by others, as mentioned earlier, and is likely to shape the belonging of minority ethnic, especially Black, students at university.

Relatedly, Alisha (East Asian woman, biomedical science) said, 'There are too many white students', while Chetachi (Black man, pharmacy) stressed, 'I barely see any Black staff', and explained that the lack of minority ethnic staff means fewer potential role models; this is important for students because 'you sort of identify with people who look more like you, because like, oh, they've made it, so you can make it'. Therefore, for students like Chetachi, the underrepresentation of Black people on the academic staff and the lack of role models can negatively affect their sense of belonging in STEM higher education.

Students also raised concerns about notions of coloniality and a lack of diverse perspectives within their STEM disciplines. For example, Kevin (Black man, biomedical science) expressed his discomfort about the continued exploitation of people in Africa, and the absence of global histories in scientific scholarship, contributing to the marginalisation of Black African students in STEM. He explained:

> People from … African backgrounds aren't reflected enough in research. … A lot of the Western countries kind of go into African

> countries and use people as [subjects of research]. … I think that's the case with a lot of things really. I think you can generalise it to … how, especially Britain got its power. … We're not taught that it took advantage of people from other countries. We need to be taught about that ... to a wider extent, … the history of science … and empire. We're just taught that this person discovered this.

Similarly, Lutah (South Asian man, pharmacy) reflected that visibility was important on the STEM curriculum, as 'where you're from is where you relate to'. He continued, 'It's like if someone talked about your house or your home. … If it's positive, you'll feel better. But, if it's negative, you'll feel really bad.' However, Disha (South Asian woman, mathematics) took an uncritical and value-free view of the STEM curriculum, and expressed her disinterest in diversity as, 'There's no pictures [in mathematics]. The books, they're just … just mathematicians.' Mawiya (Middle Eastern woman, mathematics) similarly expressed a positivist and objective mindset, and did not 'see how you can be diverse with maths. … It's just numbers … just theory.'

Therefore, social exclusion and marginalisation, including underrepresentation amongst student and staff populations, and an absence of critical and diverse perspectives on the STEM curriculum, can damage the belonging of racially minoritised students in STEM higher education. As we explain next, our findings also unveil the unique challenges associated with decolonising the STEM curriculum and countering objective approaches and ethnocentric assumptions about scientific knowledge in UK higher education.

Discussion and conclusion

The evidence is growing on racial inequalities as experienced by students from minoritised ethnic backgrounds in UK higher education, notably in their degree outcomes. In this chapter, we have focused on student belonging, our emphasis being on the racialised aspects of students' experiences across university settings. Because of the nuances and shared underpinnings of racial experiences, there were occasional overlaps between our broad themes of *unwelcoming environments*, *social exclusion* and *marginalisation*. We recognise the fluidity and temporality of these social phenomena and experiences, as unwelcoming environments may lead to, or potentially worsen, social exclusion and marginalisation. Moreover, some racially minoritised students feel demoralised, isolated, lonely or ostracised because they are underrepresented in STEM higher education.

A lack of 'people like me', in both student and staff bodies, can exacerbate marginalisation and the perpetuation of whiteness in university settings, which in turn contribute to unwelcoming environments. We suggest that these barriers are a result of institutional racism, which is often overlooked in the existing scholarship on student belonging (Ahn & Davis, 2020). As discussed below, our findings are interpreted through the lens of CRT to contextualise the lived experiences of minority ethnic students. Here, we discuss implications for the widening participation agenda in the UK and make recommendations for policy and practice.

Racism and racial inequality in higher education often manifest as racial microaggression, racial stereotypes and social exclusion. Although racial incidents are complex and intersectional (Crenshaw, 1989; Gillborn, 2018), all instances of racism contribute to an unwelcoming environment (Ong et al., 2018). To rehearse a well-worn argument, more work is needed to eradicate racism (Bhopal, 2018). Staff and students must be aware and conscious of how existing practices can reinforce a racist climate for underrepresented groups, and this awareness and consciousness should be actively enforced and consistently reiterated in policy.

We recommend that awareness of racism and racist discourses is raised within higher education institutions, to ensure that reports of racism are heard and taken seriously, perpetrators are held to account, and those subjected to racism have access to appropriate support and care (Davis & Ernst, 2019). It is also important that universities encourage and platform collective resistance to racism and racial inequality, and do not restrict freedom of expression amongst racially minoritised students. Increased visibility of these issues would bring closer an environment in which racially minoritised students feel 'seen' and 'heard', not silenced and invisible (Wong, Copsey-Blake & El Morally, 2022).

Consistently with student-led campaigns and events to decolonise university curricula and improve minority ethnic representation on the academic staff (Peters, 2015), we also suggest that universities fully commit to the decolonisation agenda and encourage wider institutional discussion about what makes 'good' teaching, and how better to take into account the vast array of knowledges, experiences and talents of those whose ethnicities and backgrounds are marginalised (UCL, 2020). To support the decolonisation agenda in STEM higher education, we recommend that assumptions that Western scientific knowledge is universal, objective or value-free are challenged, and diverse perspectives and critical dialogue about the global implications and histories of STEM are platformed and encouraged. We believe these steps will facilitate a greater sense of belonging for racially minoritised students in STEM.

Many first-generation and underrepresented students struggle to align themselves with the university culture or expectations (e.g., Ulriksen et al., 2017; Wong, 2018). Another noteworthy finding is the experience of Carol, who felt wronged by her tutor but refrained from seeking further details after her initial email was seemingly ignored. Whilst it is unknown whether the tutor consciously decided not to reply or it was a genuine oversight, Carol's reluctance to email again because of her fear of being seen as a troublemaker is telling, as she is conscious of how 'people like me' – a Black woman – can be negatively stereotyped (Ong, 2005). This fear was shared by Tenner, who was similarly afraid of being labelled as a 'Black, ignorant [or] aggressive man'. Consistently with CRT literature, racism is fluid and can change and adapt to different conditions and contexts (Gillborn, 2018). According to our understanding of racial and ethnic identity, Carol's sense of self as a Black university student appears to be under threat, as she thinks she must manage and navigate what she can and cannot do or say, in order to continue her STEM degree.

Whilst we are careful not to encourage messages of token diversity or interest convergence (Bell, 1980), a more inclusive institutional culture is likely to draw greater attention to the need to improve representation in the academic workforce and increase the number of visible role models. For example, a STEM 'wall of fame' could be presented across hallways, billboards and websites, along with stories of alumni and their pathways, with particular consideration and representations of minoritised ethnic groups and their contributions to STEM.

More generally, because of the renowned student nightlife, typically infused with alcohol, racially minoritised students appear less engaged with university clubs, societies and activities (including those which are STEM-specific). Perhaps these organised (social) events do not reflect the interest of students from minoritised ethnic backgrounds; if that is the case, concerted effort is required to broaden the range of student interest groups (Miles & Benn, 2016). Of course, we can easily say that racially minoritised students could take an active role in creating societies that are relevant to them, and some will have, but it is equally important for universities and their student unions to ensure that the university environment caters for diverse students.

Additionally, we recommend that staff take a more active role in encouraging students to engage with university support provision, including the well-being service and the process for dealing with extenuating-circumstances applications. We further suggest that universities actively encourage and create a safer and more robust reporting system to encourage students to come forward. Such systems assist students to develop a sense of entitlement over their right not to be subjugated or victimised, and create an institutional culture that is based on mutual respect and recognition of diversity. This culture can be substantiated by institutional efforts that make expectations of students more transparent and explicit (Wong & Chiu, 2021), and reduce mismatch in expectations across and within STEM disciplines (Wong, Chiu et al., 2023).

In sum, this chapter has explored the barriers to belonging for racially minoritised undergraduate students across STEM disciplines. Consistently with CRT commentaries that assert that racism is embedded and ingrained in societal structures as a product of social thought and colonial imagination, our findings reflect the institutionalisation of racism and racial inequalities in higher education, as illustrated by our students across multiple university settings and STEM contexts. We conclude that, in order to reimagine the university as a place where belonging can be experienced by all students, institutions must commit to purposeful and meaningful change across departmental levels and contexts, as part of a broader, sustained and collective effort to eradicate racism and racial inequalities in higher education.

References

Advance HE (2020). Equality in higher education: Students statistical report 2020. Advance HE. https://www.advance-he.ac.uk/knowledge-hub/equality-higher-education-statistical-report-2020. Accessed 20 December 2023.

Ahn, M. Y. & Davis, H. H. (2020). Four domains of students' sense of belonging to university. *Studies in Higher Education*, 45(3), 622–34. https://doi.org/10.1080/03075079.2018.1564902.

Arday, J. & Mirza, H. S. (eds) (2018). *Dismantling Race in Higher Education: Racism, whiteness and decolonising the academy*. Cham: Palgrave Macmillan.

Bell, D. A. (1980). Brown v. Board of Education and the Interest–Convergence Dilemma. *Harvard Law Review*, 93(3), 518–33. https://doi.org/10.2307/1340546.

Bhambra, G. K., Gebrial, D. & Nişancioğlu, K. (2018). Introduction: Decolonising the university? In G. K. Bhambra, D. Gebrial & K. Nişancioğlu (eds), *Decolonising the University*, 1–15. London: Pluto Press.

Bhopal, K. (2018). *White Privilege: The myth of a post-racial society*. Bristol: Policy Press.

Bunce, L., King, N., Saran, S. & Talib, N. (2021). Experiences of black and minority ethnic (BME) students in higher education: Applying self-determination theory to understand the BME attainment gap. *Studies in Higher Education*, 46(3), 534–47. https://doi.org/10.1080/03075079.2019.1643305.

Burr, V. (2003). *Social Constructionism*, 2nd edn. Hove: Routledge.

Corbin, J. M. & Strauss, A. L. (2014). *Basics of Qualitative Research: Techniques and procedures for developing grounded theory*, 4th edn. Thousand Oaks, CA: Sage.

Crenshaw, K. W. (1989). Demarginalizing the intersection of race and sex: A Black feminist critique of antidiscrimination doctrine, feminist theory and antiracist politics. *University of Chicago Legal Forum*, 1989, art. no. 8. https://chicagounbound.uchicago.edu/uclf/vol1989/iss1/8. Accessed 20 December 2023.

Crenshaw, K. W., Gotanda, N., Peller, G. & Thomas, K. (1995). Introduction. In K. Crenshaw, N. Gotanda, G. Peller & K. Thomas (eds), *Critical Race Theory: The key writings that formed the movement*, pp. xiii–xxxii. New York: New Press.

Davis, A. M. & Ernst, R. (2019). Racial gaslighting. *Politics, Groups, and Identities*, 7(4), 761–74. https://doi.org/10.1080/21565503.2017.1403934.

Elias, P., Jones, P. & McWhinnie, S. (2006). Representation of ethnic groups in chemistry and physics: A report prepared for the Royal Society of Chemistry and the Institute of Physics. London: Royal Society of Chemistry/Institute of Physics.

Equality and Human Rights Commission (2019). *Tackling Racial Harassment: Universities challenged*. [London]: Equality and Human Rights Commission.

Ghosh, P. (2022). Royal Society of Chemistry report says racism 'pervasive'. BBC News, 16 March. https://www.bbc.co.uk/news/science-environment-60708712. Accessed 21 March 2024.

Gillborn, D. (2018). Heads I win, tails you lose: Anti-black racism as fluid, relentless, individual and systemic. *Peabody Journal of Education*, 93(1), 66–77. https://doi.org/10.1080/0161956X.2017.1403178.

Graham, S., Kogachi, K. & Morales-Chicas, J. (2022). Do I fit in: Race/ethnicity and feelings of belonging in school. *Educational Psychology Review*, 34, 2015–42. https://doi.org/10.1007/s10648-022-09709-x.

Gravett, K. & Ajjawi, R. (2022). Belonging as situated practice. *Studies in Higher Education*, 47(7), 1386–96. https://doi.org/10.1080/03075079.2021.1894118.

Greaves, R., Kelestyn, B. Blackburn, R. A. R. & Kitson, R. R. A. (2022). The Black student experience: Comparing STEM undergraduate student experiences at higher education institutions of varying student demographic *Journal of Chemical Education*, 99(1), 56–70. https://doi.org/10.1021/acs.jchemed.1c00402.

Harris, J. C. (2017). Multiracial college students' experiences with multiracial microaggressions. *Race Ethnicity and Education*, 20(4), 429–45. https://doi.org/10.1080/13613324.2016.1248836.

HESA (2022). Higher education staff statistics: UK, 2020/21. Higher Education Statistics Agency, Cheltenham. https://www.hesa.ac.uk/news/01-02-2022/sb261-higher-education-staff-statistics. Accessed 20 December 2023.

Inyang, D. & Wright, J. (2022). Lived experiences of black women pursuing STEM in UK higher education. *The Biochemist*, 44(6), 18–24. https://doi.org/10.1042/bio_2022_134.

Jahi, J. (2014). Why isn't my professor black? https://blogs.ucl.ac.uk/events/2014/03/21/whyisntmyprofessorblack/. Accessed 21 March 2024.

Jeyasingham, D. & Morton, J. (2019). How is 'racism' understood in literature about black and minority ethnic social work students in Britain? A conceptual review. *Social Work Education*, 38(5), 563–75. https://doi.org/10.1080/02615479.2019.1584176.

Keller, E. F. (1992). *Secrets of Life, Secrets of Death: Essays on language, science and culture*. London: Routledge.

McClain, O. L. (2014). Negotiating identity: A look at the educational experiences of Black undergraduates in STEM disciplines. *Peabody Journal of Education*, 89(3), 380–92. https://doi.org/10.1080/0161956X.2014.913451.

Miles, C. & Benn, T. (2016). A case study on the experiences of university-based Muslim women in physical activity during their studies at one UK higher education institution. *Sport, Education and Society*, 21(5), 723–40. https://doi.org/10.1080/13573322.2014.942623.

Murray, Ó. M., Chiu, Y.-L. T., Wong, B. & Horsburgh, J. (2022). Deindividualising imposter syndrome: Imposter work among marginalised STEMM undergraduates in the UK. *Sociology*, 57(4), 749–66. https://doi.org/10.1177/00380385221117380.

Ong, M. (2005). Body projects of young women of color in physics: Intersections of gender, race, and science. *Social Problems*, 52(4), 593–617. https://doi.org/10.1525/sp.2005.52.4.593.

Ong, M., Smith, J. M. & Ko, L. T. (2018). Counterspaces for women of color in STEM higher education: Marginal and central spaces for persistence and success. *Journal of Research in Science Teaching*, 55(2), 206–45. https://doi.org/10.1002/tea.21417.

Peters, M. A. (2015). Why is my curriculum white? *Educational Philosophy and Theory*, 47(7), 641–6. https://doi.org/10.1080/00131857.2015.1037227.

Read, B., Archer, L. & Leathwood, C. (2003). Challenging cultures? Student conceptions of 'belonging' and 'isolation' at a post-1992 university. *Studies in Higher Education*, 28(3), 261–77. https//doi.org/10.1080/03075070309290.

Royal Society of Chemistry (2022). Missing elements: Racial and ethnic inequalities in the chemical sciences. https://www.rsc.org/globalassets/22-new-perspectives/talent/racial-and-ethnic-inequalities-in-the-chemical-sciences/missing-elements-report.pdf. Accessed 20 December 2023.
Schucan Bird, K. & Pitman, L. (2020). How diverse is your reading list? Exploring issues of representation and decolonisation in the UK. *Higher Education*, 79, 903–20. https://doi.org/10.1007/s10734-019-00446-9.
Singh, G. (2009). Black and minority ethnic (BME) students' participation in higher education: Improving retention and success. A synthesis of research evidence. Higher Education Academy.
Smith, L. T. (2021). *Decolonizing methodologies: Research and indigenous peoples*, 3rd edn. New York: Zed Books.
Solórzano, D. G. (1998). Critical race theory, race and gender microaggressions, and the experience of Chicana and Chicano scholars. *International Journal of Qualitative Studies in Education*, 11(1), 121–36. https://doi.org/10.1080/095183998236926.
UCL (2020). BAME Awarding Gap Project: Staff toolkit 2020. University College London. https://www.ucl.ac.uk/teaching-learning/sites/teaching-learning/files/bame_awarding_gap_toolkit_2020.pdf. Accessed 20 December 2023.
Ulriksen, L., Madsen, L. M. & Holmegaard, H. (2017). The first-year experience of non-traditional students in Danish science and engineering university programmes. *European Educational Research Journal*, 16(1), 45–61. https://doi.org/10.1177/1474904116678628.
Universities UK/National Union of Students (2019). *Black, Asian and Minority Ethnic Student Attainment at UK universities: #Closingthegap*. London: Universities UK.
Wong, B. (2018). By chance or by plan? The academic success of nontraditional students in higher education. *AERA Open*, 4(2), 1–14. https://doi.org/10.1177/2332858418782195.
Wong, B. & Chiu, Y.-L. T. (2021). Exploring the concept of 'ideal' university student. *Studies in Higher Education*, 46(3), 497–508. https://doi.org/10.1080/03075079.2019.1643302.
Wong, B., Chiu, Y.-L. T., Murray, Ó. M., Horsburgh, J. & Copsey-Blake, M. (2023). 'Biology is easy, physics is hard': Student perceptions of the ideal and the typical student across STEM higher education. *International Studies in Sociology of Education*, 32(1), 118–39. https://doi.org/10.1080/09620214.2022.2122532.
Wong, B., Copsey-Blake, M. & El Morally, R. (2022). Silent or silenced? Minority ethnic students and the battle against racism. *Cambridge Journal of Education*, 52(5), 651–66. https://doi.org/10.1080/0305764X.2022.2047889.
Wong, B., El Morally, R. & Copsey-Blake, M. (2021). 'Fair and square': What do students think about the ethnicity degree awarding gap? *Journal of Further and Higher Education*, 45(8), 1147–61. https://doi.org/10.1080/0309877X.2021.1932773.
Wong, B., El Morally, R., Copsey-Blake, M., Highwood, E. & Singarayer, J. (2021). Is race still relevant? Student perceptions and experiences of racism in higher education. *Cambridge Journal of Education*, 51(3), 359–75. https://doi.org/10.1080/0305764X.2020.1831441.

9

Stereotypes and their influence on belonging in UK physics

Amy Smith

Introduction

Despite targeted interventions in recent decades, women remain underrepresented in physics in most countries of the world (J. Lewis et al., 2021). Within the UK, the focus of this chapter, physics has some of the largest gender and ethnicity gaps in the STEM subjects (Institute of Physics, 2019). Over the past 30 years, women have never made up more than 25 per cent of UK undergraduate physics students; of STEM subjects, only electronic and electrical engineering, and computer sciences, have a larger gender gap. This gap is accentuated in postgraduate (Institute of Physics, 2019) and academic staff levels (Institute of Physics, 2020). In addition, an analysis of physics papers published in the past 20 years found that only 17 per cent of all authors in physics are women (Holman et al., 2018).

In the UK, as in the US (American Physical Society, n.d.) and other Western countries, racially minoritised students are underrepresented in physics. In 2018/19, white students made up 83 per cent of UK physics undergraduates, in comparison to 74.4 per cent of all STEM undergraduates, and 75 per cent of all undergraduates. All non-white ethnicity groups apart from Chinese are underrepresented on UK physics courses, with extreme underrepresentation of Black British African and Caribbean people. This is despite the fact that people from ethnic minorities are well represented in other STEM disciplines (Institute of Physics, 2021). A study of higher education staff from 2011 to 2019 found that Black people were significantly underrepresented as staff members in physics, making up only one per cent of all physics staff, compared to 3 per cent in other academic disciplines and in the general population (Institute of Physics, 2022).

Socioeconomic status is not a protected characteristic and therefore is not measured uniformly across disciplines. However, measures such as parents' highest level of qualification can be used as a proxy. The proportion of physics students whose parents are in higher managerial and professional occupations is higher than for all other subjects, including other STEM subjects (Institute of Physics, 2021). A third of undergraduate physics students in 2018/19 identified as being from this background. In the same year, the percentage of physics students from the least advantaged group, with family backgrounds in routine occupations, was only 4 per cent, and so lower than in most other STEM subjects and significantly lower than the degree average of 8 per cent. Additionally, in 2022 the Institute of Physics (IOP) reported that its member base included a disproportionate number whose parents had a first degree or higher than the general population (IOP, 2022).

Similar trends are seen in other European countries, even where the proportion of women studying undergraduate physics is high. In Finland, for example, 50 per cent of physics degree entrants, but only 25 per cent of physics graduates, are women. Here, many women enter the course as preparation for medicine or other allied courses (Miikkulainen et al., 2019). Even in Serbia, where 50 per cent of physics graduates are women, studies show that positions held beyond university show a significant gender imbalance. Most women physics graduates become primary or secondary teachers; few go on to hold positions in which scientific or educational policy is made (Stojanović et al., 2019). Overall, the prospects beyond undergraduate degrees are divided. An Elsevier report on gender in the global research landscape found that women comprise approximately 25 per cent of researchers in physics and astronomy within the EU-28 nations (Elsevier, 2017). In the US (Porter & Ivie, 2019), physics undergraduate courses have the lowest representation of women across the sciences, and women make up 21 per cent of bachelor's graduates, 20 per cent of PhD holders and 10 per cent of full professor positions in the field.

In non-Western contexts the gender picture looks somewhat different in terms of uptake. Many Muslim-majority countries, for example, have far higher levels of participation from women; in Iran women make up 60 per cent of BSc and MSc students, 47 per cent of PhD students and 18 per cent of faculty members (Iraji Zad et al., 2015). Despite these higher levels of participation at early stages, progression to professorships and other higher levels of education, teaching and research remains small. Globally the picture is clear: physics remains a subject which a disproportionate number of men study and in which they disproportionately progress. In Western contexts physics also shows overrepresention by white students and those from more privileged backgrounds, even in comparison to other STEM subjects, and despite interventions aimed at increasing representation. It is for this reason that physics is an interesting case to study.

Belonging and stereotypes

As discussed by Kandiko Howson and Kingsbury in Chapter 1 of this book, sense of belonging is a relevant theoretical perspective for understanding the current and persistent lack of diversity within STEM. Sense of belonging has been defined in many ways, but it often includes aspects of group membership, relatedness to others, and perceived feelings of support, acceptance and identification (Osterman, 2002). Focusing on student belonging, Ahn and Davis (2020) define four independent domains: academic, social, surroundings and personal space. These domains of belonging cover the situational and relational aspects of belonging, in which belonging is interpreted as a link between an individual and society. When the term is used with this broad meaning, sense of belonging has been found to affect students' motivation, achievement and well-being (Freeman et al., 2007; Kuh et al., 2011).

Within STEM, sense of belonging has been used to explore the decisions of women and ethnic minority groups to study (Rainey et al., 2018), and persist (Good et al., 2012), in STEM fields. Both women and ethnic minority students have been found to exhibit a lower sense of belonging than their male and white peers. These groups are also more likely to experience 'belonging uncertainty': 'members of socially stigmatized groups are more uncertain of the quality of their social bonds and thus more sensitive to issues of social belonging' (Walton & Cohen, 2007, p. 82).

The consistent lack of diversity within physics has brought research on sense of belonging to the forefront of physics education research (PER).[1] Some researchers have attempted to understand how discipline sense of belonging differs from other levels of belonging, such as institutional or class belonging. Drawing upon Walton and Cohen's (2007) sense-of-social-fit scale, Lewis et al. (2017, p. 420) define sense of belonging as 'the subjective feeling of fitting in and being included as a valued and legitimate member in a particular setting', in this case physics undergraduate courses. In their study, K. L. Lewis et al. found that sense of belonging is a dominant factor in continuation rates for undergraduate physics students, even when constructs such as self-efficacy and exam performance are controlled for. The link between belonging and continuation was found to be particularly strong for female students, who already exhibit a lower sense of belonging to physics (Stout et al., 2013).

Elsewhere, Hazari, Sadler & Sonnert (2013) found significant gender and ethnicity gaps in physics students' academic belonging, larger than in that of both biology and chemistry students. Multiple studies have examined the experiences of women of colour in physics through an intersectionality lens (Lewis et al., 2016; Ong, 2005; Trujillo & Tanner, 2014; see also Al Arefi, Chapter 10 in this volume). These studies show how multiple ways of not belonging can be experienced for those in more than one underrepresented group. There is evidence that sense of belonging is a stronger mediator for students later in their degree course (Hazari, Chari et al., 2020; Lewis et al., 2017), which implies that sense of belonging becomes more important as students interact more with their physics community.

In the original belonging hypothesis, Baumeister and Leary (1995) described how belongingness was built on frequent and meaningful interactions or diminished by their absence. Within physics specifically, studies have expanded the list of factors which impact belonging. These factors include stereotypes and stereotype threat (Deiglmayr et al., 2019; Ladewig et al., 2020; Stout et al., 2013), role models (Lewis et al., 2016) and interventions (Master & Meltzoff, 2020). Stereotypes are widely held oversimplified views about a group or class of people; stereotypes can apply to demographic groups. They include stereotypes about gender – 'women are bad at maths' – and race – 'Asian students are good at maths' – and about physics: 'physicists are highly intelligent'. These stereotypes can contribute to stereotype threat, defined by Steele & Aronson (1995, p. 797) as 'being at risk of confirming, as self-characteristic, a negative stereotype about one's group'. Stereotypes related to women's perceived lesser ability in physics (Devlin & Allegretti, 2022) have been shown to affect women's performance (Marchand & Taasoobshirazi, 2013; Maries, Karim & Singh, 2018; Maries & Singh, 2015) in physics, their identity development as a physicist (Smith et al., 2015) and subsequent career choice (Deemer et al., 2014).

More broadly, studies have shown that scientists are associated with more 'negative traits' than their humanities peers (Hannover & Kessels, 2002, 2004; Kessels et al., 2006; Nosek et al., 2002a; Nosek & Smyth, 2011; Steffens & Jelenec, 2011; Taconis & Kessels, 2009).

For example, scientists are associated with being less attractive, more socially awkward, less creative, and less emotionally apt than non-scientists; conversely scientists are associated with a higher intelligence and motivation than non-science contemporaries. Two recent studies (Bruun et al., 2018; Wong et al., 2023) have sought to identify how stereotypes about physics differed from those about other sciences. They both found that – in comparison to biologists – physicists are perceived as significantly more competent, and physics as being more difficult, with greater requirements for innate brilliance and effort to succeed. Deiglmayr et al. (2019) found not only that brilliance was associated with more maths-intensive fields such as physics, but that higher beliefs in brilliance correlated with higher levels of belonging uncertainty, particularly amongst women. In Bruun's study, physicists were perceived as more tech-oriented and awkward, as jobs in physics offer fewer opportunities for working with and helping others. The Institute of Physics (2020) found similar stereotypes in a survey of young people, parents and carers in the UK. In addition, the IOP found that physicists were associated with maleness and whiteness.

In a review of sense of belonging studies in physics, Lewis et al. (2016, pp. 7–8) identified stereotypes as a significant factor in forming a sense of belonging. The article recommended the following measures to increase sense of belonging in underrepresented groups:

1. Identify and temper cues that perpetuate the 'geeky' scientist stereotype,
2. openly endorse effort and hard work over brilliance,
3. send messages that concerns about belonging are normal and fade with time,
4. consider the social context constructed in the classroom and
5. consider the broader social context students are a part of outside the classroom.

These recommendations highlight two large stereotype themes: nerdiness and intelligence. In the following sections, I use a case study of women physics graduates to explore how these two stereotypes impact sense of belonging. I explore ideas around negotiations, positioning and performance in physics and how, ultimately, achieving a sense of belonging is not always a positive thing (see also Murray et al., Chapter 4 in this volume).

Methodology

This chapter draws upon findings from a larger study on the life histories of women physics graduates and their interaction with physics leading up to their graduation from university. The aim of the overall study was to investigate the questions: what influences women to choose to study physics at university, and what are their experiences with physics from childhood to graduation? One focus group lasting 2.5 hours was conducted over Zoom with nine physics graduates from a research-intensive UK university. All participants were White British and identified as cis women. The participants have been given pseudonyms. The participants grew up in a wide spread of geographic areas of the UK. Apart from Sophie, all the women identified broadly as middle-class.

The participants had studied in the same cohort and so were familiar to each other before the study. This trust and rapport are important in the discussion of sensitive topics (Elmir et al., 2011; Ramos, 1989) or when in-depth probing is required (Spradley, 1979), as participants feel more comfortable offering interpretations and personal narrative than they would otherwise (Oakley & Roberts, 1981; Owton & Allen-Collinson, 2014). Furthermore, friends as participants create a sense of intimacy and mutual bonding (Glesne, 1989), which encourages a more 'dialogical' interaction (Smith et al., 2009; Simon, 2013). The existence of this interaction hastens the process of sharing (McConnell-Henry et al., 2009) and limits the effects of friendliness bias and social desirability bias (Yuan, 2014). If they are already friends, participants are more likely to challenge and question each other's opinions, thus providing a more varied and in-depth discussion.

The focus group was semi-structured and interactive, so that participants were free to ask each other questions and probe each other's responses. The group opened with a 'grand-tour question': why did you choose to study physics at university? This grand-tour question provides the participants with a starting point from which to structure an answer based on their own priorities and judgements of what they regard as significant (Spradley, 1979). Following this, probing questions were used to gain more information on the choice of studying physics; however, subsequent discussions about stereotypes and sense of belonging came up spontaneously.

The focus group was coded in a structured way, and through the iterative process of thematic analysis (Braun & Clarke, 2006) three main themes were identified to describe the data: science capital, stereotypes and sense of belonging. These themes were chosen to represent the data, but also to be in line with current literature. Of importance to this chapter are the latter two themes, which are discussed in the following sections with relevant literature. Quotations from the focus groups have been used as section titles to represent the stereotypes of masculinity and intelligence.

Masculinity

> I'm surprised you could have so many varied interests, especially as a girl who did physics.

When reflecting on their time as undergraduate students, the women referenced many of the physics stereotypes seen in both academic and wider literature. Physics was described as a 'hard' subject, studied predominantly by those who were 'socially awkward' and 'one-dimensional'. Throughout the conversation, the women made clear that physics was seen as something inherently associated with masculinity. Zoe described choosing physics as the 'unusual masculine choice' because it differed from that of so many of her female peers, whilst Hazel described how:

> Choosing physics felt a bit like being a robot. I felt like there was no, like, personality in it, or anything which wasn't just, like, really factual, like, nothing expressive. Do you know what I mean? Like all those kind of stereotypes you put along with science, which are, like, more male things.

The association between science and masculinity has long been established through the work of feminist and social constructivist researchers such as Harding (1991, 1998), Haraway (2013) and Walkerdine (1988), who have critiqued the persistence of a masculine-centric science discourse. More recently, Francis et al. (2017) explored the ways in which masculine physics discourse is constructed and summarised five overarching themes: (1) the gender stereotyping of subjects, (2) the positioning of men and women as different and therefore having different subject interests, (3) the positioning of femininity as opposite to (masculine) male work, (4) the positioning of femininity as superficial and (5) the positioning of cleverness as masculine and physics as a difficult subject. The quote from Hazel above encapsulates how the positioning of physics as objective and the doing of physics as emotionally detached naturally opposes traditional enactments of femininity.

A similar finding by Daane et al. (2017, p. 329) was that undergraduate physics students saw physics as objective, based on facts and not depending 'on emotions or personal feelings'. Harding has argued that the construction of physics as objective and neutral expresses 'distinctive cultural features, not the absence of all culture' (Harding, 1998, p. 61). In her seminal study of high energy physics groups, anthropologist Sharon Traweek (2009, p. 162) similarly described physics as having 'a culture of extreme objectivity: a culture of no culture, which longs passionately for a world without loose ends, without temperament, gender, nationalism, or other sources of disorder – for a world outside human space and time'. In this way physics is positioned in opposition to the perspectives of 'othered' groups such as women or ethnic minority students. Prescod-Weinstein (2020) argues that this objectivity denies these groups the epistemic ability to be 'knowers' of physics, and thereby to belong fully to the field. Traweek suggests that, to achieve belonging, physicists are encouraged to omit aspects of their identity. In the study reported here Hazel acknowledges this by emphasising her studying of physics as 'not *completely* losing my personality'.

This negotiated position of women in physics has been repeatedly found in research (Gonsalves, 2014; Gonsalves et al., 2016) and has been linked to bids for belonging to the field (Walker, 2001). The best summary I have found of this negotiation is in Tsai's study of women in physics in Malaysia (Tsai, 2004, p. 114). Tsai stated that there exist conflicting discourses of 'normal physicist' and 'ordinary woman' which limit what it means to be a woman physicist and in which women must choose which parts of themselves to keep and which to leave out to be recognised as a physicist. This was evidenced in our study in the ways in which the women would hide or conceal aspects of their identity. One way in which the women suppressed their femininity was through their clothing choices: 'I feel really self-conscious, especially when it's all these, like, old men obviously you get in a physics department. And I'm like, is this too, like, sexy?' (Zoe).

Elsewhere, studies have found that women – both students and staff – frequently alter what they wear to fit in more with physics (Gonsalves, 2014; Hyater-Adams et al., 2018; Ong, 2005). In one sense this is from a worry of how others would react: as Zoe puts it. 'Am I being too provocative?' One study (Barthelemy et al., 2016) found that women downplayed their attractiveness because of concerns about being interacted with out of sexual, rather than scientific, interest. Others dressed down to fit in with those around them – majority men. For the women, even wearing a skirt felt like dressing up too much, causing them to 'stick out'. In her study of women physics PhD students, Gonsalves (2014, p. 513) describes how discourse about hard-working and dedicated physicists 'suggests that excessive care over how one dresses indicated a lack of commitment to their study'. While the women did not mention this particular concern, they did say that to fit in you would almost need to look as though you have 'not made an effort'.

It is worth noting that the depictions of femininity described by the women and cited in the literature are Western depictions of femininity. Elsewhere in the world different depictions of what is means to be feminine allow for different ways to be identified as a physicist. One study of women physicists from Muslim-majority countries (Moshfeghyeganeh & Hazari, 2021) theorised that the recruitment of large numbers of women into the field – in comparison to Western contexts – is partly due to greater overlaps between physics identities and representations of femininity. For example, the study argues, in the West, cultural expectations of women position them as more social, more communal and having a more outward projection of femininity through physical attractiveness, traits which almost entirely contradict typical depictions of physicists as unsociable, awkward and unattractive. In Muslim-majority countries, however, there is a cultural emphasis on modesty, and women are taught in single-sex schools, which makes incongruence with the classic physics identity less likely.

In addition to appearance, the women expressed belongingness uncertainty which was due to other aspects of personality and identity, particularly 'nerdiness'. Throughout their secondary and university education, the women echoed the stereotype of physics as something 'nerdy' or 'geeky'. However, unlike their agreement with the stereotype of physics as boring, which faded over time, the women continued to see physicists as nerdy throughout their degree and even into employment. The image of the 'nerdy' physicist has been explored elsewhere and been found to encompass traits of curiosity and dedication, but also lack of social skills (Johansson, 2020). Zoe labelled herself as a nerd when she recalled going to non-compulsory lectures on different subjects, while Olivia described finally finding 'dorks' like herself when she went to university, particularly in their shared social awkwardness:

> I just feel like as soon as you say physics as well, you've kind of got like a pass to be a bit weird and I feel like, it makes it better when you're a bit socially awkward. Like it's kind of, like, 'Oh, yeah, she does physics – that's why she's socially awkward, it's fine'. Like I feel like you get, like, a bit more of a free pass when you say it, so I quite like it.

For these women, undergraduate physics was a place where initially they felt they fitted in and formed a strong sense of belonging. Hazel described how university offered her the space to be 'actually really excited' about physics without the peer pressure to outwardly express a disdain for the subject. However, nerd identities can also conflict with traditional Western femininities, for example through dedication and the expectation to work long hours and forgo social commitments, something which is less achievable for women, who often have greater caring responsibilities and of whom sociability is more expected (Starr, 2018). This passion for physics is described by Johansson and Berge (2020) as a 'celebrated subject position', one which is most valued and recognised within the domain of physics.

The women in the study expressed gendered views of nerdiness in their description of peers who demonstrated this passion outwardly through extracurricular work and interest in the course beyond what was expected. Although Hazel had previously expressed excitement about discussing physics with her peers, she stated that men in her seminars would display confidence in using methods that were not covered in the syllabus, causing her to question her own belonging. In a similar example, Hazel, Sue and Zoe recalled learning coding for the first time in their physics course:

Hazel: I just remember when we started coding it, like, and there was so, so many boys who'd, like, done coding in their spare time. And they'd built their own programs. And that was like, that's so gendered. Like, there's no way I would have written my own computer program before I went to uni, like it wouldn't – it never crossed my mind at all. I didn't even know what it was.

Sue: Yeah, I was so shocked that people had done it. And I was like 'What??' It was just we were at a massive disadvantage. Yeah, like getting thrown in a swimming pool when everyone else knows how to swim.

Zoe: And you're like 'now do a race, now do a race and you've only got a week. You've only got a week and half and we're not going to give you any help. And people are going to test you on this in real life.' Like what??

The women acknowledged the celebrated position of a passionate nerdy physicist. However, they described being unable to easily identify in this way and acknowledged the negative repercussions of identifying in this way. Notably, the women discussed the conflict between the identities they embodied when at university and their 'home' identities. Olivia said it took 'a lot of my mental energy' to hide her 'nerdy' side when outside of physics. Other women expressed similar fears of being 'found out' in relation to their nerdiness or their nonconforming traits. More than one of the women recalled lying about studying physics:

> For some reason, I thought maths just sounded more normal than physics. For example, I worked in a café, and when I came back in the holidays, they thought I studied maths, and then sometimes Dad would come in and be like, oh, 'theoretical physics' and I'd be like 'Shut up Dad, get out Dad'. I didn't want them to think that I was some, like, massive nerd.

This conflict was also felt in relation to aspects of their identity that did not fit other pigeonholing views of physics linked to the nerd or geek stereotype. These related to liking video games, being inartistic and being a loner. Hazel ultimately described her revelation at meeting people in physics who were 'multifaceted': 'I'm surprised that like, you could have so many varied interests, especially as a girl who did physics.'

Enjoyment of physics-associated hobbies did not always enable the women to feel they belonged in physics. Zoe, who had previously commented on finding more acceptance in physics because of her interest in sci-fi, said, 'It's really upsetting. … There was no one that I have proper solidarity with, like, there is no one like me.' Both Zoe and Flo voiced their feeling that their interests and identity did not match those of other physicists, and that they therefore made them feel excluded. One of the most emotional moments of the focus group came when both participants voiced regrets about their choice of interests when younger. Both referenced video games as being an object of contempt, with Flo noting:

> I almost wish that I did like those things, because I would fit in so much more. I'd have fitted in more in physics. I'm a girl who does physics but doesn't really like any of the things around physics. It makes me stick out more. Because there's not anyone who actually has the same interests as me around me.

The belief that there are interests 'around physics' is what caused some of the women to relate strongly to physics and to their peers, and Flo and Zoe to feel alienated. Zoe echoed this frustration as she felt that she should play video games to fit in, but that if she did she would be 'wasting her time', as it was not a source of enjoyment. In Hasse's work on physics identity (2002, 2008), she distinguishes 'play' as a common theme within communities of physicists but notes that not all physicists – particularly women – are able to engage in this play or be in on the jokes. For the women, sense belonging to physics can only be achieved through forgoing aspects of their own identity.

Intelligence

> Now I've done physics, I've got proof that I'm clever.

In comparison to other sciences, physics is often seen as 'harder' and therefore requiring more intelligence (Bruun et al., 2018). In a recent study by Wong et al. (2023, p. 118), science undergraduates, including physics students, said that 'biology is easy; physics is hard'. A similar sentiment was echoed by Ruby: she stated that 'physics was hard … biology was a bit wishy-washy'. The intelligence required for physics is often described as a 'natural ability' or 'innate brilliance'. This discourse was seen frequently in the women's life histories, particularly when they recalled situations in which they were viewed as, and sometimes had been made to feel like, a genius. This sense of awe and respect mostly came from parents, who were quoted as using phrases such as 'Wow, it's so clever. I'll never understand it' by Flo, or 'Oh, it's so amazing. Where did you come from? How can you do this?' by Barbara. For some students, the discourse of brilliance was favoured and offered a sense of belonging. This was particularly true for Sophie:

> I used to love saying it and someone being like 'Wow, oh my god, you must really smart.' I'd be like 'What?'. I knew that for me, I didn't think I was. But I used to enjoy the fact that they had a weird view that it was this, like, magical thing on a pedestal and it was like 'Whoa, you do physics?'

For Sophie, who described herself as coming from a working-class background, this power may be seen as a representation of the social mobility she gained from studying physics. In a study of women physicists, Miller-Friedmann (2020) found social mobility to be a common theme in the narratives of working-class women, who described themselves as heroes for having persevered through the struggle of studying physics. For Flo and Gillian, however, the brilliance stereotype was a sign that they were 'different' from others, and communicating this made them a 'show-off'. Gillian, who also used the term 'showing off', said that people tended to view studying physics as something further removed from society than studying other subjects. Her reasoning for lying about studying physics at university was that she did not want to appear a 'weirdo' for having chosen it. She explained, 'There's people [at work] who aren't even going [to] uni.' Flo agreed, and said she felt that being open about studying physics would cause her to be excluded: 'They don't want to talk to you; people are just like, you can go away then.' Here, sense of belonging to physics is positioned as something that causes conflict: gaining belonging to the field may cause alienation in other aspects of life.

Overall, it was clear that the group were aware of the 'genius' stereotype and of the stereotype's effect on how others viewed them. Additionally, the interview revealed that the stereotype might have affected how members of the group viewed themselves. This was noticeable in the terminology they used, in particular the word 'clever'. Hazel recalled that peers at school were prevented from studying physics at A-level 'because they basically weren't clever enough. Like two people got asked to leave the physics class because [the teachers] were like "well we just don't think you're going to do very well".' In its definition of 'clever', the *Cambridge Advanced Learner's Dictionary* (Cambridge University Press, n.d.) uses the example 'Judy has never been very clever, but she tries hard', reiterating the contrast between natural ability and work ethic. The choice of the phrase 'weren't clever enough' therefore indicates that physics is viewed, even by the group, as something only the cleverest students, or 'geniuses', can study.

Another use of the word 'clever' was by participants about themselves. In the interview, Olivia stated how studying physics granted her 'validation' and 'proof' of being clever 'on paper'. That participants viewed themselves as 'clever' was seen multiple times throughout the interview, especially at the early stages of their study of physics, where it was clear that most participants felt that physics was an easy subject at GCSE stage, in comparison to other subjects. In contrast to succeeding by working hard, there was more of an emphasis on not trying hard but finding that the subject came to them naturally or that they 'didn't have to push too hard to be good at physics'. Alternatively, Ruby and Sue viewed physics as an extension of maths, and maths was the subject they were 'best at'.

Nearly all participants signified that finding the subject easy was a major reason why they continued the subject, to the extent that choosing physics appeared an almost obvious choice:

> I was coincidentally just interested in science because I was good at it. I guess? It wasn't an active 'Oh, I love science'. It was more I just happened to be good at it. (Ruby)
>
> I was just really good at physics. I was the best in my year, and I think being the best at something was this thing. (Sue)
>
> Especially in younger years it was easier, so you put in no effort and did really well. And that does just make you want to do it more, rather than other things which are just way harder. (Hazel)

There were other moments during the interview that showed that participants felt conflicted with the 'genius' stereotype. Sue dismissed the praise she received and chalked it up to other factors; although sharing that she was the best in her year, she quickly added, 'I don't know, I think it helped a lot that my year wasn't big. So, it wasn't much of an achievement.' The belittling of achievements is an example of imposter work; in attributing success to alternative reasons, it could be suggested, Sue, and others in the group, felt they did not belong to that stereotype of genius. Imposter work, as discussed by Murray et al. (2023), is the unevenly distributed emotional work that marginalised students often have to do to in response to exclusionary atmospheres, such as those of STEM courses. The women in this study almost unanimously described carrying out imposter work when studying physics at university. For some this manifested as comparisons with their peers; for example, Zoe said, 'I felt really, like, really sad and alone. I was like, everybody else is so smart.' For Flo, imposter feelings prevented her from continuing to study physics, even though she had 'always wanted to do a PhD'.

There was a perception by the women that this imposter work was gendered; whilst the women shared a mentality that they had experienced feelings of being an imposter, men in their cohort were described as all 'very confident'. The women said gender ability stereotypes in physics added pressure to perform well in order to represent other women in physics in a positive light. For example, for Flo:

> Sometimes in my tutorial I felt awful because I just remember being like I'm the only girl, I'm the only one who doesn't know the answers and I felt like I was letting my gender down, sometimes. So, it was

> like I actually hated them because I was like, not only am I just the stupidest one here, which you know, but I'm also the girl. And I was like how – like, who am I representing right now?

Murray et al. (2022) suggest that, to ease levels of imposter work, peer networks can be a powerful tool in helping students to share their anxieties and normalise difficult emotions. For Hazel, community was 'the most important thing' that 'helped [me] continue to do it and feel, like, at ease doing it':

> I feel like, like being at uni, like, we've probably all had it, when I first got that felt, like, really out of water, like quite intimidated, imposter syndrome, whatever. I think it's made such a massive difference having, like, a community of girls? Like basically you guys, to me feeling, like, really comfortable and confident and, like, able to say 'Yeah, I really enjoy this'. And like, it's almost like having role models, like you look at the people around you and you're like 'Oh well they're normal and cool, and they're still girls and they enjoy it and they're really good at it'.

Whilst other women in the study agreed, some felt they would have explicitly benefited from discussing feelings of belonging and imposter syndrome at an earlier stage. At the opening of this chapter, I discussed the work of Lewis et al. (2016, p. 7), who recommended that, to increase sense of belonging for underrepresented groups, we should 'send messages that concerns about belonging are normal and fade with time'. For the women in this study, the act of participating in the focus group enabled these concerns over belonging to be shared. At the end of the focus group, the following interaction occurred:

Sue: Imagine if we'd communicated this better.

Hazel: Yeah like we honestly should have got together in a room and been like 'We're all really struggling'.

Zoe: And then we'd all realise that everyone felt shit about it rather than being just like 'Oh my god, everyone else is fine and I'm really struggling'.

Discussion and conclusion

The study presented in this chapter adds to the argument of this book that sense of belonging is a complex area of study, and that forming a sense of belonging is not an inherently positive thing. Social and science-based stereotypes were prevalent in the narratives of women physics graduates and their stories of belonging. Above all, physics was described as a difficult subject studied predominantly by clever and nerdy individuals. When these stereotypes aligned with the women's own identity the stereotypes acted as a tool for gaining belonging. However, for the majority of women, the narrow stereotype and its associations with masculinity contributed to belonging uncertainty. In bids to achieve belonging, women negotiated aspects of their identity, for example by downplaying their femininity or lying about their degree choice. The women described having multiple conflicting identities, which often resulted in feelings of being an imposter. These findings echo the sentiment in the Introduction to this book: that belonging to a field is not always a positive thing, and achieving it can require more work on the part of minoritised groups. In the case of women in physics, achieving belonging can require significant identity work and be to the detriment of their own sense of self.

There are three main recommendations from this study. The first is to re-emphasise the need to broaden the stereotype of physics and physicists. Tempering the 'geeky' stereotype is important, as Lewis et al. (2016) recommended, and this can be done through more diverse representation and role models. However, addressing the 'intelligence' stereotype and its links to masculinity is arguably more pressing. There are many explanations for the 'hard' physics discourse and therefore many ways in which it can be deconstructed. One study suggests making 'invisible' cognitive processes – such as thinking during problem solving – more visible to students (Verostek et al., 2022). Others suggest that promoting a 'growth mindset' approach in teaching positively counteracts the natural-intelligence discourse often used within the sciences (Johansson, 2020). Educators should communicate and demonstrate the specific skills required to succeed in physics, and encourage students to believe that these can be gained over time.

This study is also a reminder of the value of discussion and language. Although the women had all been familiar to each other for many years before the study, they said they had never had the opportunity to discuss issues of belonging or identity. This chapter agrees with the recommendation by Francis et al. (2017, p. 171) that ample time should be provided for physics inequity to be discussed with students.

Where appropriate, teachers – who act as role models for students – can share their own experiences and stress that belonging uncertainty is a common experience. Also helpful is equipping students (and teachers) with a common language to discuss shared experiences. Social science language and concepts, such as stereotyping or imposter work, were used by women in this study, but other concepts such as discourse could be used more widely to aid in discussions on these topics.

Finally, whilst space for discussion is important, focusing solely on students' coping strategies risks reinforcing student deficit models; institutional efforts to deal with the root cause of imposter feelings within physics must be addressed. This can be challenging within STEM specifically, where equality, diversity and inclusion (EDI) work is often seen as an addition to the curriculum and to be competing for time (Fox et al., 2023). In interviews with white male physicists, Dancy and Hodari (2023) found that even those openly supportive of EDI work were complicit in maintaining power imbalances and inequity within physics, through ignorance. Improving sense of belonging not only requires time and space, but should start with those in power, to ensure that they are educated in the ways in which sense of belonging can be withheld from minoritised groups, for example by providing lecturers with microaggression awareness training. It is only through the education of and action by those who already 'belong' in physics that belonging will become accessible to all students.

Note

1 Analysis of topic trends in both major conference proceedings and journal papers shows that identity, community and culture are now the most prominent fields in PER (Yun, 2020; Odden et al., 2020).

References

Ahn, M. Y. & Davis, H. H. (2020). Four domains of students' sense of belonging to university. *Studies in Higher Education*, 45(3), 622–34. https://doi.org/10.1080/03075079.2018.1564902.

American Physical Society (n.d.). Physics degrees by race/ethnicity. https://www.aps.org/programs/education/statistics/degreesbyrace.cfm.

Barthelemy, R. S., McCormick, M. & Henderson, C. (2016). Gender discrimination in physics and astronomy: Graduate student experiences of sexism and gender microaggressions. *Physical Review Physics Education Research*, 12(2), art. no. 020119. https://doi.org/10.1103/PhysRevPhysEducRes.12.020119.

Baumeister, R. F. & Leary, M. R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin*, 117(3), 497–529. https://doi.org/10.1037/0033-2909.117.3.497.

Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. https://doi.org/10.1191/1478088706qp063oa.

Bruun, M., Willoughby, S. & Smith, J. L. (2018). Identifying the stereotypical who, what, and why of physics and biology. *Physical Review Physics Education Research*, 14(2), art. no. 020125. https://doi.org/10.1103/PhysRevPhysEducRes.14.020125.

Cambridge University Press (n.d.). 'Clever', in *Cambridge Advanced Learner's Dictionary*. Cambridge: Cambridge University Press. https://dictionary.cambridge.org/dictionary/english/clever. Accessed 21 December 2023.

Daane, A. R., Decker, S. R. & Sawtelle, V. (2017). Teaching about racial equity in introductory physics courses. *Physics Teacher*, 55(6), 328–33. https://doi.org/10.1119/1.4999724.

Dancy, M. & Hodari, A. K. (2023). How well-intentioned white male physicists maintain ignorance of inequity and justify inaction. *International Journal of STEM Education*, 10(45), 1–29. https://doi.org/10.1186/s40594-023-00433-8.

Deemer, E. D., Thoman, D. B., Chase, J. P. & Smith, J. L. (2014). Feeling the threat: Stereotype threat as a contextual barrier to women's science career choice intentions. *Journal of Career Development*, 41(2), 141–58. https://doi.org/10.1177/0894845313483003.

Deiglmayr, A., Stern, E. & Schubert, R. (2019). Beliefs in 'brilliance' and belonging uncertainty in male and female STEM students. *Frontiers in Psychology*, 10, art. no. 1114. https://doi.org/10.3389/fpsyg.2019.01114.

Devlin, H. & Allegretti, A. (2022). Girls shun physics A-level as they dislike hard maths, says social mobility head. *The Guardian*, 27 April. https://www.theguardian.com/education/2022/apr/27/girls-shun-physics-a-level-as-they-dislike-hard-maths-says-social-mobility-head. Accessed 21 December 2023.

Elmir, R., Schmied, V., Jackson, D. & Wilkes, L. (2011). Interviewing people about potentially sensitive topics. *Nurse Researcher*, 19(1), 12–16. https://doi.org/10.7748/nr2011.10.19.1.12.c8766.

Elsevier (2017). Gender in the global research landscape. https://assets.ctfassets.net/zlnfaxb2lcqx/57uxjkQA2aUQSpWayDUd5c/6653475e50db61cfb0f828e291c1e08a/Elsevier-gender-report-2017.pdf. Accessed 21 December 2023.

Fox, M. F. J., Kandiko Howson, C. & Kingsbury, M. (2023). Equity, diversity, and inclusion: Does social justice from the top trickle down? *Journal of Further and Higher Education*, 47(6), 850–61. https://doi.org/10.1080/0309877X.2023.2188178.

Francis, B., Archer, L., Moote, J., DeWitt, J., MacLeod, E. & Yeomans, L. (2017). The construction of physics as a quintessentially masculine subject: Young people's perceptions of gender issues in access to physics. *Sex Roles*, 76, 156–74. https://doi.org/10.1007/s11199-016-0669-z.

Freeman, T. M., Anderman, L. H. & Jensen, J. M. (2007). Sense of belonging in college freshmen at the classroom and campus levels. *Journal of Experimental Education*, 75(3), 203–20. https://doi.org/10.3200/JEXE.75.3.203-220.

Glesne, C. (1989). Rapport and friendship in ethnographic research. *International Journal of Qualitative Studies in Education*, 2(1), 45–54. https://doi.org/10.1080/0951839890020105.

Gonsalves, A. J. (2014). 'Physics and the girly girl – There is a contradiction somewhere': Doctoral students' positioning around discourses of gender and competence in physics. *Cultural Studies of Science Education*, 9, 503–21. https://doi.org/10.1007/s11422-012-9447-6.

Gonsalves, A. J., Danielsson, A. & Pettersson, H. (2016). Masculinities and experimental practices in physics: The view from three case studies. *Physical Review Physics Education Research*, 12(2), art. no. 020120. https://doi.org/10.1103/PhysRevPhysEducRes.12.020120.

Good, C., Rattan, A. & Dweck, C. S. (2012). Why do women opt out? Sense of belonging and women's representation in mathematics. *Journal of Personality and Social Psychology*, 102(4), 700–17. https://doi.org/10.1037/a0026659.

Hannover, B. & Kessels, U. (2002). Challenge the science-stereotype: Der Einfluss von Technik-Freizeitkursen auf das Naturwissenschaften-Stereotyp von Schülerinnen und Schülern. In M. Prenzel & J. Doll, *Bildungsqualität von Schule: Schulische und ausserschulische Bedingungen mathematischer, naturwissenschaftlicher und* überfachlicher Kompetenzen, pp. 341–58. Weinheim: Beltz.

Hannover, B. & Kessels, U. (2004). Self-to-prototype matching as a strategy for making academic choices: Why high school students do not like math and science. *Learning and Instruction*, 14(1), 51–67. https://doi.org/10.1016/j.learninstruc.2003.10.002.

Haraway, D. (2013). *Simians, Cyborgs, and Women: The reinvention of nature*. New York: Routledge.

Harding, S. (1991). *Whose Science? Whose Knowledge? Thinking from women's lives*. Ithaca, NY: Cornell University Press.

Harding, S. (1998). *Is Science Multicultural? Postcolonialisms, feminisms, and epistemologies*. Bloomington: Indiana University Press.

Hasse, C. (2002). Gender diversity in play with physics: The problem of premises for participation in activities. *Mind, Culture, and Activity*, 9(4), 250–69. https://doi.org/10.1207/S15327884MCA0904_02.

Hasse, C. (2008). Learning and transition in a culture of playful physicists. *European Journal of Psychology of Education*, 23(2), art. no. 149. https://doi.org/10.1007/BF03172742.

Hazari, Z., Chari, D., Potvin, G. & Brewe, E. (2020). The context dependence of physics identity: Examining the role of performance/competence, recognition, interest, and sense of belonging for lower and upper female physics undergraduates. *Journal of Research in Science Teaching*, 57(10), 1583–1607. https://doi.org/10.1002/tea.21644.

Hazari, Z., Sadler, P. M. & Sonnert, G. (2013). The science identity of college students: Exploring the intersection of gender, race, and ethnicity. *Journal of College Science Teaching*, 42(5), 82–91.

Holman, L., Stuart-Fox, D. & Hauser, C. E. (2018). The gender gap in science: How long until women are equally represented? *PLoS Biology*, 16(4), e2004956. https://doi.org/10.1371/journal.pbio.2004956.

Hyater-Adams, S., Fracchiolla, C., Finkelstein, N. & Hinko, K. (2018). Critical look at physics identity: An operationalized framework for examining race and physics identity. *Physical Review Physics Education Research*, 14(1), art. no. 010132. https://doi.org/10.1103/PhysRevPhysEducRes.14.010132.

Institute of Physics (2019). Students and graduates in UK physics departments. Data Brief, July. https://www.iop.org/sites/default/files/2019-10/Students-graduates-in-UK-physics-departments.pdf. Accessed 21 December 2023.

Institute of Physics (2020). Academic staff in UK physics departments. https://www.iop.org/sites/default/files/2020-07/Staff-characteristics-2017-18.pdf. Accessed 21 December 2023.

Institute of Physics (2021). Physics students in UK universities: Data brief. https://www.iop.org/sites/default/files/2021-12/Physics-Students-in-UK-Universities-HESA-Data-Brief.pdf. Accessed 21 December 2023.

Institute of Physics (2022). Written evidence submitted by the Institute of Physics (IOP) (DIV0033). https://committees.parliament.uk/writtenevidence/42480/pdf/. Accessed 21 December 2023.

Iraji Zad, A., Roshani, F. & Izadi, D. (2015). Improving the status of Iranian women in physics. In *AIP Conference Proceedings*, 1697(1), 060024. AIP Publishing LLC. https://doi.org/10.1063/1.4937671.

Johansson, A. (2020). Negotiating intelligence, nerdiness, and status in physics master's studies. *Research in Science Education*, 50(6), 2419–40. https://ui.adsabs.harvard.edu/link_gateway/2020RScEd..50.2419J/doi:10.1007/s11165-018-9786-8.

Johansson, A. & Berge, M. (2020). Lecture jokes: Mocking and reproducing celebrated subject positions in physics. In A. J. Gonsalves & A. T. Danielsson (eds), *Physics Education and Gender: Identity as an analytic lens for research*, pp. 97–113. Cham: Springer.

Kessels, U., Rau, M. & Hannover, B. (2006). What goes well with physics? Measuring and altering the image of science. *British Journal of Educational Psychology*, 76(4), 761–80. https://doi.org/10.1348/000709905x59961.

Kuh, G. D., Kinzie, J., Schuh, J. H. & Whitt, E. J. (2011). *Student Success in College: Creating conditions that matter*. San Francisco, CA: Jossey-Bass.

Ladewig, A., Keller, M. & Klusmann, U. (2020). Sense of belonging as an important factor in the pursuit of physics: Does it also matter for female participants of the German Physics Olympiad? *Frontiers in Psychology*, 11, art. no. 548781. https://doi.org/10.3389/fpsyg.2020.548781.

Lewis, J., Schneegans, S. & Straza, T. (2021). *UNESCO Science Report: The race against time for smarter development*. Paris: UNESCO Publishing.

Lewis, K. L., Stout, J. G., Finkelstein, N. D., Pollock, S. J., Miyake, A., Cohen, G. L. & Ito, T. A. (2017). Fitting in to move forward: Belonging, gender, and persistence in the physical sciences, technology, engineering, and mathematics (pSTEM). *Psychology of Women Quarterly*, 41(4), 420–36. https://doi.org/10.1177/0361684317720186.

Lewis, K. L., Stout, J. G., Pollock, S. J., Finkelstein, N. D. & Ito, T. A. (2016). Fitting in or opting out: A review of key social-psychological factors influencing a sense of belonging for women in physics. *Physical Review Physics Education Research*, 12(2), art. no. 020110. https://link.aps.org/doi/10.1103/PhysRevPhysEducRes.12.020110.

Marchand, G. C. & Taasoobshirazi, G. (2013). Stereotype threat and women's performance in physics. *International Journal of Science Education*, 35(18), 3050–61. https://doi.org/10.1080/09500693.2012.683461.

Maries, A., Karim, N. I. & Singh, C. (2018). Is agreeing with a gender stereotype correlated with the performance of female students in introductory physics? *Physical Review Physics Education Research*, 14(2), art. no. 020119. https://link.aps.org/doi/10.1103/PhysRevPhysEducRes.14.020119.

Maries, A. & Singh, C. (2015). Stereotype threat? Effects of inquiring about test takers' gender on conceptual test performance in physics. In *AIP Conference Proceedings*, 1697(1), 120008. AIP Publishing LLC.

Master, A. & Meltzoff, A. N. (2020). Cultural stereotypes and sense of belonging contribute to gender gaps in stem. *International Journal of Gender, Science and Technology*, 12(1), 152–98.

McConnell-Henry, T., James, A., Chapman, Y. & Francis, K. (2009). Researching with people you know: Issues in interviewing. *Contemporary Nurse*, 34(1), 2–9. https://doi.org/10.5172/conu.2009.34.1.002.Miikkulainen, K., Ott, J. & Vapaavuori, J. (2019). Update on women in physics in Finland. In *AIP Conference Proceedings*, 2109(1), art. no. 050015. AIP Publishing LLC.

Miller-Friedmann, J. (2020). Elite British female physicists: Social mobility and identity negotiations. In A. J. Gonsalves & A. T. Danielsson (eds), *Physics Education and Gender: Identity as an analytic lens for research*, pp. 153–70. Cham: Springer.

Moshfeghyeganeh, S. & Hazari, Z. (2021). Effect of culture on women physicists' career choice: A comparison of Muslim majority countries and the West. *Physical Review Physics Education Research*, 17(1), art. no. 010114. https://doi.org/10.1103/PhysRevPhysEducRes.17.010114 .

Murray, Ó. M., Chiu, Y.-L. T., Wong, B. & Horsburgh, J. (2022). Deindividualising imposter syndrome: Imposter work among marginalised STEMM Undergraduates in the UK. *Sociology*, 57(4), 749–66, https://doi.org/10.1177/00380385221117380.

Nosek, B. A., Banaji, M. R. & Greenwald, A. G. (2002). Math = male, me = female, therefore math ≠ me. *Journal of Personality and Social Psychology*, 83(1), 44–59. https://doi.org/10.1037//0022-3514.83.1.44.

Nosek, B. A. & Smyth, F. L. (2011). Implicit social cognitions predict sex differences in math engagement and achievement. *American Educational Research Journal*, 48(5), 1125–56. https://doi.org/10.3102/0002831211410683.

Oakley, A. & Roberts, H. (1981). Doing feminist research. In H. Roberts (ed.), *Doing Feminist Research*, pp. 30–61. London: Routledge & Kegan Paul.

Odden, T. O. B., Marin, A. & Caballero, M. D. (2020). Thematic analysis of 18 years of physics education research conference proceedings using natural language processing. *Physical Review Physics Education Research*, 16(1), art. no. 010142. https://link.aps.org/doi/10.1103/PhysRevPhysEducRes.16.010142.

Ong, M. (2005). Body projects of young women of color in physics: Intersections of gender, race, and science. *Social Problems*, 52(4), 593–617. https://doi.org/10.1525/sp.2005.52.4.593.

Osterman, K. F. (2000). Students' need for belonging in the school community. *Review of Educational Research*, 70(3), 323–67. https://doi.org/10.3102/00346543070003323.

Owton, H. & Allen-Collinson, J. (2014). Close but not too close: Friendship as method(ology) in ethnographic research encounters. *Journal of Contemporary Ethnography*, 43(3), 283–305. https://doi.org/10.1177/0891241613495410.

Porter, A. M. & Ivie, R. (2019). Women in physics and astronomy, 2019. American Institute of Physics. https://www.aip.org/statistics/reports/women-physics-and-astronomy-2019. Accessed 21 December 2023.

Prescod-Weinstein, C. (2020). Making Black women scientists under white empiricism: The racialization of epistemology in physics. *Signs: Journal of Women in Culture and Society*, 45(2), 421–47. http://dx.doi.org/10.1086/704991.

Rainey, K., Dancy, M., Mickelson, R., Stearns, E. & Moller, S. (2018). Race and gender differences in how sense of belonging influences decisions to major in STEM. *International Journal of STEM Education*, 5, art. no. 10. https://doi.org/10.1186/s40594-018-0115-6.

Ramos, M. C. (1989). Some ethical implications of qualitative research. *Research in Nursing and Health*, 12(1), pp. 57–63. https://doi.org/10.1002/nur.4770120109.

Simon, G. (2013). Relational ethnography: Writing and reading in research relationships. *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research*, 14(1), art. no. 4. https://doi.org/10.17169/fqs-14.1.1735.

Smith, B., Allen-Collinson, J., Phoenix, C., Brown, D. & Sparkes, A. (2009). Dialogue, monologue, and boundary crossing within research encounters: A performative narrative analysis. *International Journal of Sport and Exercise Psychology*, 7(3), 342–58. https://doi.org/10.1080/1612197X.2009.9671914.

Smith, J. L., Brown, E. R., Thoman, D. B. & Deemer, E. D. (2015). Losing its expected communal value: How stereotype threat undermines women's identity as research scientists. *Social Psychology of Education*, 18, 443–66. https://doi.org/10.1007/s11218-015-9296-8.

Spradley, J. P. (1979). *The Ethnographic Interview*. Fort Worth, TX: Harcourt Brace College Publishers.

Starr, C. R. (2018). 'I'm not a science nerd!' STEM stereotypes, identity, and motivation among undergraduate women. *Psychology of Women Quarterly*, 42(4), 489–503. https://doi.org/10.1177/0361684318793848.

Steele, C. M. & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology*, 69(5), 797–811. https://doi.org/10.1037/0022-3514.69.5.797.

Steffens, M. C. & Jelenec, P. (2011). Separating implicit gender stereotypes regarding math and language: Implicit ability stereotypes are self-serving for boys and men, but not for girls and women. *Sex Roles*, 64(5), 324–35. http://dx.doi.org/10.1007/s11199-010-9924-x.

Stojanović, M., Pavkov-Hrvojević, M., Božić, M., Knežević, D., Davidović, M., Trklja, N., Žekić, A., Marković-Topalović, T. & Jovanović, T. (2019). Gender imbalance in the number of PhD physicists and in key decision-making positions in the Republic of Serbia. In *AIP Conference Proceedings*, 2109(1), art. no. 050033. AIP Publishing LLC. https://doi.org/10.1063/1.5110107.

Stout, J. G., Ito, T. A., Finkelstein, N. D. & Pollock, S. J. (2013). How a gender gap in belonging contributes to the gender gap in physics participation. In *AIP Conference Proceedings*, 1513(1), 402–40. https://doi.org/10.1063/1.4789737.

Taconis, R. & Kessels, U. (2009). How choosing science depends on students' individual fit to 'science culture'. *International Journal of Science Education*, 31(8), 1115–32. https://doi.org/10.1080/09500690802050876.

Traweek, S. (2009). *Beamtimes and Lifetimes: The world of high energy physicists*. Cambridge, MA: Harvard University Press.

Trujillo, G. & Tanner, K. D. (2014). Considering the role of affect in learning: Monitoring students' self-efficacy, sense of belonging, and science identity. *CBE Life Sciences Education*, 13(1), pp. 6–15. https://doi.org/10.1187%2Fcbe.13-12-0241.

Tsai, L. (2004). Women in physics? Identity and discourse in Taiwan. PhD thesis, University of British Columbia.

Verostek, M., Griston, M., Botello, J. & Zwickl, B. M. (2022). Making expert cognitive processes visible: Planning and preliminary analysis in theoretical physics research. In B. W. Frank, D. L Jones & Q. X. Ryan (eds), *2022 Physics Education Research Conference*, 469–74. College Park, MD: American Association of Physics Teachers.

Walker, M. (2001). Engineering identities. *British Journal of Sociology of Education*, 22(1), 75–89. https://doi.org/10.1080/01425690020030792.

Walkerdine, V. (1988). *The Mastery of Reason: Cognitive development and the production of rationality*. London: Routledge.

Walton, G. M. & Cohen, G. L. (2007). A question of belonging: Race, social fit, and achievement. *Journal of Personality and Social Psychology*, 92(1), 82–96. https://doi.org/10.1037/0022-3514.92.1.82.

Wong, B., Chiu, Y.-L. T., Murray, Ó. M., Horsburgh, J. & Copsey-Blake, M. (2023). 'Biology is easy, physics is hard': Student perceptions of the ideal and the typical student across STEM higher education. *International Studies in Sociology of Education*, 32(1), 118–39. https://doi.org/10.1080/09620214.2022.2122532.

Yuan, Y. (2014). Turning friends into research participants: Rationale, possibilities and challenges. *CORERJ: Cambridge Open-Review Educational Research Journal*, 1(1), 88–104. http://dx.doi.org/10.17863/CAM.40965.

Yun, E. (2020). Review of trends in physics education research using topic modeling. *Journal of Baltic Science Education*, 19(3), 388–400. https://doi.org/10.33225/jbse/20.19.388.

10

An intersectional lens on the formation of STEM identity: beyond gender

Salma M. S. Al Arefi

Introduction

Analysis of science, technology, engineering, and mathematics (STEM) diversity with respect to race, ethnicity or class has long existed in silos. Efforts to understand factors that shape women's interest, persistence and retention in STEM education and professions remain limited to the gendered identity. Emerging inquiries into the complexities of identities that intersect with gender show promise of contextualising the lived experience of women in STEM, but tend to homogenise it, ignoring intersecting subjectivities. The impact that identities that intersect with gender can have on promoting or precluding STEM participation, and on nurturing or hindering formation of STEM identity, is yet to be considered. This is because characteristics such as race, class, age, language, religion and disability can exacerbate the experience of exclusion and otherness for already marginalised individuals (see also in this volume Murray et al., Chapter 4, Wong et al., Chapter 8 and Leigh et al., Chapter 14). We thus need to account for other determinants of the ignition and acceleration formula for sustaining the engagement of women in STEM education and professions.

Considering the potential multiple effects experienced by marginalised individuals, cultivating a sense of belonging can play a major role in enhancing their self-concept of being accepted, valued and included. This is because such an inherent feeling of connectedness and involvement encourages one to be more authentic and feel oneself to be an integral part of a system or an environment. Such an environment could thus be a healthy fertiliser to the formation of STEM identity. In contrast, perceived threats to one's belonging because of feelings of exclusion or rejection can trigger an adverse reaction, negatively impacting one's self-efficacy and hence one's affiliation with STEM. As Murray et al. note in Chapter 4 of this volume, belonging is not always a positive experience, particularly if one must compromise aspects of one's identity in order to belong. The formation of STEM identity thus needs to be expressed as a direct function of a positive sense of belonging that is best cultivated through self-authenticity enablement.

In an effort to bridge the inequality differential gap that may arise from the unintentionally discrete nature of existing attempts that homogenise the lived experience of women, this chapter presents a critique of women's marginalisation in STEM narratives through an autoethnographic lens. The conceptual analysis presented here urges STEM educators, researchers and professional bodies to rethink the marginalisation of women in STEM through a sustainable approach that spans the lifecycle of STEM women and contextualises the lived experience of women, shaped by their intersecting identities. This critique argues that fostering the formation of STEM identity should have, at its core, the enabling of authentic self-expression and the cultivation of a positive sense of belonging, in order to empower women to be their authentic selves by fulfilling their inherent need to affiliate with, and be accepted as part of, the STEM community.

The chapter concludes by highlighting the need for theoretical research frameworks to capture the complex intersections between the lived experience of women with marginalised social identities, and their STEM identities, in order to gain more insight into factors that promote or discourage women's intention to study STEM, remain in it, and feel affiliated with it. I acknowledge that women are not the only marginalised group in the STEM population, but the focus of this chapter is the marginalisation imposed by gendered identity: by 'marginalised women' I mean those who are actively being disadvantaged, underrepresented or minoritised by factors out of their control, not because they exist as minorities.

Case study: Why does the marginalisation of women in STEM matter?

In the UK, despite sustained efforts to ignite women's interest in STEM through early exposure, underrepresentation of women in STEM education and careers continues to contribute to the gendered skill gap. Not only would closing the gendered skills gap allow greater representation of women in STEM, but it would also broaden viewpoints, encouraging alternative perspectives and hence more creative innovations. Indeed, enabling women to make contributions to emerging technological advancement can enhance the inclusivity of technologies and foster innovations to improve women's experiences. This is evident in how the increased uptake of medical studies by women continues to revolutionise medical health (Nelson, 2015) and challenge male-default bias in medical training and practices (Khamis et al., 2016; Plataforma SINC, 2008).

The marginalisation of women in automotive occupant safety assessment provides an example of the benefits of inclusive innovation. Since the 1970s, the crash-test dummies used to test the effectiveness of seatbelts and other safety features have been based on male physical proportions, without catering for anatomical differences (Criado Perez, 2019). This is despite statistical evidence on the inequality of protection from crash injuries for women and men (Linder & Svedberg, 2019). Research has shown that, despite the low risk of crash, women are twice as likely to sustain severe injuries when belt-restrained, and are at nearly triple the risk of soft-tissue-related neck injuries that could lead to permanent physical disabilities (Bose et al., 2011; Cullen et al., 2021; Linder & Svensson, 2019; Mordaka & Gentle, 2003).

A proxy for a female crash-test dummy exists as a scaled-down manikin based on a male body that disregards musculoskeletal anatomical differences, and it is not mandated for all safety testing (National Federation of Women's Institutes, n.d.). Pregnant crash dummies were introduced in 1996 (Pearlman & Viano, 1996), but their use in testing remains unmandated in the EU and the USA (National Federation of Women's Institutes, n.d.). The need to narrow the vehicle-occupant safety gap by tailoring motor vehicle safety technologies to the female population has been the subject of research on equity in automotive design and safety assessment (Bose et al., 2011; Linder & Svensson, 2019). In 2022 Dr Astrid Linder, a Swedish engineer, led the development of the first seat-evaluation tool based on the body of average women (McCallum, 2022). If its adoption is enforced by regulators, her invention will not only bridge the gap in vehicle safety assessment between men and women, but also revolutionise the inclusivity of automotive design and construction.

The lack of personal protective equipment (PPE) specifically designed for women, rather than being a scaled-down version of that designed for men, is another example of the extent of the marginalisation of women in STEM workplaces (Del Castillo, 2015). The impact of improperly fitted PPE on job satisfaction (e.g. employer–employee relationships), efficiency (production losses) and women's safety (severe injury or death) is well documented (Curtis et al., 2016; Larmour & Peters, 2010; Oo & Lim 2020; Wagner et al., 2013). The lack of maternity PPE is brought to public attention in the Women's Engineering Society (WES)'s investigation of UK engineering and construction workplace safety and working conditions, which revealed that three-quarters of the participants reported using PPE that is designed for and prototyped on men (Larmour & Peters, 2010). Internationally, the evidence is similar in Australia (Oo & Lim, 2020), despite the availability of women's PPE in the Australian market. In the UK, WES has launched the 'Purple Boot campaign' in partnership with industrial organisations to work on designing and manufacturing safety boots for women (Del Castillo, 2015). However, more work needs to be done to recognise the contribution of inappropriate workplace safety measures to women's health issues, ranging from musculoskeletal discomfort to life-changing injuries.

The recent involvement of women in STEM research and development continues to give women a voice, paving the way to more inclusive innovation. An example of inclusive innovation is challenging the gender bias of artificial-intelligence-based decision-making systems (Nadeem et al., 2022). Addressing disparities in health care is another example of enabling women's health challenges to benefit from biomedical engineering research and innovation (e.g. precision medicine, screening, monitoring and modelling) (De Vita & Munson, 2021). Today, the therapeutic application of micro-engineered 3D tumour models continues to emerge as a promising anti-cancer drug discovery and screening technology that has the potential to improve survival rates for women diagnosed with cancers related to their sex, such as breast and ovarian cancer (Amirghasemi et al., 2021). Maternal health, too, can potentially benefit from emerging research on the spectral properties of photoacoustic imaging and its application for transabdominal imaging of the placenta, an organ that develops during pregnancy to support fetal growth. This development may revolutionise diagnostics during pregnancy that would otherwise be limited to existing technologies (foetal growth monitoring, pre-eclampsia diagnosis, analysis of the impact of gestational diabetes, etc.) (Huda et al., 2021).

The transformative effect of including women's perspectives in STEM has been seen in the energy sector. Mukuru Clean Stoves, which were invented by a pioneering Kenyan woman, Charlot Magayi, and won a prestigious award, provide a clean cooking technology that replaces solid fuels with biomass alternatives; they have the potential to improve the lives of millions in Africa (Earthshot Prize, 2023). This is a problem that impacts billions of people globally: the household air pollution associated with traditional stoves contributes to around 4 million premature deaths annually (WHO, 2016, p. 81). Not only will her invention help to eradicate health problems historically known to affect women in particular, it will also provide a low-cost clean cooking solution.

Rethinking the marginalisation of women in STEM

Gendered identity is typically recognised as being part of the cause of marginalisation of women in STEM (see also Smith, Chapter 9 in this volume). To date, progress towards bridging the skills gap remains very modest, despite wide-scale initiatives aimed at accelerating the recognition of women in STEM while igniting the interest of future generations. Beyond gender, other determinants need to be taken into account, namely the sustaining of engagement and belonging through a lifecycle approach, and the inhomogeneity of lived experiences shaped by intersecting identities.

A sustainability lens: cradle-to-cradle theory

Through a sustainability lens, one could argue that existing efforts to diversify STEM are sometimes one-off events and are not maintained throughout the lifecycle of a woman. For example, exposure in early education can play a key role in building the science capital of a young woman, but on its own it does not support women's intention to study and remain in STEM subjects. Similarly, promotion of women's empowerment in STEM careers is often perceived to be tokenistic and motivated by statistical analysis. The continuation and attainment of women in STEM professions requires bridging the gap between promoting participation in STEM education and accelerating progression to STEM careers.

I propose a theoretical model for a cradle-to-cradle sustainable approach to promoting participation while sustaining engagement (Al Arefi, 2022b). The cradle-to-cradle approach stresses the need to rethink existing promotion practices in order to narrow the inequity gap, which may be broadening because of the focus on early exposure and because the different key stages of women in the STEM lifecycle are overlooked. The impact of focusing on early exposure could lead to the 'STEM trap', whereby women are encouraged to take an interest in STEM, but are neither equipped with the tools, nor provided with the support systems, to help them navigate an environment in which they are marginalised.

In the area of participation in STEM education, for example, the lack of equitable support tailored to the needs of women students can have an adverse effect on a woman's learning experience. That having lower self-efficacy than male counterparts, despite comparable academic achievement, has an impact is evident from the literature (Kang et al., 2021; Pajares, 2005). Research by Watt (2006) has shown that self-perception exerts the strongest force on women's intention to choose, and remain in, STEM subjects, even the women with high mathematical achievement.

Sustaining support beyond access, through a cradle-to-cradle approach, is therefore necessary to create opportunities for women to develop awareness and appreciation of their own efficacies, attributes and competencies, and thus to cultivate a stronger STEM self-concept. I identify two main avenues to realise that: inclusive learning, and equitable opportunities tailored to the developmental needs of women in STEM. The former can be achieved by removing barriers to integration through an inclusive curriculum that infuses authentic learning experiences to recognise and celebrate women's lived experience, allowing them to see their own identities reflected in the dominant STEM depictions. This fosters the formation of STEM identity (Singer et al., 2020), whereby women are empowered to value their own attributes and enabled to envisage themselves as scientists and engineers.

While more research is needed to understand the long-term impact of inclusive and authentic teaching and learning practices on the formation of STEM identity, emerging evidence continues to confirm a strong positive correlation between them, irrespective of personal identities (gendered or otherwise). Exposure to project-based learning before university education correlates with higher STEM participation and persistence, as this learning approach provides an enhanced perception of one's own STEM skills (Beier et al. 2019; see also Luk et al.,Chapter 15 in this volume). In pedagogical research centred on engineering (Al Arefi, 2022a), I examined the connections between authentic learning, sense of belonging to the module, degree programme and career, and STEM identity, through the co-creation of learning activities. These provided opportunities to practise higher-order cognitive skills that support the formation of STEM identity, by offering enhanced learning agency (see also Kinchin et al., Chapter 17 in this volume).

Complementing authentic learning experiences with equitable developmental opportunities, while supporting transition into and out of STEM education, can help women unlock their potential. The cradle-to-cradle feedback loop would ultimately be closed by equipping women in STEM with the skill set that would enable them to empower future generations of STEM learners, so that women with a stronger sense of belonging to STEM can become role models. This, however, would require the establishment of accessible support platforms (e.g., mentoring), the creation of developmental opportunities beyond curriculum activities (e.g., participation in student research conferences and competitions), and the provision of funds to support engagement with national and international networks (subsided society membership, conference registration). In this context, the term 'equitable' is intentionally used instead of 'equal' to imply the provision of support, resources and opportunities to help women students in STEM to reach outcomes equal to those of their male counterparts. Achieving this would require one to embrace a decolonial mindset in order to prioritise the needs of the learners and to be willing to offer access to support and supervision, beyond the potential personal gain from engagement. The additional representational work for women in STEM also highlights a paradox in which more is asked of an already marginalised group, thus requiring such activity to be acknowledged in workload, progression and promotion policies, and not unfairly increasing the demand on the role models.

Similar analogies of the cradle-to-cradle framework are applicable across women's STEM careers, whereby women must be supported throughout the entirety of their STEM careers. That is because more than STEM education is needed to enable women to have a direct impact on the decision making of future innovations. As well as supporting women at the early stages of their careers, the core of the 'cradle-to-cradle' hypothesis should be aimed at removing structural barriers and eradicating systematic inequalities that have long hindered the attainment of women. In the UK, the increase in the number of women electing to do STEM higher education is yet to translate into increased proportions of women taking jobs in STEM fields, let alone higher leadership positions. In 2021, women formed just 16.5 per cent of the engineering population, despite making up half of the STEM student population (Catalyst, 2022). The globally recognised STEM gender imparity expands further to the far end of the career pipeline, where only 3 per cent of STEM chief executive officers are women (Catalyst, 2022).

A study of the career progression of women academics in STEM roots the challenges of women's career progression and retention, irrespective of seniority, in stereotypical beliefs that begin at the initial stages of the STEM lifecycle, as early as primary education (O'Connell & McKinnon, 2021). Considering the narrative of the research, which is based on the lived experience of women in STEM academia – from early to late career stages –stereotypical beliefs, which stem from the perception of one's own science capital, seem to have a long-lasting impact that continues to pressure women to prove themselves even when they outperform their male counterparts.

With an emphasis on the 'cradle-to-cradle' hypothesis, research has shown a positive correlation between professional development on the one hand, and career attainment and progression on the other (Main et al., 2022). Main et al.'s findings suggest that participation in professional development training by women in the early stages of their career can directly contribute to their attainment of leadership positions. The role that mentoring, exposure to role models, networking and diversity allies play in enhancing attainment and career progression as a by-product of supporting women to cultivate a strong sense of self-perception is echoed by O'Connell and McKinnon (2021) and reinforces the necessity for equitable opportunities tailored to the developmental needs of women in STEM.

An intersectionality lens: beyond gender

Overlooking intersecting identities when addressing the root causes of women's marginalisation in STEM can perpetuate structural inequalities that have long needed to be eradicated. Evidence of research design that applies critical theory to gain insight into the underpinning factors of women's participation and persistence in STEM is very limited (Gaston Gayles & Smith, 2018). Despite a growing knowledge of the factors that influence young people's intention to choose, and remain in, STEM subjects, most research data homogenises gendered identity. Thus, the complexities of identity intersections continue to be overlooked. This is alarming because, firstly, disregarding women's other identities and homogenising the experiences of women in STEM poses an unintentional risk of feeding into the inequality gap. Secondly, while women and minorities can both be marginalised, and individuals may exist in both groups, the lived experiences shaped by having a gendered identity or identifying as a member of a minoritised group are not mutually exclusive (see also Murray et al., Chapter 4 in this volume). Anecdotal evidence has long shown that the challenges experienced by women are exacerbated when they identify with multiple marginalised identities. The impact of intersecting subjectivities has been described as double, triple or multiple bind/jeopardy (Clancy et al., 2017; Ong et al., 2011).

Race, class, age, language, religion and disability might all contribute to the formation of an intersecting identity. Because identities do not exist in isolation from each other, exploring the marginalising effect of one's gendered identity requires a comprehensive understanding of the intersection of the complexities of multiple dimensions of identities shaped by the individual's lived experience. Since 1989 (Crenshaw, 2018), the term 'intersectionality' has been used to explain the implications and effects of group membership in multiple categories (Cole, 2009).

While intersectionality could define the power of creating privilege through identifying with multiple privileged categories, in this context an intersectionality lens can help us to examine critically the extent to which the intersection of identities feeds into the power of marginalisation. Marginalised groups are those which do not exist naturally as minorities but are actively excluded and isolated so that they exist on the peripheries (Gunaratnam, 2003). However, intersectional approaches should recognise, and value, individual lived experiences which the rhetorical focus on 'intersectionality' might otherwise obscure, giving rise to the intersectionality trap: 'blanket statements to describe a race or group of individuals without considering variations of experience within the population' (Sparks, 2017, p. 162). Such a trap risks pressurising individuals to adopt the societal norms of others, which might lead to unintentional counterproductive effects. To combat this, intersectionality research design and analysis should clearly define the role of power and privilege (Syed, 2010).

The urge to introduce intersectionality as a multidimensional analysis tool should not suggest a hierarchy of oppression (Berger & Guidroz, 2010). It should instead give voice to the lived experiences of women who identify with multiple marginalised identities and guide inquiry to tease out systematic inequalities and suppressions and gauge individuals' awareness of how their intersecting identities influence their STEM identity (Gaston Gayles & Smith, 2018).

Emerging research on the complexities of intersections between gender and race (Gaston Gayles & Smith, 2018; Hanson, 2004; Johnson, 2011; Ong, Smith & Ko, 2018), continues to contribute new insights. However, it largely remains limited to the experience of women who identify with multiple marginalised identities in American educational institutions. Considering the vital importance of centring the lived experiences of individuals within the social context they exist in, there is a gap in examining the matter through a critical pedagogical framework by UK scholars. The work of the UK scholar Louise Archer continues to command attention and to introduce an informed understanding of how intersecting subjectivities impacts young individuals' intention to participate, and remain, in STEM education and professions (Archer & DeWitt, 2016; Archer, De Witt et al., 2012; Archer, Nomikou et al., 2019; Dawson et al., 2020). This work focuses on intersections with gendered identity, and these research findings could guide enquiry at each stage of the lifecycle of STEM women beyond the stimulation of interest at a young age.

STEM identity formation through theoretical lenses

Identifying with a STEM identity entails recognition by one's self and by others as a STEM person (Carlone & Johnson, 2007). This recognition develops in addition to a personal identity defined by one's recognition of one's own self as an individual (Luhtanen & Crocker, 1992). Carlone and Johnson (2007) introduced a STEM identity framework that comprises three pillars: competency, performance and recognition. Indeed, perception of one's own knowledge competencies, self-efficacy, appreciation of one's attributes, and acknowledgement of added value, can have a greater impact in nurturing or hindering STEM identity formation in marginalised groups. However, inclusion through social acceptance and recognition alone is not an indicator of the extent to which individuals are empowered and enabled to be themselves as part of the STEM community. Central to the marginalisation of women in STEM, the examples presented in this chapter suggest that the formation of STEM identity should have, at its core, the enabling of authentic self-expression and the cultivation of a strong sense of belonging, which will enable women to be their authentic selves as they fulfil their inherent need to affiliate with and be accepted as part of the STEM community.

A positive correlation between authenticity and STEM identity is apparent in studies that introduce ways of developing higher-order cognitive skills through authentic learning experiences that are of direct relevance and add value to one's aspirations (Al Arefi, 2022a). An interventional study by Singer et al. (2020), which aimed to infuse authentic learning opportunities to foster STEM identity, highlighted the significance of the interactions between STEM identity and social identities, whereby gendered and ethnic identities were found to be central to enhanced perception of affiliation with STEM identity (e.g., self-identifying as a Black woman scientist, not just as a scientist). In addition to race and ethnicity, women's affiliation to STEM can be disturbed by having lower educational capital (formal and informal

STEM education), which can also be shaped by their social class (Cheryan et al., 2015; Seebacher et al., 2021). This, coupled with the evident challenges experienced by women, who identify as being racialised or classed in pursuing STEM while being their authentic selves (Dawson et al., 2020; Seebacher et al., 2021), urges the necessity of prioritising self-authenticity enablement in addressing STEM identity formation.

The social and interactive nature of how individuals' perception of competency, performance and recognition impacts their development of STEM identity is examined through social identity theory (Tajfel & Turner, 1986) in work by Kim et al. (2018). Central to social identity theory (Cheryan et al., 2015) is the proposition that a social identity defines one's perception of group membership; STEM identity has been identified as inherently social in nature (Kim et al., 2018; see also Myyry et al., Chapter 6 in this volume). This is conceivable, considering that the formal and informal development of one's STEM capital is often pursued in social endeavours (such as early exposure to STEM-related activities at school or with family).

Through a psychological lens, the understanding of self-perception within a social context and its impact on uncertainties about sense of belonging in or exclusion from STEM has been advanced in the work of Kim et al. (2018) through uncertainty–identity theory (Hogg, 2007). The psychological perspective brings to light the factors that guide the identification with STEM through social mobility and social change (Kim et al., 2018). The former implies the navigation of excluding environments: a woman may leave STEM roles to reduce her experience of marginalisation, which could explain why the number of women in STEM education does not translate to STEM professions.

'Social change' describes a shift of perspective whereby women choose and remain in STEM majors and become agents to influence positive change for others. The association of a STEM person with positive change and with the potential to add value to the community is apparent in the findings of recent qualitative research. Stewart (2022) employs the communication theory of identity as a sensitising framework for STEM identities. As well as foregrounding social contributions, the communicative perspective on understanding the formation and expression of STEM identity revealed the significance of relationships with STEM peers in reinforcing one's STEM identity. The importance of peers underlines the fact that a woman identifies with STEM when 'she is recognized by meaningful others, people whose acceptance of her matters to her, as a [STEM] person' (Carlone & Johnson, 2007, p. 1192). While the interpretation of 'meaningful others' may vary between individuals, the findings centre on peer relationships and communities. These are prioritised over formal methods of intervention (e.g., academics and student support staff).

A strong correlation between STEM identity and formal and informal peer interactions is evident in the literature (Agne & Muller, 2019; Espinosa, 2011). Efforts to enact STEM identity by reaching out to traditionally isolated learners and educators have also given promise of success (Nadelson et al., 2017; Robnett et al., 2018). This might not be true for individuals whose personal identity is comprised of membership of multiple marginalised groups. Intersections between STEM identity and other socially marginalised identities have been shown to deny individuals recognition in and ascription to STEM identity by scientific others as well as peers (Avraamidou, 2020; Carlone & Johnson, 2007; Kim et al., 2018).

The evidence reviewed in this section identifies a gap in theoretical frameworks that captures the intersections between the lived experience of women with marginalised social identities and their STEM identities. Communication theory of identity coupled with social identity theory offers a multidimensional framework to centre the intersections of multiple social identities and guide enquiry of how they influence the formation of STEM identities for women. Existing applications of the theories (Kim et al., 2018; Stewart, 2022) introduce valuable understanding but are limited to quantitative analysis and lack diverse intersectional analysis. Qualitative approaches could provide more assistance to unpick underlying determinants that might nurture or hinder the development of women's STEM identity.

An individual's identity is impacted by different situations; however, the correlation between identities and situations is not strong (Hurtado & Figueroa, 2013). Thus, understanding the 'identity gap' caused by discrepancies between or among the four frames of identity (Kam & Hecht, 2009) can draw out the factors that influence how women choose to self-disclose their identity. Work in progress on investigating sense of belonging for women engineering students at the University of Leeds aims to contribute understanding to bridge this gap.

Conclusion

The evidence-informed critique presented in this chapter highlights the importance of contextualising the lived experience of women, shaped by their intersecting identities. It identifies the need for theoretical research frameworks to advance understanding of STEM identity formation as a function of intersecting social identities. Beyond the gendered identity, the conceptual analysis presented in this chapter supports the argument to rethink widening women's participation through sustainability and intersectionality lenses. Drawing on the cradle-to-cradle approach (Al Arefi, 2022b), the chapter considers the role that inclusive learning and equitable opportunities tailored to the developmental needs of women can play in combating the 'STEM trap' by supporting women's continuation, attainment, progression and retention, going beyond mere access.

The critique centres intersectionality as a core theoretical research framework in guiding understanding of the influence of multiple marginalised social identities on women's participation and persistence in, and affiliation with, STEM, which may otherwise be obscured by aggregated data. The chapter warns about the 'intersectionality trap' to sidestep any stereotypical threats that might arise from homogenising the lived experiences of individuals who identify with marginalised intersecting identities, as detailed by Murray et al. in Chapter 4 of this volume. Advice and examples from related research by Wong et al. in Chapter 8, Smith in Chapter 9 and Leigh et al. in Chapter 14 indicate ways to address the inequities faced by those with marginalised identities.

Critical evaluation of the theories in the literature, such as sensitising frameworks to STEM identities, reveals the need for qualitative and intersectional frameworks to guide inquiry of the complexities of the identity layers shaped by membership of multiple marginalised identities. Analysis presented in this chapter encourages STEM educators, researchers and professionals to rethink women's marginalisation. It is important to advance understanding of the factors that drive women to choose and remain in STEM, and to be affiliated with a STEM identity in a way that acknowledges the diversity of women beyond their gender and does not homogenise their lived experiences.

References

Agne, R. R. & Muller, H. L. (2019). Discourse strategies that co-construct relational identities in STEM peer tutoring. *Communication Education*, 68(3), 265–86. https://doi.org/10.1080/03634523.2019.1606433.

Al Arefi, S. M. S. (2022a). Avenues for authentic learning in engineering education through reflection and co-creation. In *2022 IEEE World Engineering Education Conference* (EDUNINE), Santos, Brazil, pp. 1–6.

Al Arefi, S. M. S. (2022b). Rethinking women in engineering marginalisation: Beyond interest ignition. In *2022 IEEE Global Engineering Education Conference (EDUCON)*, pp. 2037–43. Tunis. IEEE. https://doi.org/10.1109/EDUCON52537.2022.9766589.

Amirghasemi, F., Adjei-Sowah, E., Pockaj, B. A. & Nikkhah, M. (2021). Microengineered 3D tumor models for anti-cancer drug discovery in female-related cancers. *Annals of Biomedical Engineering*, 49(8), 1943–72. https://doi.org/10.1007/s10439-020-02704-9.

Archer, L. & DeWitt, J. (2016). *Understanding Young People's Science Aspirations: How students form ideas about 'becoming a scientist'*. Abingdon: Routledge.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B. & Wong, B. (2012). 'Balancing acts': Elementary school girls' negotiations of femininity, achievement, and science. *Science Education*, 96(6), 967–89. https://doi.org/10.1002/sce.21031.

Archer, L., Nomikou, E., Mau, A., King, H., Godec, S., DeWitt, J. & Dawson, E. (2019). Can the subaltern 'speak' science? An intersectional analysis of performances of 'talking science through muscular intellect' by 'subaltern' students in UK urban secondary science classrooms. *Cultural Studies of Science Education*, 14(3), 723–51. https://doi.org/10.1007/s11422-018-9870-4.

Avraamidou, L. (2020). Science identity as a landscape of becoming: Rethinking recognition and emotions through an intersectionality lens. *Cultural Studies of Science Education*, 15(2), 323–45. https://doi.org/10.1007/s11422-019-09954-7.

Beier, M. E., Kim, M. H., Saterbak, A., Leautaud, V., Bishnoi, S. & Gilberto, J. M. (2019). The effect of authentic project-based learning on attitudes and career aspirations in STEM. *Journal of Research in Science Teaching*, 56(1), 3–23. https://doi.org/10.1002/tea.21465.

Berger, M. T. & Guidroz, K. (eds) (2010). *The Intersectional Approach: Transforming the academy through race, class, and gender*. Chapel Hill: University of North Carolina Press.

Bose, D., Segui-Gomez, M. & Crandall, J. R. (2011). Vulnerability of female drivers involved in motor vehicle crashes: An analysis of US population at risk. *American Journal of Public Health*, 101(12), 2368–73. https://doi.org/10.2105%2FAJPH.2011.300275.

Carlone, H. B. & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching*, 44(8), 1187–1218. https://doi.org/10.1002/tea.20237.

Catalyst (2022). Women in science, technology, engineering, and mathematics (STEM): Quick take. Catalyst. https://www.catalyst.org/research/women-in-science-technology-engineering-and-mathematics-stem/.

Cheryan, S., Master, A. & Meltzoff, A. N. (2015). Cultural stereotypes as gatekeepers: Increasing girls' interest in computer science and engineering by diversifying stereotypes. *Frontiers in Psychology*, 6(49), 1–8. https://doi.org/10.3389/fpsyg.2015.00049.

Clancy, K. B. H., Lee, K. M. N., Rodgers, E. M. & Richey, C. (2017). Double jeopardy in astronomy and planetary science: Women of color face greater risks of gendered and racial harassment. *Journal of Geophysical Research: Planets*, 122(7), 1610–23. https://doi.org/10.1002/2017JE005256.

Cole, E. R. (2009). Intersectionality and research in psychology. *American Psychologist*, 64(3), 170–80. https://doi.org/10.1037/a0014564.

Crenshaw, K. (2018). Demarginalizing the intersection of race and sex: A Black feminist critique of antidiscrimination doctrine, feminist theory, and antiracist politics. In K. T. Bartlett & R. Kennedy (eds), *Feminist Legal Theory: Readings in law and gender*, pp. 57–80. New York: Routledge. First published in 1989.

Criado Perez, C. (2019). *Invisible Women: Exposing data bias in a world designed for men*. New York: Abrams Press.

Cullen, P., Möller, H., Woodward, M., Senserrick, T., Boufous, S., Rogers, K., Brown, J. & Ivers, R. (2021). Are there sex differences in crash and crash-related injury between men and women? A 13-year cohort study of young drivers in Australia. *SSM –Population Health*, 14, art. no. 100816. https://doi.org/10.1016/j.ssmph.2021.100816.

Curtis, H. M., Meischke, H., Simcox, N., Laslett, S. & Seixas, N. (2016). P343 Addressing health and safety risks for tradeswomen in the construction industry. *Occupational and Environmental Medicine*, 73(suppl. 1), A236.3–A237. http://dx.doi.org/10.1136/oemed-2016-103951.658.

Dawson, E., Archer, L., Seakins, A., Godec, S., DeWitt, J., King, H., Mau, A. & Nomikou, E. (2020). Selfies at the science museum: Exploring girls' identity performances in a science learning space. *Gender and Education*, 32(5), 664–81. https://doi.org/10.1080/09540253.2018.1557322.

De Vita, R. & Munson, J. (2021). Special issue on the advances in engineering for women's health [editorial]. *Annals of Biomedical Engineering*, 49(8), 1785–7. https://doi.org/10.1007/s10439-021-02837-5.

Del Castillo, A. P. (2015). Personal protective equipment: Getting the right fit for women. *HesaMag*, 12, 34–7.

EarthShot Prize. (2023). Mukuru Clean Stoves. https://earthshotprize.org/winners-finalists/mukuru-clean-stoves/. Accessed 23 December 2023.

Espinosa, L. L. (2011). Pipelines and pathways: Women of color in undergraduate STEM majors and the college experiences that contribute to persistence. *Harvard Educational Review*, 81(2), 209–41. https://doi.org/10.17763/haer.81.2.92315ww157656k3u.

Gaston Gayles, J. & Smith, K. N. (2018). Advancing theoretical frameworks for intersectional research on women in STEM. *New Directions for Institutional Research*, 2018(179), 27–43. https://doi.org/10.1002/ir.20274.

Gunaratnam, Y. (2003). *Researching 'Race' and Ethnicity: Methods, knowledge and power*. London: SAGE Publications.

Hanson, S. L. (2004). African American women in science: Experiences from high school through the post-secondary years and beyond. *Feminist Formations*, 16(1), 96–115. https://www.jstor.org/stable/4317036.

Hogg, M. A. (2007). Uncertainty–identity theory. *Advances in Experimental Social Psychology*, 39, 69–126. https://doi.org/10.1016/S0065-2601(06)39002-8.

Huda, K., Swan, K. F., Gambala, C. T., Pridjian, G. C. & Bayer, C. L. (2021). Towards transabdominal functional photoacoustic imaging of the placenta: Improvement in imaging depth through optimization of light delivery. *Annals of Biomedical Engineering*, 49(8), 1861–73. https://doi.org/10.1007%2Fs10439-021-02777-0.

Hurtado, S. & Figueroa, T. (2013). Women of color among STEM faculty: Experiences in academia. In National Research Council, *Seeking Solutions: Maximizing American talent by advancing women in color in academia: Summary of a conference*, pp. 93–107. Washington, DC: National Academies Press. https://nap.nationalacademies.org/18556. Accessed 23 March 2024.

Johnson, D. R. (2011). Women of color in science, technology, engineering, and mathematics (STEM). *New Directions for Institutional Research*, 2011(152), 75–85. https://doi.org/10.1002/ir.410.

Kam, J. A. & Hecht, M. L. (2009). Investigating the role of identity gaps among communicative and relational outcomes within the grandparent–grandchild relationship: The young-adult grandchildren's perspective. *Western Journal of Communication*, 73(4), 456–80. https://doi.org/10.1080/10570310903279067.

Kang, J., Keinonen, T. & Salonen, A. (2021). Role of interest and self-concept in predicting science aspirations: Gender study. *Research in Science Education*, 51(Suppl. 1), 513–35. https://doi.org/10.1007/s11165-019-09905-w.

Khamis, R. Y., Ammari, T. & Mikhail, G. W. (2016). Gender differences in coronary heart disease. *Heart*, 102(14), 1142–9. https://doi.org/10.1136/heartjnl-2014-306463.

Kim, A. Y., Sinatra, G. M. & Seyranian, V. (2018). Developing a STEM identity among young women: A social identity perspective. *Review of Educational Research*, 88(4), 589–625. https://doi.org/10.3102/0034654318779957.

Larmour, J. & Peters, J. (2010). WES safety clothing and footwear survey. Women's Engineering Society.

Linder, A. & Svedberg, W. (2019). Review of average sized male and female occupant models in European regulatory safety assessment tests and European laws: Gaps and bridging suggestions. *Accident Analysis & Prevention*, 127, 156–62. https://doi.org/10.1016/j.aap.2019.02.030.

Linder, A. & Svensson, M. Y. (2019). Road safety: The average male as a norm in vehicle occupant crash safety assessment. *Interdisciplinary Science Reviews*, 44(2), 140–53.

Luhtanen, R. & Crocker, J. (1992). A collective self-esteem scale: Self-evaluation of one's social identity. *Personality and Social Psychology Bulletin*, 18(3), 302–18. https://doi.org/10.1177/0146167292183006.

Main, J. B., Wang, Y. & Tan, L. (2022). Preparing industry leaders: The role of doctoral education and early career management training in the leadership trajectories of women STEM PhDs. *Research in Higher Education*, 63(3), 400–24. https://doi.org/10.1007/s11162-021-09655-7.

McCallum, S. (2022). The crash dummy aimed at protecting women drivers. *BBC News*, 28 October. https://www.bbc.co.uk/news/technology-62877930. Accessed 23 December 2023.

Mordaka, J. & Gentle, C. R. (2003). Biomechanical analysis of whiplash injuries: Women are not scaled down men. *Proceedings of the 4th European LS-DYNA Users Conference*, 57–70.

Nadeem, A., Marjanovic, O. & Abedin, B. (2022). Gender bias in AI-based decision-making systems: A systematic literature review. *Australasian Journal of Information Systems*, 26. https://doi.org/10.3127/ajis.v26i0.3835.

Nadelson, L. S., McGuire, S. P., Davis, K. A., Farid, A., Hardy, K. K., Hsu, Y.-C., Kaiser, U., Nagarajan, R. & Wang, S. (2017). Am I a STEM professional? Documenting STEM student professional identity development. *Studies in Higher Education*, 42(4), 701–20. https://doi.org/10.1080/03075079.2015.1070819.

National Federation of Women's Institutes (n.d.). Female crash test dummies. https://www.thewi.org.uk/__data/assets/pdf_file/0005/389084/Female-Crash-Test-Dummies.pdf. Accessed 23 December 2023.

Nelson, J. (2015). Introduction. In *More Than Medicine: A history of the feminist women's health movement*, pp. 1–14. New York: New York University Press.

O'Connell, C. & McKinnon, M. (2021). Perceptions of barriers to career progression for academic women in STEM. *Societies*, 11(2), art. no. 27. https://doi.org/10.3390/soc11020027.

Ong, M., Smith, J. M. & Ko, L. T. (2018). Counterspaces for women of color in STEM higher education: Marginal and central spaces for persistence and success. *Journal of Research in Science Teaching*, 55(2), 206–45. https://doi.org/10.1002/tea.21417.

Ong, M., Wright, C., Espinosa, L. & Orfield, G. (2011). Inside the double bind: A synthesis of empirical research on undergraduate and graduate women of color in science, technology, engineering, and mathematics. *Harvard Educational Review*, 81(2), 172–209. http://dx.doi.org/10.17763/haer.81.2.t022245n7x4752v2.

Oo, B. L., & Lim, T. H. B. (2020). Women's accessibility to properly fitting personal protective clothing and equipment in the Australian construction industry. *IOP Conference Series: Earth and Environmental Science*, 498, art. no. 012096. https://dx.doi.org/10.1088/1755-1315/498/1/012096.

Pajares, F. (2005). Gender differences in mathematics self-efficacy beliefs. In A. M. Gallagher & J. C. Kaufman (eds), *Gender Differences in Mathematics: An integrative psychological approach*, pp. 294–315. Cambridge: Cambridge University Press.

Pearlman, M. D. & Viano, D. (1996). Automobile crash simulation with the first pregnant crash test dummy. *American Journal of Obstetrics and Gynecology*, 175(4), 977–81. https://doi.org/10.1016/s0002-9378(96)80036-6.

Plataforma SINC (2008). Medical textbooks use white, heterosexual men as a 'universal model'. *ScienceDaily*, 17 October. https://www.sciencedaily.com/releases/2008/10/081015132108.htm. Accessed 23 December 2023.

Robnett, R. D., Nelson, P. A., Zurbriggen, E. L., Crosby, F. J. & Chemers, M. M. (2018). Research mentoring and scientist identity: Insights from undergraduates and their mentors. *International Journal of STEM Education*, 5, art. no. 41. https://doi.org/10.1186/s40594-018-0139-y.

Seebacher, L. M., Vana, I., Voigt, C. & Tschank, J. (2021). Is science for everyone? Exploring intersectional inequalities in connecting with science. *Frontiers in Education*, 6, art. no. 673850. https://doi.org/10.3389/feduc.2021.673850.

Singer, A., Montgomery, G, & Schmoll, S. (2020). How to foster the formation of STEM identity: Studying diversity in an authentic learning environment. *International Journal of STEM Education*, 7(1), art. no. 57. https://doi.org/10.1186/s40594-020-00254-z.

Sparks, D. M. (2017). Navigating STEM-worlds: Applying a lens of intersectionality to the career identity development of underrepresented female students of color. *Journal for Multicultural Education*, 11(3), 162–75. https://doi.org/10.1108/JME-12-2015-0049.

Stewart, C. O. (2022). STEM Identities: A communication theory of identity approach. *Journal of Language and Social Psychology*, 41(2), 148–70. https://doi.org/10.1177/0261927X211030674.

Syed, M. (2010). Disciplinarity and methodology in intersectionality theory and research. *American Psychologist*, 65(1), 61–2. http://dx.doi.org/10.1037/a0017495.

Tajfel, H. & Turner, J. (1986). An integrative theory of intergroup conflict. In W. G. Austin & S. Worchel (eds), *Psychology of Intergroup Relations*, pp. 7–24. Monterey, CA: Brooks Cole.

Wagner, H., Kim, A. J. & Gordon, L. (2013). Relationship between personal protective equipment, self-efficacy, and job satisfaction of women in the building trades. *Journal of Construction Engineering and Management*, 139(10), art. no. 04013005. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000739.

Watt, H. M. G. (2006). The role of motivation in gendered educational and occupational trajectories related to math. *Educational Research and Evaluation*, 12(4), 305–22. http://dx.doi.org/10.1080/13803610600765562.

WHO (2016). *Burning Opportunity: Clean household energy for health, sustainable development, and wellbeing of women and children*. Geneva: World Health Organization. https://www.who.int/publications/i/item/9789241565233. Accessed 23 December 2023.

11

Higher education teachers' identity development and sense of belonging

Jo Horsburgh

Introduction

The importance of a strong professional identity amongst higher education teachers is well established (van Lankveld, Schooneboom, Kusurkar et al., 2017) and there has been significant focus on teacher identity development in recent years (Feser & Haak, 2023). Higher education teachers often hold multiple professional identities alongside their teacher identity, e.g., researcher, manager, practitioner (McCune, 2021). These multiple professional identities can consist of subforms, such as teacher identity, which is part of a greater professional identity. Holding multiple professional identities can be both beneficial or cause tensions (Billot, 2010) depending on how these identities and associated roles are perceived by both the individual and others. For example, in the higher education context teaching is often considered less prestigious than clinical or research activities (Ortiz-Paredes et al., 2022; Sabel & Archer, 2014).

However, changes in the higher education landscape, particularly within the UK, such as the introduction of the Teaching Excellence Framework (TEF), the National Student Survey (NSS) and a rise in tuition fees, have brought greater emphasis to and focus on teaching quality.

To respond to these changes and the increased focus on teaching quality, many higher education institutions have developed teaching-focused roles: staff whose primary remit is teaching, with no or little requirement to undertake research in their primary discipline. However, staff in teaching-focused roles often experience a lack of clear career pathways and less esteem than research-focused colleagues, both of which can impact negatively on the development of their professional identity and sense of belonging. And without a strong professional identity and sense of belonging, staff in these teaching-focused roles may not have the impact that they could.

This chapter therefore draws upon existing literature to discuss the factors that influence professional identity development and sense of belonging amongst higher education teachers. Key concepts such as agency and boundary crossing are used to illuminate the identity tensions and synergies that higher education teachers might experience. Practical strategies to foster professional identity and sense of belonging are explored, including faculty development initiatives (Lieff et al., 2012), the impact of pursuing formal educational qualifications (Sethi et al., 2018), the development of educational networks (van Lankveld, Schoonenboom, Volman et al., 2017) and longitudinal approaches (Jauregui et al., 2019).

Within this chapter the term 'university teachers' is used to refer to anyone in a university context who is involved in teaching students, either undergraduate or postgraduate. As Skelton helpfully notes, university teachers may have differing levels of engagement with teaching; he refers to 'teaching specialists', 'blended professionals' and 'researchers who teach' (2012, p. 23). The term 'teaching' refers to a range of activities, including lecturing, facilitating seminars and group work, supervision at various levels including PhD supervision, pastoral support, personal tutoring, and teaching in laboratories and on fieldwork.

It is also important to note, as other authors have (e.g. Kandiko Howson and Kingsbury, Chapter 1 in this volume), the distinction between not belonging and not yet belonging. Developing a sense of belonging may be more challenging for marginalised groups, and in addition there may be individuals who choose, for good reason, not to develop a sense of belonging within their work context. The focus of the strategies discussed in this chapter is on developing a sense of belonging (for example, from a position of not yet belonging), although the concept of non-belonging should be acknowledged. Individuals may find a sense of belonging in their professional role through different methods and in different settings, and therefore a 'one size fits all' approach to supporting higher education teachers is unlikely to be successful. The concept of professional identity has been critiqued for perpetuating a historically white, male, heteronormative view of professional identity and not acknowledging how professional identity might be presented differently within diverse populations (Volpe et al., 2019). Those within universities who have a role in supporting the professional identity development of teachers and developing their sense of belonging, such as educational developers, should be mindful of these nuances and critiques.

Conceptualising identity development

Early theories of identity tended to focus on identity development as a staged process through which identity is developed and then becomes fixed (Monrouxe & Rees, 2015). However, contemporary theories of identity development focus on its being a dynamic, fluid and changing process (Feser & Haak, 2023; Monrouxe, 2010) that is continually being constructed and negotiated (Barrow & Xu, 2022; Trede et al., 2012). A significant range of other identity development theories exist, including those positioned in cognitive, sociocultural or narrative approaches (Monrouxe & Rees, 2015).

Approaches to identity development can be grouped into the theoretical frameworks of the personal, the social and the collective (Feser & Haak, 2023). Personal theories of teacher identity focus on the individual's personal attributes, such as their subject knowledge, and on their beliefs about teaching. For example, university teacher identities are constructed through interaction between personal beliefs about and values related to the role and practice of teaching, and one's self-identity and self-concept (Kreber, 2010). Social theories focus on group membership and role as key factors in professional identity development (Cornett et al., 2023), and collective theories focus on the identity of a group of individuals, for example a sports team or a religious group.

Collective identities are closely intertwined with, and influenced by, group membership and the interaction between group members. A collective identity can facilitate a sense of belonging and strengthen identity through common norms and values which are passed on through shared stories and narratives (Feser & Haak, 2023). Whilst there is a range of lenses and theories through which to consider professional identity development, many current theories on professional identity development have the view that identity development is a process of ongoing construction, reconstruction, negotiation and renegotiation in response to others and to changing contexts (McNaughton & Billot, 2016; Sheridan, 2013).

What is professional identity and why is it important?

Many definitions of professional identity focus on identity or self-image, which encompasses the values, behaviours, attitudes and standards that align with the expectations of a particular profession (Trede et al., 2012). Professional identity is typically considered to be influenced by socialisation, by how an individual thinks about themselves, and by how others think about them (Bale & Anderson, 2022; van Lankveld, Schoonenboom, Kusurkar et al., 2017). Van Lankveld et al. also argue that identity development has an emotional component: the professional identity of an individual is part of who they are and so they have an emotional connection to it. Professional identity includes a sense of belonging to a professional group (Sturtevant & Wheeler, 2019), and sense of belonging has been shown to be a key component of an individual's professional identity (Barbour & Lammers, 2015).

Trede et al. (2012) suggest that professional identity is a useful concept through which professionals can learn, develop and evaluate their practice. It is an organising element through which teachers make sense of their role and bring meaning to educational activities (Beauchamp & Thomas, 2009). However, university teachers' identity is complex, as they typically hold multiple identities, for example researcher, manager or practitioner (e.g., health care professional, engineer, lawyer) alongside their teacher identity (Trautwein, 2018). But the importance to university teachers of a strong professional identity is well established (van Lankveld, Schoonenboom, Volman et al., 2017) and linked to well-being, motivation, productivity (Lieff et al., 2012), to adopting a learner-centred approach to their teaching practice (Pape et al., 2018) and greater career satisfaction (Triemstra et al., 2021). Strong university teacher identity has also been linked to openness to professional development as a teacher and to a greater likelihood of trying new techniques, both of which have been shown to improve teaching and learner outcomes (Snook et al., 2019).

Therefore, supportive mechanisms need to be in place to ensure that this complexity, and the multiple identities that a university teacher holds, can be advantageous rather than causing tensions, which may lead to erosion of identity (Jauregui et al., 2019). It is important that university leaders and educational developers consider how strong professional identities amongst university teachers can be developed and how a sense of belonging – an important component of identity development – can be cultivated (Sturtevant & Wheeler, 2019).

Change in higher education landscapes and the position of teaching as a role and practice

In recent years, recognition of the importance of teaching and learning within universities has increased (van Dijk et al., 2020). In the UK specifically, more emphasis has been placed on teaching in higher education because of various government policies. These have included an increase in student numbers, the introduction of the Teaching Excellence Framework (Gunn, 2018), and the development of quality assurance processes such as the National Student Survey (Bell & Brooks, 2018). These policies have resulted in greater emphasis on curriculum design and development, and a focus on teaching quality and on student satisfaction and experience (Smith & Walker, 2024).

There has also been greater emphasis on the accreditation of university teachers, for example a requirement to have a postgraduate certificate in education or to be accredited by organisations such as Advance HE (a UK-based membership organisation focused on improving higher education for staff and students) or by discipline-specific organisations such as the Academy of Medical Educators. The greater use of technology has also impacted on how teachers and students engage with learning and with each other (McNaughton & Billot, 2016). Similar changes have occurred in higher education systems in other countries, for example as shown in Laiho et al.'s (2022) research on university teacher identity development within a Finnish university.

In addition, and as a response to these changes, many universities introduced teaching- or education-focused staff members, sometimes called teaching fellows, and often located in non-academic job families. These roles focus on teaching, assessment, and curriculum development, and such education-focused roles may be viewed either positively or negatively. For example, changes to funding mean that research posts are in decline, and so individuals may take a positive step of moving to a more teaching-focused role in order to remain in academia and make use of their subject knowledge (Peters & Turner, 2014). Those in teaching-focused positions may choose this type of role to pursue their interests in teaching, supervision and the pastoral care of students, or to seek opportunities for educational research and scholarship, although typically such roles have little or no allocated time for research and scholarship. Such posts are often fixed-term and temporary, sometimes being filled to cover gaps in teaching provision (Peters & Turner, 2014).

Despite the increase in these teaching-focused roles, there is a lack of clear pathways for career progression, and few teaching-focused academics are represented at senior leadership levels (Smith & Walker, 2024). Thus, neoliberal practices impact on all university staff, but particularly teaching-focused staff (Lopes & Dewan, 2014), and experiences of casualisation and insecurity in relation to job role and contract can have negative impacts on professional identity and sense of belonging (Read & Leathwood, 2020).

These changes and the way teaching is viewed mean that the landscape of higher education is increasingly complex in terms of university teachers developing a strong professional identity and sense of belonging both in their local context and in the wider academic community (see also Hauke, Chapter 7 in this volume). Therefore, an intentional focus on professional identity is important in supporting university teachers who are navigating this changing and complex landscape.

Case study: pedagogical training evolution

Voluntary

In common with most other UK institutions of higher education, Imperial College London, a medium-sized research-intensive STEM-focused institution, provides training for staff involved in teaching. Initially this was limited to a range of half- to two-day workshops. Three one-day workshops were compulsory for most probationary staff involved in teaching. In January 2001 the institution launched a voluntary academic programme for those interested in teaching, the Certificate of Advanced Study in Learning and Teaching (CASLAT). The master's-level programme was offered by a central educational-development staff, and recruited annually until January 2010. Whilst it was initially a voluntary part-time programme free to interested staff, it was briefly made a compulsory requirement for probation, between 2007 and its end in 2010.

The programme aimed to ensure that participants built on a foundation of practice and theory of teaching, supervision, learning, assessment and course design in higher education. The teaching methods encouraged participants and tutors to engage constructively in critical examination of the underpinning theory and principles, to consider the implications of these for pedagogical practice, and to scrutinise and enhance their own practice. The programme was sensitive to the STEM-focused nature of disciplines at the institution, the various levels of teaching (undergraduate and postgraduate), and the wider Imperial College context. The programme drew upon education theory and research, but retained a primary intention to focus on practice, showcasing good practice across the higher education sector. It assumed that all participants were experts in their disciplinary field and fully conversant with the subject material they taught. Therefore, the programme provided a recognised qualification for teaching. It built on the fledgling community of practice of STEM teachers that had arisen from a subgroup that voluntarily engaged with the initial training offer and went beyond the compulsory requirements. This group sought out professional development and recognition in addition to that supplied as part of induction and the more basic, pragmatic training and support offered to all teaching staff.

Compulsory

Initially CASLAT was popular with university staff and National Health Service (NHS) staff teaching on the undergraduate medicine programme. Cohort numbers grew from 10 to around 25 in 2007, when it was made compulsory. This changed the nature of the cohort, and many of the 45 participants did little teaching and were frustrated at being required to complete a teaching qualification during probation, when they were prioritising developing their research. This move towards compulsion was detrimental to the community of practice and in September 2010 the programme was relaunched as a voluntary, three-stage, part-time master's programme in University Learning and Teaching.

Competitive entry

When the course relaunched it offered a limited number of places, with competitive entry. The first stage is a postgraduate Certificate of University Learning and Teaching (PGCert); this is flexible and based in participants' practice. Similarly to the CASLAT, it aims to provide a foundation for practice based in education theory, but the emphasis is on the participants' disciplinary context and their teaching practices. On completing this stage participants have three options: exit with the PGCert qualification, pause and hold the academic credit for up to two years to facilitate agentic control of complex STEM research careers, or continue to the next level.

The second level is a PG Diploma. This is different from the PGCert and the CASLAT that preceded it, taking STEM-discipline experts away from their practice and teaching them to engage critically with education theory and literature in a social science paradigm. Once again, on completion of this stage participants can exit with the qualification earned, pause and hold the academic credit or continue to study for the full master's in University Learning and Teaching. This final stage focuses on teaching education research methodology and methods to students who are usually new to qualitative approaches, despite being expert in the quantitative approaches more common in their primary STEM disciplines. In the master's, students complete a research study that applies their newly acquired critical knowledge of educational theory in their own disciplinary teaching context.

Institutionally tailored

The new course has been very successful, with around 100 applicants every year for 45 places on the initial PGCert stage. Between 2010 and 2022 there have been 193 students who have graduated with a full MEd in University Learning and Teaching. These students have developed a new identity, with dual expertise in their STEM discipline and STEM-based pedagogical expertise. Many staff have progressed into positions of educational leadership across the institution, forming a distributed community of pedagogical expertise.

The rationale behind this programme is based on flexibility, and relevance to the students' STEM areas; and by being academically challenging it recognises the prestige of education as a discipline. The competitive application follows the nature of STEM research and the institutional culture. The course provides a portable and valuable formal qualification and professional recognition through fellowship of Advance HE. Further, it offers a community of practice, and a distributed educational expertise that has changed institutional culture and increased the prestige of teaching and learning in a research-intensive context.

Recent developments to extend pedagogical training, and scholarship in learning and teaching, have been the instigation and funding of joint discipline-based educational research PhD projects which are supervised jointly by MEd graduates in the discipline and by centrally based pedagogical experts. Two such funded positions are available a year and the competitive bidding process invites research proposals linked to the institutional educational strategy. This provision offers further development opportunities and recognition for the STEM pedagogy community and provides research that benefits the disciplines and the institution, and increases the voice and visibility of STEM education research in the wider higher education sector.

Developing a sense of belonging

Evaluation of this programme has shown that for many participants it provides an important community, and for some it validated the choice to move to a more teaching-focused role and thus supported their identity development as an educator (Murray, 2022). Supportive teaching teams are not universal, and so the MEd programme provides a space for participants to develop their sense of belonging outside of these teams. The programme is designed to develop this sense of belonging and community via several mechanisms. Firstly, the programme brings together staff from all departments and faculties as well as support services such as the library and careers services. Secondly, the teaching sessions often include group work, for example critiquing articles or producing posters on learning theories, and these groups are of mixed disciplines. Participants often remark on the benefit of these cross-disciplinary groups. Finally, outside of these teaching sessions, students are encouraged to engage with one another through a peer observations process at PGCert level, as well as in online discussion forums. Participants are encouraged to engage with cross-college education groups and events, often taking a lead in these activities.

There is, however, a risk in relying on a single programme to foster belonging amongst all educators. The MEd programme does require time and commitment, and students often undertake some of this study outside of work hours. This has led to some feeling frustrated and undervalued, particularly as they viewed the completion of the MEd programme as directly relevant to their job role. Those with caring responsibilities or chronic illness may find completing the programme more challenging (Murray, 2022). However, the number of professional development days for teaching staff has recently been increased to 10, in line with research-focused staff, which may make completion of such a programme more feasible. Even after completing the programme, participants were seeking additional community-building opportunities (Murray, 2022). Other opportunities to build community amongst teachers at Imperial include cross-college events focused on teaching and learning, engagement with Imperial's Supporting Teaching Accreditation and Recognition (STAR) framework leading to fellowship of Advance HE, and education-focused Special Interest Groups; all provide alternative spaces of belonging for those not engaged with the MEd programme. Furthermore, one aim of the MEd programme is to develop a distributed network of educational expertise. Therefore, holders of the MEd are well placed to support the sense of belonging and identity development of other teachers within their primary discipline and thus to influence the wider teaching culture within departments.

Factors influencing university teachers' professional identity development

Numerous factors have been found to influence the professional identity development of university teachers. The psychological processes involved in university teachers' identity development include being appreciated, having a sense of belonging, believing oneself to be competent in the role, being committed to teaching, and being able to imagine a future career path (van Lankveld, Schoonenboom, Volman et al., 2017). Challenges to developing a strong teacher identity include the low prestige given to education and teaching in some contexts, the transition from one professional identity to another (e.g., clinician or researcher to teacher), managing multiple identities (e.g., teacher, researcher, manager), a lack of education community, and feeling undervalued (Snook et al., 2022).

Many authors recognise the tensions that often occur when people are developing a teacher identity, as university teachers aim to reconcile different elements of their identity, as well as the conflicting messages they might receive about the role and status of teaching. As van Lankveld, Schoonenboom, Volman et al. (2017) argue, teacher identity development does not occur in a vacuum; rather, it is influenced by social and cultural factors. Within the workplace, such factors include the dominant discourses about education and the role of students as well as professional hierarchies (Cornett et al., 2023). Such discourses can either hinder or facilitate professional identity development. A lack of opportunities for training and professional development can also impede professional identity development and a sense of belonging amongst university teachers (Cornett et al., 2023). Several of these factors – institutional culture, teacher agency and boundary crossing – are considered in more detail.

Institutional culture of teaching and learning

University teacher identity is shaped by the norms and values of the culture within which teachers work (O'Sullivan & Irby, 2011) This may be at the level of the university, or that of a department or degree programme. Often these norms and values are not explicitly expressed; however, this culture around teaching and education can either support or undermine teacher identity development. In cases where a cultural norm is that education is not important, teachers may feel marginalised or undervalued (van Lankveld, Thampy et al., 2021). One example of such a norm is that research and clinical activities may be prioritised over teaching activities (Kreber, 2010; Sabel & Archer, 2014; van Dijk et al., 2020). Church and Brown (2022) have highlighted the stigmatisation of clinical doctors who move into medical education roles. They emphasise a lack of clear career pathways, and a hierarchy which positions clinical expertise and experience above educational expertise and experience (even for senior medical education roles), as factors contributing to the stigma that those such as medical educators are likely to experience. Institutional culture can also hinder engagement with professional development activities and networks, and, in doing so, lessen teachers' identity.

Teacher agency

Agency has also been recognised as an important factor in university teachers who are developing their professional identity (Du et al., 2021). Agency is teachers' ability to act and make decisions about their professional practice. Greater demands placed on university teachers to implement pedagogical innovations, prepare students for a complex future world and provide pastoral support, as well as keep up to date with disciplinary research, can challenge identities and the agency that university teachers have. Utilising individual agency can be an important strategy in navigating this complex academic landscape and for individuals to develop their desired identity. However, many lack agency and therefore feel unable to develop their professional identity.

Boundary crossing

As previously discussed, many university teachers hold multiple professional identities (McCune, 2021; van Dijk et al., 2020) and are members of several different communities of practice (Wenger, 1998), such as their primary discipline community and an education or teaching community. Crossing between these communities, often called boundary crossing (Akkerman & Bakker, 2011), can be both challenging and beneficial. One challenge of moving towards an education-focused community of practice is engagement with new paradigms of research, new terminology and new ways of thinking about learning and teaching (Kneebone, 2002). Undertaking pedagogical research can mean engaging with research methods and methodologies that may be very different from teachers' disciplinary background, which may unsettle their sense of identity (Tierny et al., 2020).

In addition, teachers moving towards a more education-focused role may find themselves without a disciplinary 'home', or find their disciplinary identity lessening, which may contribute to a sense of not belonging. For example, clinically qualified medical educators often occupy a liminal space between their clinical role and practice, which they feel gives them more credibility, and their educational role and practice, which they feel gives them less (Browne et al., 2018). Their primary discipline identity might lessen as they take on more teaching and undertake less research within their discipline.

Sturtevant and Wheeler (2019) found that tensions between research and teacher identities were a barrier to implementing an evidence-based pedagogical approach within a science, technology, engineering and mathematics (STEM) context. However, those who work across such disciplinary boundaries can develop the professional identity of a broker (Wenger, 1998). This role can be beneficial in terms of sharing learning and expertise (Wenger et al., 2002) and bringing new cultures and practices to a community (Wenger, 1998). The challenges of this role can be mitigated through effective social support (van den Berg et al., 2017) and connection with others who have similar roles.

Practical strategies to foster university teachers' identity and sense of belonging

Given both the complexity and the importance of identity development and cultivating a sense of belonging, which is important for identity development, universities need to adopt an intentional and multifaceted approach to these processes. The following strategies are drawn from research on university teacher identity development.

Faculty development initiatives

Many university teachers engage with faculty or educational development activities, not only those which are required as part of an induction process. However, few faculty development programmes explicitly focus on the professional identity development of educators (Ortiz-Paredes et al., 2022). Therefore, educational and faculty developers should consider where there might be opportunities for building a sense of belonging and supporting identity development within faculty development programmes, or indeed one-off workshops. Specifically, Lieff et al. (2012) recommend that faculty developers be cognisant of the personal, relational and contextual factors involved in teacher identity development, and that the design and implementation of faculty development programmes take account of these factors. This might include being explicit about identity development, providing opportunities for sharing experiences and challenges with others, and facilitating access to role models and opportunities for reflection on practice (Steinert, 2010).

In addition, Whitton et al. (2022) recommend that faculty development programmes are not one-off events but rather programmes that build communities and thus develop a sense of belonging in participants. Bouwma-Gearhart (2012) found that university STEM educators were motivated to engage with faculty development initiatives in order to connect with other university teachers, rather than solely from a desire to develop their teaching practices, and therefore this motivation could be capitalised on. Such programmes should also be endorsed by senior leaders and align with institutional aims which see teaching as a valued endeavour (Steinert et al., 2019).

Several researchers have also highlighted the importance of induction in supporting professional identity development and developing a sense of belonging, particularly for newer university teachers (Sánchez-Tarazaga et al., 2022). Induction can provide opportunities for socialisation and connecting with others, which feed into the development of a teacher identity for new staff (Billot & King, 2017). Despite this, Ennals et al. (2016) found that induction often focused on the 'doing' aspects of academic work, with few or no opportunities to consider its 'being' and 'belonging' aspects. Therefore, induction should address aspects of developing a professional identity and provide opportunities for enhancing belonging through engagement with others. Van Lankveld, Schoonenboom, Kusurkar et al. (2017) suggest that positive stories and examples about teaching are particularly helpful for newer university teachers to identify with and that they could be included in an induction programme.

Furthermore, opportunities for reflection on an individual's teaching role and identity should be included (Sánchez-Tarazaga et al., 2022). Reflection on teaching beliefs and experiences, ideally with an experienced mentor, can be an important mechanism for newer teachers' identity development (Trede et al., 2012; Walkington, 2005). These examples provide opportunities for newer teachers to connect with others and develop their sense of belonging with other teachers and the wider institution.

Communities of practice and networks

Wenger (1998) describes a community of practice as a group of people who together learn to perform an activity or develop a role. The original intention of the theory was to describe how people might develop their practice, role and identity within a work context, rather than prescribing the ideal way to do this. However, many organisations and workplaces (including universities) have used this theory in an intentional way to develop communities as a mechanism for professional learning and development (de Carvalho-Filho et al., 2020).

Within such communities of practice less experienced teachers can engage with and learn from those who are more experienced. The deliberate and intentional creation of such communities of practice provides ways teachers can share experiences and in doing so construct their teacher identity (Kensington-Miller, 2021). In addition, creating communities of practice for teachers has been found to facilitate a sense of belonging amongst university teachers (Barrow & Xu, 2022; van Lankveld, Schoonenboom, Volman et al., 2017). Recognising that others had similar experiences and faced similar challenges facilitated a sense of belonging and encouraged teachers to take action to develop their practice and identity.

Reporting on a local faculty learning community, MacKenzie et al. (2010) found that membership of such communities strengthens professional identities and addresses feelings of isolation. They argue that engagement in such communities results in more motivated teachers who then have a greater positive impact on their students. Such communities also provide access to mentors and role models who are important in the process of socialisation and thus to development as an educator (Pape et al., 2018; Triemstra et al., 2021). Educational communities of practice also provide opportunities to share learning and create useful support networks (Steinert, 2010). Support from seniors and from belonging to a community of practice enhances identity development (Soemantri et al., 2023), and motivation to teach has been shown to be influenced by feeling connected to such education communities (Wisener et al., 2021).

However, if such positive outcomes are to be achieved, care must be taken to construct and maintain educational communities of practice. De Carvalho-Filho et al. (2020) provide useful strategies for doing so, including ensuring clarity about the goals and values of the community of practice, making it inclusive and non-judgemental, and ensuring its sustainability. Educational communities of practice risk becoming isolated and siloed; local communities of practice which are integrated into research or clinical contexts can allow professional identity development to take place over time and in a context where the educational challenges teachers are experiencing are located (Cuming & Horsburgh, 2019).

Education networks have been shown to be useful mechanisms for strengthening teacher identity development and developing a sense of belonging amongst teachers (Hurkett & Raine, 2013; Triemstra et al., 2021; van Lankveld, Schoonenboom, Volman et al., 2017). These may be local, sometimes informal in nature and self-organising (van Lankveld, Thampy et al., 2021), or wider, sometimes linked to higher education membership organisations or disciplinary societies.

Formal qualifications and accreditation

Completing a formal qualification in education, such as a Master's in Education, has been found to impact on teacher identity development, both on the way teachers saw themselves and on how others saw them (Sethi et al., 2018). The impact included increased confidence as teachers and in their teacher identity, although the process of undertaking an education qualification can have a disorienting effect for some (Ippolito & Pazio, 2019). But Hodson (2021) argues that rather than hiding this uncomfortable aspect of professional development, or viewing it as a negative process, such academic programmes can support teachers to become 'brokers' and work across disciplinary boundaries, sharing knowledge between themselves and in doing so developing a valid and important role and identity.

However, not all university teachers have the capacity or motivation to undertake formal qualifications; accreditation by professional bodies can provide an alternative way of demonstrating a level of proficiency in teaching and engagement in professional development as a teacher. Such accreditation typically involves a written application, oral presentation or portfolio, which require the applicant to reflect on their practice and development as a teacher. This exercise provides an opportunity to reflect on one's professional identity as a teacher, one's beliefs and philosophies about teaching, and aspects of practice for further development. Many universities provide institutional programmes and frameworks for such accreditation and, whilst a university teacher may go through the process as an individual, engagement in such a scheme can also provide access to communities of practice and networks of other educators (both local and national). In addition, the mentoring and coaching which often form part of such programmes can support a sense of belonging (Zaniewski & Reinholz, 2016) which leads to a greater commitment to education (Lee et al., 2023).

Organisational culture

The culture of an institution or department in relation to education (is education valued? is professional development as an educator promoted?) has been shown to shape educator identity development (Triemstra et al., 2021). Focusing on the developmental of medical educators specifically, Church and Brown (2022) consider an organisational culture approach to addressing the stigma of those who move away from clinical practice to an education-focused role, and thus supporting the identity development of these educators. Proposed strategies for addressing this stigma include greater acceptance of diverse career paths, opening leadership roles to all regardless of disciplinary background, mentorship, and funding to pursue formal educational qualifications such as a master's or a PhD. This focus on organisational culture as a way to address the stigma and lack of a sense of belonging that clinical educators experience is likely to be transferable to other disciplinary contexts within higher education.

Organisational culture may also facilitate or hinder teacher agency, which has been shown to impact on professional identity. Individual agency has been shown to be important in negotiating and making sense of a newly developed educator identity, particularly for someone graduating from a faculty development programme or similar, and thus reconstructing and negotiating this identity within the workplace context (Jauregui et al., 2019). Positive outcomes from undertaking faculty development are more likely to be implemented within a workplace if they are supported by the culture and if agency is high. If individual agency is high but the context does not support or value education, then university teachers are likely to experience 'identity frustration'. If the context values education, but teachers do not have high levels of agency then 'identity drift' is likely. Therefore, the organisational culture needs both to value education and to support and facilitate individual teacher agency in order for 'identity salience' to occur and identity development to be strengthened (Jauregui et al., 2019).

The concept of job crafting, from organisational psychology, provides a useful lens through which to consider how teacher agency influences how university teachers make sense of their role, identity and practice. Bochatay et al. define job crafting as 'the dynamic relationship between individuals' sense of identity, the work they perform and their formal roles that are associated with different levels of autonomy' (2020, p. 973).

Job crafting can be used when an individual feels that there is misalignment between their identity and the work they are engaged with; it can be undertaken in three main ways. The first is task crafting, which involves an individual changing the tasks that they engage with (as far as they can). Secondly, relationship crafting involves giving some work relationships precedence over others. Finally, cognitive crafting involves reframing how an individual thinks about their work (Bochatay et al., 2020). Facilitating university teachers to engage with job crafting can be one way to promote ownership of their professional identity formation (Bochatay et al., 2020).

Practical strategies have been shown to promote the value of education and university teachers' identity. Peters (Peters & Turner, 2014) writes about the importance to her, as a newly appointed teaching fellow, of being allocated an office with her own name plate, which enabled her to have a sense of belonging. Virtual places such as a professional webpage can contribute to respect for teaching fellows (Peters & Turner, 2014). Time to undertake professional development, qualifications, and professional recognition can enhance the value of education and teachers. Van Lankveld, Thampy et al. (2021) also stress the importance of linking such qualifications and recognition to career progression and promotion, which give such recognition value and meaning. However, it is important that the necessary time and support are given, so that engaging in qualifications or other professional development and recognition is accessible to all.

As part of the culture of teaching and learning, many universities have awards and prizes for teachers. These often address a range of educational activities, such as pastoral support, PhD supervision and lecturing. Such award schemes are often instigated to reward and recognise high-quality education and thus highlight the value of teaching and learning. National awards such as National Teaching Fellowships also aim to raise the profile of and provide a sense of value to teaching roles and activities (Skelton, 2004), thus supporting identity development (Hurkett & Raine, 2013). However, Hurkett and Raine (2013) caution that such awards can risk causing disadvantage to recipients. Prizes and awards for teaching may be viewed negatively depending on the status that teaching is given within an institution, and they may cause greater division between teaching and research. Furthermore, well-intentioned incentives for teaching can have a negative impact if they are felt to be impersonal or not equitable in distribution (Wisener et al., 2021), or where policies of recognition for teaching are not reflected in the practices of institutional or departmental culture (Cox et al., 2011). At Imperial College London the current Learning and Teaching Strategy (Imperial College London, 2017) utilises a competitive internal grant application process and funded PhDs in education to recognise the existing joint expertise in the discipline and pedagogy of the discipline. This purposeful mimicry of the processes and values of research can go some way to preventing a division between teaching and research.

Conclusion

Identity development and a sense of belonging are important to higher education teachers for a variety of reasons. The changing and complex nature of higher education means that often university teachers hold multiple identities which may be beneficial or cause tensions. It also means that teacher identity development involves a continual process of negotiation and renegotiation. Given this complex nature of identity development, a 'one size fits all' approach to supporting higher education teachers is not suitable and several practical strategies are needed. Specifically, university leaders and educational developers should focus on strategies that support the individual, social and collective aspects of identity development.

As well as addressing one or more of these aspects of teacher identity development, practical strategies are opportunities to engage with others and share experiences, which can cultivate a sense of belonging. However, educational developers and university leaders need to caution against these approaches becoming siloes and thus perpetuating a lower status for teaching. Therefore, in addition to individual strategies to strengthen professional identity development, an organisational culture approach is required to ensure that higher education teachers are working within a context in which they are valued and recognised.

References

Akkerman, S. F. & Bakker, A. (2011). Boundary crossing and boundary objects. *Review of Educational Research*, 81(2), 132–69. https://doi.org/10.3102/0034654311404435.

Bale, R. & Anderson, M. (2022). Teacher identities of graduate teaching assistants: How we (de) legitimise GTAs' role identities. *Teaching in Higher Education*, 1–16. https://doi.org/10.1080/13562517.2022.2109015.

Barbour, J. B. & Lammers, J. C. (2015). Measuring professional identity: A review of the literature and a multilevel confirmatory factor analysis of professional identity constructs. *Journal of Professions and Organization*, 2(1), 38–60. https://doi.org/10.1093/jpo/jou009.

Barrow, M. & Xu, L. (2022). Constructing university-based teacher educators: Serendipity, complexity and community. *Higher Education Research & Development*, 42(3), 530–43. https://doi.org/10.1080/07294360.2022.2089099.

Beauchamp, C. & Thomas, L. (2009). Understanding teacher identity: An overview of issues in the literature and implications for teacher education. *Cambridge Journal of Education*, 39(2), 175–89. https://doi.org/10.1080/03057640902902252.

Bell, A. R. & Brooks, C. (2018). What makes students satisfied? A discussion and analysis of the UK's national student survey. *Journal of Further and Higher Education*, 42(8), 1118–42. https://doi.org/10.1080/0309877X.2017.1349886.

Billot, J. (2010). The imagined and the real: Identifying the tensions for academic identity. *Higher Education Research & Development*, 29(6), 709–21. https://doi.org/10.1080/07294360.2010.487201.

Billot, J. & King, V. (2017). The missing measure? Academic identity and the induction process. *Higher Education Research & Development*, 36(3), 612–24. https://doi.org/10.1080/07294360.2017.1288705.

Bochatay, N., van Schaik, S. & O'Brien, B. (2020). Medical trainees as job crafters: Looking at identity formation through another lens. *Medical Education*, 54(11), 972–4. https://doi.org/10.1111/medu.14342.

Bouwma-Gearhart, J. (2012). Research university STEM faculty members' motivation to engage in teaching professional development: Building the choir through an appeal to extrinsic motivation and ego. *Journal of Science Education and Technology*, 21, 558–70. https://doi.org/10.1007/s10956-011-9346-8.

Browne, J., Webb, K. & Bullock, A. (2018). Making the leap to medical education: A qualitative study of medical educators' experiences. *Medical Education*, 52(2), 216–26. https://doi.org/10.1111/medu.13470.

Church, H. & Brown, M. E. L. (2022). Rise of the Med-Ed-ists: Achieving a critical mass of non-practicing clinicians within medical education. *Medical Education*, 56(12), 1160–2. https://doi.org/10.1111/medu.14940.

Cornett, M., Palermo, C. & Ash, S. (2023). Professional identity research in the health professions: A scoping review. *Advances in Health Sciences Education*, 28(2), 589–642. https://doi.org/10.1007/s10459-022-10171-1.

Cox, B. E., McIntosh, K. L., Reason, R. D. & Terenzini, P. T. (2011). A culture of teaching: Policy, perception, and practice in higher education. *Research in Higher Education*, 52(8), 808–29. https://doi.org/10.1007/s11162-011-9223-6.

Cuming, T. & Horsburgh, J. (2019) Constructing surgical identities: Becoming a surgeon educator. In D. Nestel, K. Dalrymple, J. T. Paige & R. Aggarwal (eds), *Advancing Surgical Education: Theory, evidence and practice*, pp. 133–40. Singapore: Springer.

de Carvalho-Filho, M. A., Tio, R. A. & Steinert, Y. (2020). Twelve tips for implementing a community of practice for faculty development. *Medical Teacher*, 42(2), 143–9. https://doi.org/10.1080/0142159x.2018.1552782.

Du, X., Naji, K. K., Ebead, U. & Ma, J. (2021). Engineering instructors' professional agency development and identity renegotiation through engaging in pedagogical change towards PBL. *European Journal of Engineering Education*, 46(1), 116–38. https://doi.org/10.1080/03043797.2020.1832444.

Ennals, P., Fortune, T., Williams, A. & D'Cruz, K. (2016). Shifting occupational identity: Doing, being, becoming and belonging in the academy. *Higher Education Research & Development*, 35(3), 433–46. https://doi.org/10.1080/07294360.2015.1107884.

Feser, M. S. & Haak, I. (2023). Key features of teacher identity: A systematic meta-review study with special focus on teachers of science or science-related subjects. *Studies in Science Education*, 59(2), 287–320. https://doi.org/10.1080/03057267.2022.2108644.

Gunn, A. (2018). Metrics and methodologies for measuring teaching quality in higher education: Developing the Teaching Excellence Framework (TEF). *Educational Review*, 70(2), 129–48. https://doi.org/10.1080/00131911.2017.1410106.

Hodson, N. (2021). Equipping brokers for medical landscapes of practice. *Medical Education*, 55 (10), 1114–16. https://doi.org/10.1111/medu.14598.

Hurkett, C. & Raine, D. (2013). UKTF Forum: Supporting the teaching fellow community. *New Directions in the Teaching of Natural Sciences*, 9(1), 33–41. https://doi.org/10.29311/ndtps.v0i9.485.

Imperial College London (2017). Innovative teaching for world class learning: Learning and teaching strategy. Imperial College London.

Ippolito, K. & Pazio, M. (2019). Suck it and see: Transforming STEMM university teachers' assessment perspectives and practices through disorientating experiential learning. *Higher Education Pedagogies*, 4(1), 331–46. https://doi.org/10.1080/23752696.2019.1631707.

Jauregui, J., O'Sullivan, P., Kalishman, S., Nishimura, H. & Robins, L. (2019). Remooring: A qualitative focus group exploration of how educators maintain identity in a sea of competing demands. *Academic Medicine*, 94(1), 122–8. https://doi.org/10.1097/acm.0000000000002394.

Kensington-Miller, B. (2021). 'My attention shifted from the material I was teaching to student learning': The impact of a community of practice on teacher development for new international academics. *Professional Development in Education*, 47(5), 870–82. https://doi.org/10.1080/19415257.2019.1677746.

Kneebone, R. (2002). Total internal reflection: An essay on paradigms. *Medical Education*, 36(6), 514–18. https://doi.org/10.1046/j.1365-2923.2002.01224.x.

Kreber, C. (2010). Academics' teacher identities, authenticity and pedagogy. *Studies in Higher Education*, 35(2), 171–94. https://doi.org/10.1080/03075070902953048.

Laiho, A., Jauhiainen, Arto & Jauhiainen, Annukka (2022). Being a teacher in a managerial university: Academic teacher identity. *Teaching in Higher Education*, 27(2), 249–66. https://doi.org/10.1080/13562517.2020.1716711.

Lee, D. W-C., Tan, C. K. N., Tan, K., Yee, X. J., Jion, Y., Roebertsen, H. & Dong, C. (2023). How community and organizational culture interact and affect senior clinical educator identity *Medical Teacher*. https://doi.org/10.1080/0142159X.2023.2262103.

Lieff, S., Baker, L., Mori, B., Egan-Lee, E., Chin, K. & Reeves, S. (2012). Who am I? Key influences on the formation of academic identity within a faculty development program. *Medical Teacher*, 34(3), E208–E215. https://doi.org/10.3109/0142159x.2012.642827.

Lopes, A. & Dewan, I. A. (2014). Precarious pedagogies? The impact of casual and zero-hour contracts in higher education. *Journal of Feminist Scholarship*, 7(7), 28–42. https://digitalcommons.uri.edu/jfs/vol7/iss7/5. Accessed 26 December 2023.

MacKenzie, J., Bell, S., Bohan, J., Brown, A., Burke, J., Cogdell, B., Jamieson, S., McAdam, J., McKerlie, R., Morrow, L., Paschke, B., Rea, P. & Tierney, A. (2010). From anxiety to empowerment: A learning community of university teachers. *Teaching in Higher Education*, 15(3), 273–84. https://doi.org/10.1080/13562511003740825.

McCune, V. (2021). Academic identities in contemporary higher education: Sustaining identities that value teaching. *Teaching in Higher Education*, 26(1), 20–35. https://doi.org/10.1080/13562517.2019.1632826.

McNaughton, S. M. & Billot, J. (2016). Negotiating academic teacher identity shifts during higher education contextual change. *Teaching in Higher Education*, 21(6), 644–58. http://dx.doi.org/10.1080/13562517.2016.1163669.

Monrouxe, L. V. (2010). Identity, identification and medical education: Why should we care? *Medical Education*, 44(1), 40–9. https://doi.org/10.1111/j.1365-2923.2009.03440.x.

Monrouxe, L. V. & Rees, C. E. (2015). Theoretical perspectives on *identity*: Researching identities in healthcare education. In J. Cleland and S. J. Durning (eds), *Researching Medical Education*, pp. 129–40. Chichester: Wiley Blackwell.

Murray, Ó. M. (2022). Enhancing academic culture: The role of teaching fellows and learning technologists. Imperial College London.

Ortiz-Paredes, D., Rodríguez, C., Nugus, P., Carver, T. & Risør, T. (2022). Embedding identity and how clinical teachers reconcile their multiple professional identities to meet overlapping demands at work. *Teaching and Learning in Medicine*, 34(4), 405–17. https://doi.org/10.1080/10401334.2021.1930545.

O'Sullivan, P. S. & Irby, D. M. (2011). Reframing research on faculty development. *Academic Medicine*, 86(4), 421–8. https://doi.org/10.1097/acm.0b013e31820dc058.

Pape, G., Dong, F. & Horvath, Z. (2018). Assessing the professional identity of dental school faculty: An exploratory study. *Journal of Dental Education*, 82(11): 1140–5. https://doi.org/10.21815/jde.018.117.

Peters, K. & Turner, J. (2014). Fixed-term and temporary: Teaching fellows, tactics, and the negotiation of contingent labour in the UK higher education system. *Environment and Planning A: Economy and Space*, 46(10), 2317–31. https://doi.org/10.1068/a46294.

Read, B. & Leathwood, C. (2020). Casualised academic staff and the lecturer–student relationship: Shame, (im)permanence and (il)legitimacy. *British Journal of Sociology of Education*, 41(4), 539–54. https://doi.org/10.1080/01425692.2020.1748570.

Sabel, E. & Archer, J. (2014). 'Medical education is the ugly duckling of the medical world' and other challenges to medical educators' identity construction: A qualitative study. *Academic Medicine*, 89(11), 1474–80. https://doi.org/10.1097/ACM.0000000000000420.

Sánchez-Tarazaga, L., Ruiz-Bernardo, P., Viñoles Cosentino, V. & Esteve-Mon, F. M. (2022). University teaching induction programmes. A systematic literature review. *Professional Development in Education*, 1–17. https://doi.org/10.1080/19415257.2022.2147577.

Sethi, A., Schofield, S., McAleer, S. & Ajjawi, R. (2018). The influence of postgraduate qualifications on educational identity formation of healthcare professionals. *Advances in Health Sciences Education: Theory and Practice*, 23(3), 567–85. https://doi.org/10.1007/s10459-018-9814-5.

Sheridan, V. (2013). A risky mingling: Academic identity in relation to stories of the personal and professional self. *Reflective Practice*, 14(4), 568–79. https://doi.org/10.1080/14623943.2013.810617.

Skelton, A. (2004). Understanding 'teaching excellence' in higher education: A critical evaluation of the National Teaching Fellowships Scheme. *Studies in Higher Education*, 29(4), 451–68. https://doi.org/10.1080/0307507042000236362.

Skelton, A. (2012). Teacher identities in a research-led institution: In the ascendancy or on the retreat? *British Educational Research Journal*, 38(1), 23–39. http://dx.doi.org/10.1080/01411926.2010.523454.

Smith, S. & Walker, D. (2024). Scholarship and teaching-focused roles: An exploratory study of academics' experiences and perceptions of support. *Innovations in Education and Teaching International*, 61(1), 193–204. https://doi.org/10.1080/14703297.2022.2132981.

Snook, A. G., Schram, A. B. & Arnadottir, S. A (2022). 'I am a teacher': Exploring how to support teacher identity formation in physical therapists. *Physical Therapy Reviews*, 27(1), 73–80. https://doi.org/10.1080/10833196.2021.2000809.

Snook, A. G., Schram, A. B., Jones, B. D. & Sveinsson, T. (2019). Factors predicting identity as educators and openness to improve: An exploratory study. *Medical Education*, 53(8), 788–98. https://doi.org/10.1111/medu.13909.

Soemantri, D., Findyartini, A., Greviana, N., Mustika, R., Felaza, E., Wahid, M. & Steinert, Y. (2023). Deconstructing the professional identity formation of basic science teachers in medical education. *Advances in Health Sciences Education*, 28(1), 169–80. https://doi.org/10.1007/s10459-022-10150-6.

Steinert, Y. (2010). Faculty development: From workshops to communities of practice. *Medical Teacher*, 32(5), 425–8. https://doi.org/10.3109/01421591003677897.

Steinert, Y., O'Sullivan, P. S. & Irby, D. M. (2019). Strengthening teachers' professional identities through faculty development. *Academic Medicine*, 94(7), 963–8. https://doi.org/10.1097/acm.0000000000002695.

Sturtevant, H. & Wheeler, L. (2019). The STEM Faculty Instructional Barriers and Identity Survey (FIBIS): Development and exploratory results. *International Journal of STEM Education*, 6, art. no. 35. https://doi.org/10.1186/s40594-019-0185-0.

Tierney, A. M., Aidulis, D., Park, J. & Clark, K. (2020). Supporting SoTL development through communities of practice. *Teaching & Learning Inquiry*, 8(2), 32–52. https://doi.org/10.20343/teachlearninqu.8.2.4.

Trautwein, C. (2018). Academics' identity development as teachers. *Teaching in Higher Education*, 23(8), 995–1010. https://doi.org/10.1080/13562517.2018.1449739.

Trede, F., Macklin, R. & Bridges, D. (2012). Professional identity development: A review of the higher education literature. *Studies in Higher Education*, 37(3), 365–84. https://doi.org/10.1080/03075079.2010.521237.

Triemstra, J. D., Iyer, M. S., Hurtubise, L., Poeppelman, R. S., Turner, T. L., Dewey, C., Karani, R. & Fromme, H. B. (2021). Influences on and characteristics of the professional identity formation of clinician educators: A qualitative analysis. *Academic Medicine*, 96(4), 585–91. https://doi.org/10.1097/acm.0000000000003843.

van den Berg, J. W., Verberg, C. P. M., Scherpbier, A. J. J. A., Jaarsma, A. D. C. & Lombarts, K. M. J. M. H. (2017). Is being a medical educator a lonely business? The essence of social support. *Medical Education*, 51(3), 302–15. https://doi.org/10.1111/medu.13162.

van Dijk, E. E., van Tartwijk, J., van der Schaaf, M. F. & Kluijtmans, M. (2020). What makes an expert university teacher? A systematic review and synthesis of frameworks for teacher expertise in higher education. *Educational Research Review*, 31, art. no. 100365. https://doi.org/10.1016/j.edurev.2020.100365.

van Lankveld, T., Schoonenboom, J., Kusurkar, R. A.,Volman, M., Beishuizen, J. & Croiset, G. (2017). Integrating the teaching role into one's identity: A qualitative study of beginning undergraduate medical teachers. *Advances in Health Sciences Education: Theory and Practice*, 22, 601–22. https://doi.org/10.1007/s10459-016-9694-5.

van Lankveld, T., Schoonenboom, J., Volman, M., Croiset, G. & Beishuizen, J. (2017). Developing a teacher identity in the university context: A systematic review of the literature. *Higher Education Research & Development*, 36(2), 325–42. https://doi.org/10.1080/07294360.2016.1208154.

van Lankveld, T., Thampy, H., Cantillon, P., Horsburgh, J. & Kluijtmans, M. (2021). Supporting a teacher identity in health professions education: AMEE Guide No. 132, *Medical Teacher*, 43(2), 124–36. https://doi.org/10.1080/0142159x.2020.1838463.

Volpe, R. L., Hopkins, M., Haidet, P., Wolpaw, D. R. & Adams, N. E. (2019). Is research on professional identity formation biased? Early insights from a scoping review and metasynthesis. *Medical Education*, 53(2), 119–32. https://doi.org/10.1111/medu.13781.

Walkington, J. (2005). Becoming a teacher: Encouraging development of teacher identity through reflective practice. *Asia-Pacific Journal of Teacher Education*, 33(1), 53–64. https://doi.org/10.1080/1359866052000341124.

Wenger, E. (1998). *Communities of Practice: Learning, meaning, and identity*. Cambridge: Cambridge University Press.

Wenger, E., McDermott, R. & Snyder, W. M. (2002). *Cultivating Communities of Practice: A guide to managing knowledge*. Boston, MA: Harvard Business School Press.

Whitton, J., Parr, G. & Choate, J. (2022). Developing the education research capability of education-focused academics: Building skills, identities and communities. *Higher Education Research & Development*, 41(6), 2122–36. https://doi.org/10.1080/07294360.2021.1946016.

Wisener, K. M., Driessen, E. W., Cuncic, C., Hesse, C. L. & Eva, K. W. (2021). Incentives for clinical teachers: On why their complex influences should lead us to proceed with caution. *Medical Education*, 55(5), 614–24. https://doi.org/10.1111/medu.14422.

Zaniewski, A. M. & Reinholz, D. (2016). Increasing STEM success: A near-peer mentoring program in the physical sciences. *International Journal of STEM Education*, 3(1), art. no. 14. https://doi.org/10.1186/s40594-016-0043-2.

Part III

Supporting belonging and alternative ways of engaging

12
Active learning and Japanese students' belonging in mathematics, physics and chemistry

Fujio Ohmori, Jun Saito and Hisao Suzuki

Introduction

As the discourse of the knowledge-based economy has become almost universal, many national governments put emphasis on human resources with expertise in science, technology, engineering and mathematics (STEM). Japan is not an exception. In May 2022, Japan's Council for the Creation of Future Education, chaired by the Prime Minister, set a target of increasing the proportion of university students majoring in STEM and other science-based disciplines from 35 per cent to around 50 per cent. With this policy trend emphasising STEM, it has become a priority to capture the current state of, and issues with, teaching methods and learning outcomes in STEM higher education.

Evidence-based teaching in STEM subjects has been promoted by policy makers in many national higher education systems. For example, in the USA the President's Council of Advisors on Science and Technology (2012, p. iii) proposed to '[c]atalyze widespread adoption of empirically validated teaching practices' as the very first recommendation in its report to the then president, Barack Obama. The recommendation contains the following:

> Classroom approaches that engage students in 'active learning' improve retention of information and critical thinking skills, compared with a sole reliance on lecturing, and increase persistence of students in STEM majors. STEM faculty need to adopt teaching methods supported by evidence derived from experimental learning research as well as from learning assessment in STEM courses. (p. iii)

In the case of Japan, the government has been endorsing the replacement of traditional lecture-based teaching with active learning in higher education in general for more than 10 years, yet little is known about how successful this endeavour is. In particular, there has been almost no empirical measurement of how widespread active learning is in basic science modules. Although it is widely believed that traditional lecture formats have been persistently dominant in those modules, there have been virtually no nationwide data on this issue.

On the other hand, internationally, discipline-based education research (DBER) has been producing an overwhelming amount of evidence that demonstrates the advantage of active learning over the traditional lecture in terms of enhancing students' learning outcomes (e.g., Freeman et al., 2014). DBER, as a distinct research field which combines expertise in a discipline and expertise in teaching and learning science, has developed mainly in North America and almost exclusively in STEM disciplines. Physics education research (PER) is regarded as the most developed branch of DBER. Even in the USA, however, 'DBER and related research have not yet prompted widespread changes in teaching practice among science and engineering faculty' (National Research Council, 2012, p. 3). In Japanese academia, the term 'DBER' is not yet well known.

As discussed in more detail later in this chapter, it is well established in DBER that active learning is more likely than traditional lecture methods to enhance conceptual understanding in STEM fields. Conceptual understanding, as one of the key concepts in DBER, is not rote memorisation of factual and theoretical information, but rather an expert-like understanding of key concepts in a discipline and its integration into the learner's own conceptual framework.

Conceptual understanding closely aligns with the STEM ways of thinking discussed in Chapter 1. There, they are described as specific modes of thinking deeply rooted in the disciplinary contexts and their inherent logic. Unlike rote memorisation and mere regurgitation of accumulated knowledge and procedures, STEM ways of thinking emphasise sense making as a crucial aspect. These characterisations of STEM ways of thinking bear a striking resemblance to descriptions of conceptual understanding. As argued in Chapter 1, such modes of thinking signify sense of belonging as a cognitive function within the academic realm of STEM fields. Additionally, active learning methods have been shown to bolster both conceptual understanding and sense of belonging. Consequently, DBER's focus on expert-like conceptual understanding and active learning holds significant promise for advancing research on the sense of belonging in STEM higher education.

Despite extensive DBER research showing the effectiveness of active learning in STEM disciplines, many academics remain reluctant to shift away from their traditional lecture-based teaching approach. But what about students? How do they perceive pedagogy? Research in this area often treats students as mere objects, objectively measuring their knowledge and skills through tests, exams, or concept inventory scores.

This chapter places emphasis on students' agency as learners and explores their reflection upon their learning experiences. For this purpose, the authors carried out an online survey and collected data from 2,000 graduates and students in STEM and other science-based fields at universities across Japan. The online questionnaire investigated participant experiences of learning introductory mathematics, physics and chemistry in Years 1 and 2 of bachelor's degree programmes.

The results show that the learners' self-assessed understanding of each discipline's basic concepts tends to be significantly higher if those subjects are taught in active learning formats, rather than traditional didactic formats. This tendency is consistent between selective universities with competitive admission and non-selective ones. Despite this evidence of the advantages of active learning, the traditional lecture approach stubbornly dominates basic science education at Japanese universities. The chapter examines both the national and international implications of this rare nationwide research on learners' views of pedagogy for furthering research on intersections of cognitive and affective aspects, including science identity and sense of belonging, in STEM higher education.

Background of the study

Conceptual understanding and pedagogy

Conceptual understanding has been the most heavily researched topic in DBER. This is related to the fact that conceptual understanding has been a focal point for science education reform, as Tanner and Allen (2005, p. 112) neatly explain, as follows:

> Underpinning science education reform movements in the last 20 years – at all levels and within all disciplines – is an explicit shift in the goals of science teaching from students simply creating a knowledge base of scientific facts to students developing deeper understandings of major concepts within a scientific discipline. … This emphasis on conceptual understanding in science education reform has guided the development of standards and permeates all major science education reform policy documents.

Understanding the key concepts in a discipline is essential if one is to apply or transfer that discipline's scientific knowledge and skills. In contrast to simply memorising facts and theories, conceptual understanding involves 'a more complex, multidimensional integration of information into a learner's own conceptual framework' (Tanner & Allen, 2005, p. 113). However, students often have misconceptions or alternative conceptions. They are naive preconceptions that are based on intuition or on their daily life experiences and not aligned with the scientist's understanding.

After the success of the Force Concept Inventory (FCI), concept inventories have been developed in other areas of physics and in a wide range of STEM disciplines, including chemistry, biology, geoscience, engineering, mathematics and computer science. A concept inventory is a multiple-choice test to measure students' conceptual understanding, a test of qualitative reasoning rather than declarative knowledge. Each question, or item, in a concept inventory has one correct answer, and a few incorrect answers that accord with common misconceptions (Sands et al., 2018).

'The most common use of concept inventories is to test the effectiveness of a particular pedagogical practice' (Sands et al., 2018, p. 174). In this regard, DBER has been producing an overwhelming amount of evidence that demonstrates the advantage of active learning over traditional lecture-based teaching in terms of enhancing conceptual understanding as measured by concept inventories. For example, Hake (1998), Wallace et al. (2018) and Rodriguez and Potvin (2021) can be named in PER, Partanen (2018) in chemistry education research and Ng et al. (2020) in mathematics education research.

Self-assessment of conceptual understanding

Regarding conceptual understanding, however, there is an issue left for further research. While most research in this domain has objectively measured students' understanding using concept inventory scores, less research attention has been devoted to students' assessment of their own conceptual understanding. This situation means that the research tends to treat students as objects and rarely focuses on students' agency as learners.

Furthermore, the research on students' self-assessment of conceptual understanding has so far produced inconsistent findings, some of which rebut the argument for the advantages of active learning, while others support it in line with the research on objective measurement. Peteroy-Kelly (2007) found that the introductory biology class students felt that a discussion group programme helped them understand and use the main concepts in biology to solve the problems logically. Tien et al. (2002) showed the effectiveness of peer-led team learning (PLTL) in improving students' self-assessed understanding of organic chemistry. On the other hand, Chan and Bauer (2015) found no effect of PLTL on students' self-concept as chemistry learners, including on their assessment of their own understanding.

More interestingly, Yadav et al. (2014) exhibited an inconsistency between students' conceptual understanding and their perception of learning gains. In their research on a mechanical engineering class, they found that case-based instruction, involving problem solving and decision making, was better than the traditional lecture-based teaching at developing students' conceptual understanding. Nonetheless, there was no statistically significant difference in students' perceptions of learning gains between the two pedagogies. Yadav et al. (2014, pp. 672–3) insisted that student perceptions are not an accurate representation of their learning, referring to Dunlosky and Lipko (2007), who reviewed psychological research that indicated that people's self-judgements of text learning, or metacomprehension, tended to be quite poor. In contrast to this argument, Ganajová et al. (2020) showed that the correlation between students' self-assessment of conceptual understanding and their real score in secondary school chemistry was significant and high. These contradictory findings imply that more research is needed to understand fully the nature of students' self-assessment of conceptual understanding in the higher education context.

According to Tashiro et al. (2021, p. 675), much research on science and non-science education has revealed that lower-performing students tend to overestimate their ability. While some researchers regard the misalignment between perception and reality as detrimental to learning, others have argued that such overestimation may not be entirely detrimental, because it may encourage learners to undertake challenging learning eagerly.

Intersection of cognitive and affective outcomes?

Aside from the issue of alignment between objective measurement and self-assessment of conceptual understanding, or accuracy of self-assessment, the intrinsic significance of affective factors, including self-perceptions, should be noted. The following quote (Nieswandt, 2007, p. 908) points to the linkage between affect and conceptual understanding and the necessity of more research on the linkage.

> A discussion with teachers or a perceptive look into a science classroom is sufficient to realize that the learning of scientific concepts is more than a cognitive process. Students' interests and attitudes toward science as well as their perceptions of how well they will perform in learning contexts (self-concept) may play important roles in developing a meaningful understanding of scientific concepts, an understanding that goes beyond rote memorization toward the ability to explain everyday phenomena with current scientific knowledge. Despite the apparent importance of affect in the learning process, research exploring this linkage is limited.

Nieswandt found that students' perception of themselves as doing well in chemistry, a positive discipline-specific self-concept, resulted in their meaningful conceptual understanding. Trujillo and Tanner (2014, p. 13) say, 'Conceptual learning is a uniquely human behavior that engages all aspects of individuals: cognitive, metacognitive, and affective', and suggest monitoring both affective experiences and conceptual understanding.

Regarding the linkage between affect and pedagogy, Ballen et al. (2017) argued that active learning led to an increase in science self-efficacy for university students. Lombardi et al. (2021), and research teams from psychology and DBER (including physics, astronomy, chemistry, engineering, biology, geoscience and geography education research), synthesised an overview of undergraduate STEM education practices and reached the conclusion that student agency in meaning making and knowledge construction lies at the core of active learning, which is used as an alternative to traditional lecture-based teaching and as an umbrella term to cover a wide variety of practices.

In short, students' self-assessment of their conceptual understanding is not merely an inaccurate approximation to the objective measurement of conceptual understanding but has its own inherent value as a variable, containing both affective and cognitive aspects, which may relate to student agency for learning. Whether or not active learning enhances students' self-assessed conceptual understanding is an important issue left for further research, which the present study aims to contribute to.

Sense of belonging and science identity

Among affective constructs in the higher education context, students' sense of belonging and science identity are particularly relevant to the current study. Belonging is students' connectedness to the institution, the staff and the other students, as well as to the discipline that they study, and the degree of belonging may directly influence retention and can also affect success through its impact on engagement (Kahu & Nelson, 2018).

Evidence has been growing that students' sense of belonging correlates with academic outcomes in STEM education. For example, Fink, Frey and Solomon (2020) found that the belonging measures at the beginning of a general chemistry course predicted performance and attrition for the students enrolled in the course, and that female students, especially those from minority groups, tended to report lower belonging. Also, regarding an introductory physics course, Stout et al. (2013) presented similar findings, that women feel a lower sense of belonging than men in physics and that having a sense of belonging in physics predicted performance on exams and the degree to which students see the value of physics in their daily life.

In the case of computer science, Krause-Levy et al. (2021) found that women and first-generation students had a lower sense of belonging and that lower sense of belonging was correlated with lower pass rates and lower course performance, but that the correlation weakened as students progressed through the curriculum. Survey research by Marra et al. (2012) on factors that led students to transfer out of engineering indicated that lack of belonging, as well as curriculum difficulty and poor teaching and advice, contributed to students' decisions to leave engineering.

Interestingly for the present research, there has also been some evidence that active learning enhances both academic performance and sense of belonging. According to Wilton et al. (2019), an introductory biology course with active learning approaches resulted in better academic achievement and retention and greater perceptions of classroom belonging than the traditional lecture course. James and LaDue (2021) found that students in an introductory chemistry class reformed by the introduction of active learning, in comparison with those in two unreformed didactic-lecture classes, scored higher on common exam items and held more positive attitudes towards chemistry after taking the course. The finding tells us that students in the unreformed classes reported more negative attitudes towards chemistry after taking the course than they did at the beginning of the course, while students in the reformed class reported more positive attitudes at the end of the course. Although the concept of belonging was not used in this research, the finding has an important implication for research on sense of belonging.

Already by the end of the last century, the positive impacts of active learning in STEM subjects, on both academic performance and attitudes, were known. Springer et al. (1999) carried out a meta-analysis of research on undergraduate STEM education (it was called 'SMET' at that time) since 1980 and demonstrated that various forms of small-group learning were effective in promoting greater academic achievement, more favourable attitudes towards learning and increased persistence through STEM courses and programmes.

Although there has been a considerable amount of research on correlations between affective attributes, including sense of belonging, and academic outcomes, not much is known about the mechanisms of the correlations or the causal relationships between them. While correlations show how course belonging and other variables relate, they do not prove the directionality of those relationships (Fink, Young et al., 2023). In this regard, Edwards et al. (2022) presented a notable finding, that sense of belonging and exam performance interacted with each other through a recursive mechanism during a semester of general chemistry. It means that sense of belonging changed in response to midterm exam performance, and then the changed sense of belonging influenced final exam performance. The finding implies that the causal relationship between sense of belonging and academic achievement may be bidirectional and successive.

Another notable finding was provided by Veilleux et al. (2013), who suggested that sense of belonging was related more to a student's perception of their ability than to their actual performance in computer science. These findings have important implications for the current study, which focuses on students' self-assessed conceptual understanding as a possible intersection of cognitive and affective outcomes. Wilson et al. (2015) measured sense of belonging at three levels (class, major and university), and behavioural and emotional engagement among STEM students, in five US institutions, and found that class belonging was most consistently linked to engagement, while university belonging was linked least consistently, which shows the importance of sense of belonging at the class level; this has an implication for the present study on undergraduates' experiences of pedagogy (active learning or didactic lecture) in basic science classes.

Science identity is another affective construct that has a particular relevance to the current study. A kind of role identity, science identity means seeing oneself as a student of science, and the identity influences students' behaviours and outcomes (Stets et al., 2017). Science identity is regarded as key in student persistence and retention in the sciences

(Trujillo & Tanner, 2014). In their research on practising scientists, Carlone and Johnson (2007) proposed a model that suggested science identity's three components: 'competence', 'performance' and 'recognition'. As students have not yet committed to a particular major or career, unlike practising scientists, Hazari et al. (2010) suggested an updated identity framework that includes 'interest' as a fourth component, and found that US university students' 'physics identity' was positively predicted by high school physics characteristics and experiences, such as a focus on conceptual understanding, real-world and contextual connections, students answering questions or making comments, students teaching classmates, and having an encouraging teacher. The inclusion of conceptual understanding and active learning elements has a significant implication for the present study.

As the results of a longitudinal study of undergraduate students enrolled in an introductory physics course for STEM majors at a US university, Seyranian et al. (2018) found that women reported less course belonging and less physics identification than men, and that physics identification and course grades were in a bidirectional and successive relationship for all students, regardless of gender. The bidirectional and successive relationship means that students with higher physics identification at the beginning of the course were more likely to earn higher grades, and that students with higher grades evidenced more physics identification at the end of the course. This relationship is very similar to the one mentioned above, between sense of belonging and academic achievement. Both relationships may be recursive and cyclical. This similarity is not surprising if we consider that these affective constructs are interrelated and not entirely distinct, as Trujillo and Tanner (2014) argued.

This discussion on sense of belonging and science identity, and their relationships with academic performance, implies the importance of intersections of cognitive and affective aspects of learning. Self-assessed conceptual understanding may play an important role as such an intersection, especially as bidirectional and cyclical relationships between cognitive and affective outcomes may suggest that self-assessed conceptual understanding, as a sense of mastery of disciplinary concepts, also drives the next cycle of learning. Another implication is that it seems natural that active learning enhances self-assessed conceptual understanding, as it raises both academic performance and sense of belonging, but this is an issue to be resolved empirically.

Basic science education at Japanese universities

Before the present study is introduced, it is helpful to have a brief overview of basic science education at Japanese universities. Most Japanese undergraduate programmes are broadly divided by the dichotomy of science-based fields, including STEM and medical disciplines, and non-science ones, including humanities and social sciences. This dichotomy begins at high school stage, for pupils usually aged between 16 and 18, in the Japanese education system. From the second year of a three-year high school education, pupils learn with an emphasis either on mathematics and science or on Japanese language and social studies, including history and geography. This emphasis generally corresponds to university entrance examination subjects for either science-based or non-science degree programmes. English is normally required for both. The dichotomy between science-based and non-science tracks prevails even up to the recruitment of graduates by companies, government and other employers, and further occupational careers. This dichotomy of education and career tracks between science-based ones, called 'ri-kei', and non-science ones, called 'bun-kei', has historically been established in Japan's modernisation process (Oki, 2019).

It is, of course, problematic that economics degree programmes accept students with weak mathematics preparation. As other social sciences and humanities have developed to engage in quantitative research methods, the above dichotomy is already a serious issue for academia. Furthermore, for many businesses and industries, data science and artificial intelligence are becoming more and more crucial. Against this background, the government has started to try to equip not only ri-kei but also bun-kei students with basic mathematical skills (Ministry of Economy, Trade and Industry, 2021), hoping to mitigate the dichotomy. However, the basic structure of the dichotomy, from the high school stage, does not yet seem to waver, as both universities and high schools may lose popularity and competitiveness in the hierarchically established education market if they diverge from these two major tracks.

In theory, this tracking can promote ri-kei students' science identity. However, whether their learning experiences in higher education enhance science identity is an open question that needs empirical investigation. The following description of the current state of basic science education at Japanese universities may imply an obstacle to the enhancement of science identity.

Four-year undergraduate programmes for ri-kei students normally provide introductory mathematics, physics and chemistry modules in the first and/or second year. As Japanese universities are hierarchically ordered according to entrance examinations, curricula for such basic science education can be very different in selective and non-selective institutions. Within selective, research-intensive university programmes, although there is general agreement on the topics to be covered, curriculum details, including expected standards, can be diverse not only between institutions but also between academics, as they often do not communicate with each other (Ogasawara, 2007).

Regarding teaching methods in basic science education at Japanese universities, there is almost no nationwide data. A research team led by Lang (2020) studied 29 physics classes across Japan and found that 20 of them were taught in traditional lecture formats and nine in active learning formats. Only five of these nine were identified as using evidence-based pedagogy that achieved conspicuous gains in conceptual understanding measured by the FCI, according to the Science Council of Japan (2020), which reported on the same study.

Furthermore, the Science Council of Japan study revealed more serious results. The average gain of all the 29 classes, measured as the difference between pre- and post-test scores of FCI, was very small, and smaller than the USA's corresponding data. Some classes' gains were even negative. Although pre-test scores had a strong correlation with the degree of university selectivity, gains were independent of the degree. Compared with the universities' results, the high schools' results in the study were much better and almost as good as the USA's corresponding data in terms of gains.

These results imply that even PER, arguably the most developed branch of DBER both nationally and internationally, has not been successful in disseminating its research-based teaching in Japanese higher education, and that there may be an extremely serious issue in basic science education at undergraduate level. This situation may have a negative impact on ri-kei students' sense of belonging and potential for science identity, which might have been promoted by the early tracking from high school stage. This impact may also be found in self-assessment of conceptual understanding.

Aims and methodology

Against the backdrop of the situations described above, the primary objective of the current study is to contribute to discussions on both the national and the international issues, which have not yet been resolved, with regard to students' perceptions of pedagogy and conceptual understanding in undergraduate science education. Nationally, this study tries to grasp the Japanese nationwide picture of pedagogy in undergraduate basic science education, from the viewpoints of students and graduates, and to explore the impact of pedagogy on their self-assessment of conceptual understanding. Internationally, the study seeks to contribute to the unresolved issue of whether active learning enhances self-assessed conceptual understanding, using the unique nationwide data set.

For the objective stated above, the authors carried out an online survey and collected data from 2,000 graduates and students in STEM and other science-based fields at various universities across Japan. The online questionnaire investigated participant experiences of learning introductory mathematics, physics and chemistry in Year 1 and/or 2 of bachelor's degree programmes. The web survey was conducted between 4 and 8 February 2021 through a Japanese internet research service company called Rakuten Insight, Inc. (https://insight.rakuten.co.jp/, accessed 27 December 2023), which has 2.2 million nationwide monitors registered with the company. The survey invitation was sent to those monitors who met the inclusion criteria. The criteria were: university students and graduates in the past five years, and their undergraduate programme is not within bun-kei (non-science track), that is, the programme is within either ri-kei (science-based track) or interdisciplinary areas difficult to classify. Of the monitors, those who responded to the survey were self-selected, and the sampling continued until the total number of respondents reached 2,000, the sample size large enough for the authors' intended analysis.

The survey was approved beforehand by the research ethics committee of the first author's institution. Furthermore, the survey was conducted anonymously with the agreement of respondents.

The comprehensive description of the survey and its results had already been published in the Japanese language (Ohmori et al., 2022). While the publication, as a journal article, contained technical details, the survey results were used only for empirically austere analyses and discussions in the article. On the other hand, the present chapter focuses on the issues explained above and discusses the theoretical implications of the results more boldly. Its originality also lies in the overview introduced above of the basic science education and ri-kei track in the Japanese upper-secondary and higher education for international readers. Based on the overview, the implications for both national and international contexts are discussed.

For the current study's focus, the most important question in the survey was that on pedagogy. It asked respondents whether their subject (mathematics, physics or chemistry) was taught in traditional lecture formats or active learning formats and invited them to answer on a four-point scale. In the actual questionnaire, the technical terms of 'traditional lecture' and 'active learning' were not used, and instead descriptions of these two kinds of pedagogy were presented. The traditional lecture was described as a 'class mostly with the teacher talking to the whole class, and the students passively listening to the lecture, and with little interactive communication, discussion, group work, or student-centred activity'. Active learning was described as 'class with a substantial amount of interactive communication, discussion, group work, or student-centred activity'. This latter description was intended to cover a wide variety of active learning formats.

The other relevant question was on self-assessment of conceptual understanding. It asked each respondent whether they relied on rote memorisation of knowledge and formulae without understanding the meanings of important concepts of the subject, or largely understood the meanings of the concepts. Respondents were instructed to answer on a four-point scale. In this way, self-assessed conceptual understanding was operationally defined.

In addition, other questions related to learning outcomes, that is to say, a self-reported grade of the subject on a three-point scale and an assessment of the usefulness of the subject to subsequent study on a four-point scale, are of use to later analysis and discussion in this chapter. In the context of the present study, the question on the degree of university selectivity, on a five-point scale, is also important, as Japanese universities are hierarchically ordered on the basis of undergraduate entrance examinations.

Survey results

Attributes of respondents

Of the sample of 2,000 respondents, approximately two-thirds (68 per cent) were undergraduate students and one-third (32 per cent) were graduates. The majority were female (67 per cent); 31.8 per cent were male and 1.2 per cent gave no answer.

Although the respondents' fields of undergraduate study were quite diverse, gender characteristics were obvious in the most frequent field of study for each sex. For females, it was nursing and health care (28.6 per cent), and for males engineering (34.6 per cent). Mathematics (male 5.2 per cent; female 2.5 per cent) and physics (male 4.6 per cent; female 1.5 per cent) were male-dominant fields of study. These characteristics largely reflect the official data on undergraduate students in Japanese higher education.

Graduate respondents' statuses were as follows. A little more than a quarter (28.2 per cent) of them advanced to postgraduate study, while 71.8 per cent did not. Most (87.8 per cent) of them had a job while some (9.2 per cent) were postgraduate students at the time of the survey, leaving 3 per cent in neither category.

Learners' perceptions of pedagogy in basic science subjects

Of the sample of 2,000 respondents, 1,369 (68.4 per cent) studied mathematics in Year 1 and/or 2 of bachelor's degree programmes, 1,226 (61.3 per cent) physics and 1,313 (65.6 per cent) chemistry.

As Table 12.1 clearly indicates, the great majority of the respondents perceived that they had studied each of the basic science subjects in traditional lecture formats rather than active learning formats.

Self-assessment of conceptual understanding in the three disciplines

Self-assessed understanding of the basic concepts in each subject is presented in Table 12.2. For mathematics and physics, slightly more than half of the respondents showed low or somewhat low self-assessment. For chemistry, it was almost half and half.

Other variables regarding learning outcomes of the three subjects

The respondents reported their grade of each subject, as Table 12.3 shows. While 'middle' was chosen by the largest number of respondents, the answer 'high' was reported by more respondents than 'low'.

As Table 12.4 indicates, chemistry was evaluated as useful to subsequent study by a clear majority of the respondents (68 per cent voted 'high' or 'somewhat high'); the positive evaluation of physics saw only a slight majority (54 per cent), and the evaluation of mathematics was almost even (52 per cent and 48 per cent).

University selectivity

The respondents rated their university's selectivity as in Table 12.5. The answers 'high' and 'somewhat high' were reported by more respondents than 'low' and 'somewhat low'.

Table 12.1 Perceived pedagogy in basic science subjects (%)

Subject	AL	Somewhat AL	Somewhat TL	TL
Mathematics (n = 1369)	3.3	17.6	37.8	41.3
Physics (n = 1226)	3.6	18.8	39.3	38.3
Chemistry (n = 1313)	5.3	21.4	40.8	32.5

Note: 'AL' = active learning, 'TL' = traditional lecture.
Source: authors

Table 12.2 Self-assessed understanding of each discipline's basic concepts (%)

	High	**Somewhat high**	**Somewhat low**	**Low**
Mathematics (n = 1369)	9.1	33.7	42.4	14.7
Physics (n = 1226)	9.9	32.7	38.3	19.1
Chemistry (n = 1313)	14.2	37.9	32.8	15.1

Source: authors

Table 12.3 Self-reported grade distributions of the three subjects (%)

	High	**Middle**	**Low**	**Don't know**
Mathematics (n = 1369)	32.9	46.3	16.4	4.5
Physics (n = 1226)	26.8	44.0	24.9	4.3
Chemistry (n = 1313)	28.5	46.5	20.0	5.0

Source: authors

Table 12.4 Perceived usefulness of the subject to subsequent study (%)

	High	**Somewhat high**	**Somewhat low**	**Low**
Mathematics (n = 1369)	14.5	37.2	32.3	16.0
Physics (n = 1226)	17.9	36.1	28.0	18.1
Chemistry (n = 1313)	28.6	39.1	20.3	11.9

Source: authors

Table 12.5 University selectivity (%)

	High	Somewhat high	Neither	Somewhat low	Low
All (n = 2000)	17.0	31.3	20.8	17.4	13.5
Mathematics (n = 1369)	21.2	33.0	20.7	14.5	10.6
Physics (n = 1226)	22.3	33.6	19.8	14.3	10.0
Chemistry (n = 1313)	20.6	33.1	20.2	15.2	11.0

Source: authors

Analysis of the results

Overview of correlations between the variables

The analysis of the results examines correlations between variables important to the present study's focus, namely perceived pedagogy, self-assessed conceptual understanding, self-reported grade, perceived usefulness of the subject to subsequent study, and university selectivity. Using Spearman's rank correlation coefficient (ρ), correlation matrices are presented in Tables 12.6, 12.7 and 12.8 for mathematics, physics and chemistry respectively.

Correlation between pedagogy and self-assessed conceptual understanding

Spearman's rank correlation coefficient (ρ) between pedagogy and self-assessed conceptual understanding is +0.25 for mathematics, +0.31 for physics and +0.35 for chemistry. These correlations mean that self-assessed understanding of the subjects' concepts tends to be higher in active learning formats than in traditional lecture formats.

Cross-tabulation of the two variables visualises the correlation as in Figures 12.1, 12.2 and 12.3, for mathematics, physics and chemistry respectively. The correlations in these figures are statistically confirmed by Goodman and Kruskal's gamma, $\gamma = 0.33$ for mathematics, 0.39 for physics, and 0.44 for chemistry.

Relationships between the variables relating to learning outcomes

Self-assessed conceptual understanding has significant correlation with the other variables regarding learning outcomes, namely self-reported grades and perceived usefulness of the subject to subsequent

Table 12.6 Correlation matrix of variables for mathematics

	P	C	G	U	S
Pedagogy (P)		0.25	0.07	0.29	–0.04
Conceptual understanding (C)	0.25		0.30	0.32	0.01
Grade (G)	0.07	0.30		0.20	–0.02
Usefulness (U)	0.29	0.32	0.20		0.08
Selectivity (S)	–0.04	0.01	–0.02	0.08	

Source: authors

Table 12.7 Correlation matrix of variables for physics

	P	C	G	U	S
Pedagogy (P)		0.31	0.10	0.25	0.02
Conceptual understanding (C)	0.31		0.35	0.40	0.09
Grade (G)	0.10	0.35		0.23	0.07
Usefulness (U)	0.25	0.40	0.23		–0.01
Selectivity (S)	0.02	0.09	0.07	–0.01	

Source: authors

Table 12.8 Correlation matrix of variables for chemistry

	P	C	G	U	S
Pedagogy (P)		0.35	0.11	0.25	–0.01
Conceptual understanding (C)	0.35		0.34	0.44	0.04
Grade (G)	0.11	0.34		0.28	0.00
Usefulness (U)	0.25	0.44	0.28		–0.09
Selectivity (S)	–0.01	0.04	0.00	–0.09	

Source: authors

study. Spearman's rank correlation coefficient (ρ) between self-assessed conceptual understanding and self-reported grade is +0.30 for mathematics, +0.35 for physics and +0.34 for chemistry. That between self-assessed conceptual understanding and usefulness of the subject to subsequent study is +0.32 for mathematics, +0.40 for physics and +0.44 for chemistry.

By contrast, self-reported grade has no correlation with perceived usefulness of the subject to subsequent study for mathematics and physics, while there is some correlation between these two variables in chemistry ($\rho = 0.28$). Pedagogy has some correlation with perceived usefulness of the subject to subsequent study: $\rho = 0.29$ for mathematics and 0.25 for physics and chemistry. It means that active learning tends to enhance perceived usefulness of the subject.

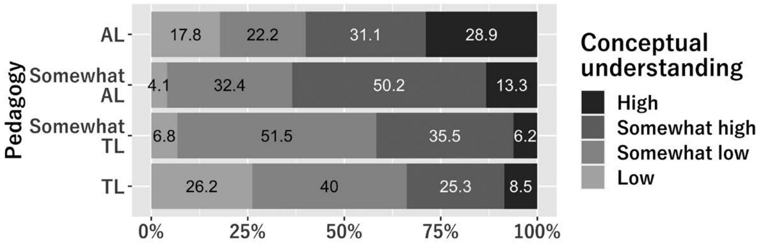

Figure 12.1 Relationship between pedagogy and conceptual understanding in mathematics. AL = active learning, TL = traditional lecture. © Authors.

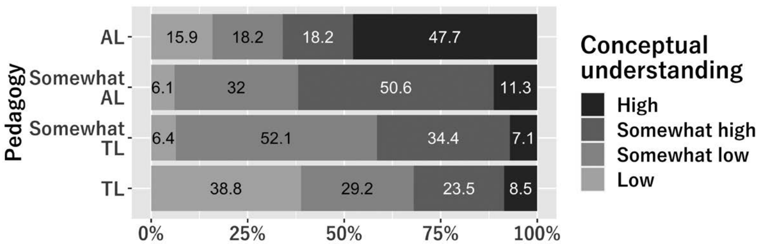

Figure 12.2 Relationship between pedagogy and conceptual understanding in physics. AL = active learning, TL = traditional lecture. © Authors.

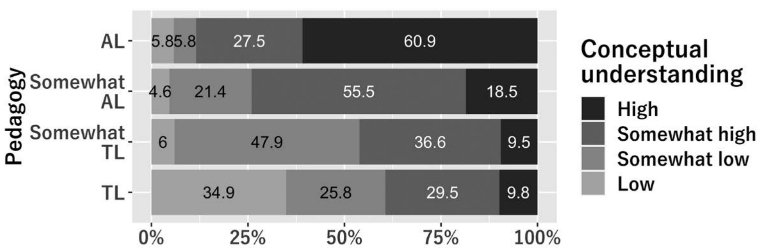

Figure 12.3 Relationship between pedagogy and conceptual understanding in chemistry. AL = active learning, TL = traditional lecture. © Authors.

University selectivity not correlated with pedagogy or self-assessed learning outcomes

As Tables 12.6, 12.7 and 12.8 show, university selectivity has almost no correlation with any other variable. Pedagogy does not differentiate on the basis of university selectivity. Astonishingly, neither self-assessed conceptual understanding nor perceived usefulness of the subject to subsequent study seems to be impacted by university selectivity. Interestingly, the tendency of traditional lecture formats to lower self-assessed conceptual understanding is also independent of university selectivity.

Discussion

Internationally, DBER has produced an overwhelming amount of evidence that demonstrates the advantage of active learning over traditional lectures in terms of enhancing conceptual understanding. Most research in this domain tends to treat students as objects; that is, the researchers objectively measure the students' understanding using concept inventory scores. Less attention has been devoted to students' agency as learners and their self-assessment of understanding. Such research has so far produced inconsistent findings, some of which deny the advantages of active learning, while others support the advantages in line with the objective measurement.

In this regard, the current study, based on a nationwide survey of students and graduates, provides important new evidence in support of the argument that active learning is advantageous in terms of self-assessed conceptual understanding. The survey results suggest that if basic science subjects – introductory mathematics, physics and chemistry – are taught in active learning formats rather than traditional lecture formats, students' self-assessed understanding of each discipline's basic concepts tends to be significantly higher. This finding may be interpreted as consistent with earlier studies reporting the bidirectional and recursive relationships between academic achievements and affective constructs (including sense of belonging and science identity), and the positive effects of active learning on both academic and affective outcomes. The current study shows that focusing on self-assessed conceptual understanding, containing both cognitive and affective elements, has the potential to further research on intersections of cognitive and affective aspects of learning.

Nationally, this chapter reveals a persistent dominance of traditional lecture-based teaching in the basic science subjects at Japanese universities, despite the benefits of active learning. This dominance is independent of the degree of university selectivity. The superiority of active learning to traditional lecture formats in enhancing self-assessed conceptual understanding is also consistent between selective and non-selective institutions. Surprisingly, university selectivity, which is often regarded as ruling everyday life in Japanese higher education, has no impact on self-assessed conceptual understanding or the perceived usefulness of the subject to subsequent study. Even though self-assessment and perception are different from objective measurement, these findings imply that basic science education at undergraduate level in Japan has issues applicable to both selective and non-selective universities.

Against the background of the early tracking between science-based and non-science tracks, the potential to develop science identity, possibly generated at high school stage, may be hindered by the didactic style of teaching in basic science classes at undergraduate level. The issue of pedagogy in those classes can be very serious, as there is evidence that sense of belonging is more influential on student engagement at class level than at disciplinary and university levels.

In short, we need to increase the number of academic staff members in charge of basic science education who adopt active learning methods that lead to beneficial learning outcomes, a stronger sense of belonging, and enhanced science identity.

Conclusion and implications

In summary, the current study, based on a rare nationwide survey of learners' views of pedagogy and learning outcomes in undergraduate basic science education, has produced important findings that have implications nationally and internationally. Learners' self-assessment and perception are not merely inaccurate approximations to the objective measurements but have intrinsic value as reflections on their own learning. As a mixture of affective and cognitive factors, these judgements may impact on learner agency and encourage or discourage further learning.

Nationally, the dominance of traditional lecture-based teaching and its negative effect on self-assessed conceptual understanding and the perceived usefulness of basic science disciplines may imply that Japanese undergraduate education fails to make the most of ri-kei students' early tracking from high school stage, which has the potential to promote science identity. This situation may also cast a shadow over the Japanese government's policy of increasing the proportion of university students majoring in STEM and other science-based disciplines.

Furthermore, science identity and sense of belonging are rarely researched in the Japanese higher education context and urgently need to be studied, against the background of the lowest share of women graduates in STEM fields among the OECD member countries (OECD, 2022). Future research should also investigate relationships between self-assessed conceptual understanding and science identity or sense of belonging. Those relationships may further inform mechanisms of entangled affective and academic outcomes.

In short, the present study has resulted in findings that have both national and international implications for pedagogy and outcomes in STEM higher education and shown that this kind of study with focus on the self-assessed conceptual understanding has a potential for advancing research on learning and teaching.

However, the current study has some limitations. One of the issues left for future research is the relationship between self-assessed conceptual understanding and objectively measured understanding in individuals. Another issue is academics' views of pedagogy and learning outcomes. Furthermore, the present study does not cover the curriculum and organisational issues behind the dominance of traditional lecture-based teaching. With all its limitations, the authors hope that this chapter provides meaningful findings and implications for advancing research on STEM higher education.

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References

Ballen, C. J., Wieman, C., Salehi, S., Searle, J. B. & Zamudio, K. R. (2017). Enhancing diversity in undergraduate science: Self-efficacy drives performance gains with active learning. *CBE – Life Sciences Education*, 16(4), art. no. 56: 1–6. https://doi.org/10.1187/cbe.16-12-0344.

Carlone, H. B. & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching*, 44(8), 1187–1218. https://doi.org/10.1002/tea.20237.

Chan, J. Y. K. & Bauer, C. F. (2015). Effect of peer-led team learning (PLTL) on student achievement, attitude, and self-concept in college general chemistry in randomized and quasi experimental designs. *Journal of Research in Science Teaching*, 52(3), 319–46. https://doi.org/10.1002/tea.21197.

Dunlosky, J. & Lipko, A. R. (2007). Metacomprehension: A brief history and how to improve its accuracy. *Current Directions in Psychological Science*, 16(4), 228–32. https://doi.org/10.1111/j.1467-8721.2007.00509.x.

Edwards, J. D., Barthelemy, R. S. & Frey, R. F. (2022). Relationship between course-level social belonging (sense of belonging and belonging uncertainty) and academic performance in general chemistry 1. *Journal of Chemical Education*, 99(1), 71–82. https://doi.org/10.1021/acs.jchemed.1c00405.

Fink, A., Frey, R. F. & Solomon, E. D. (2020). Belonging in general chemistry predicts first-year undergraduates' performance and attrition. *Chemistry Education Research and Practice*, 21(4), 1042–62. https://doi.org/10.1039/D0RP00053A.

Fink, A., Young, J. D., Vuppala, N. K. & Frey, R. F. (2023). Mixed-methods exploration of students' written belonging explanations from general chemistry at a selective institution. *Chemistry Education Research and Practice*, 24(1), 327–52. https://doi.org/10.1039/D2RP00166G.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H. & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Science*, 111(23), 8410–15. https://doi.org/10.1073/pnas.1319030111.

Ganajová, M., Sotáková, I., Jurková, V., Brestenská, B., Szarka, K. & Kožurková, M. (2020). Investigating students' self-assessment of conceptual understanding using self-assessment cards in chemistry. In *ICMET '20: Proceedings of the 2020 2nd International Conference on Modern Educational Technology*, pp. 30–3. New York: Association for Computing Machinery. https://doi.org/10.1145/3401861.3401864.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, 66(1), 64–74. https://doi.org/10.1119/1.18809.

Hazari, Z., Sonnert, G., Sadler, P. M. & Shanahan, M.-C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching*, 47(8), 978–1003. https://doi.org/10.1002/tea.20363.

James, N. M. & LaDue, N. D. (2021). Pedagogical reform in an introductory chemistry course and the importance of curricular alignment. *Journal of Chemical Education*, 98(11), 3421–30. https://doi.org/10.1021/acs.jchemed.1c00688.

Kahu, E. R. & Nelson, K. (2018). Student engagement in the educational interface: Understanding the mechanisms of student success. *Higher Education Research & Development*, 37(1), 58–71. https://doi.org/10.1080/07294360.2017.1344197.

Krause-Levy, S., Griswold, W. G., Porter, L. & Alvarado, C. (2021). The relationship between sense of belonging and student outcomes in CS1 and beyond. In A. J. Ko, J. Vahrenhold, R. McCauley & M. Hauswirth (eds), *ICER 2021: Proceedings of the 17th ACM Conference on International Computing Education Research*, 29–41. New York: Association for Computing Machinery. https://doi.org/10.1145/3446871.3469748.

Lang, R. (2020). Investigative research on the current status of Japanese physics education using evaluation tools based on physics education research. KAKENHI (Grants-in-Aid for Scientific Research) Project Report. (In Japanese.) https://kaken.nii.ac.jp/ja/file/KAKENHI-PROJECT-26282032/26282032seika.pdf. Accessed 28 December 2023.

Lombardi, D., Shipley, T. F., Astronomy Team, Biology Team, Chemistry Team, Engineering Team, Geography Team, Geoscience Team & Physics Team (2021). The curious construct of active learning. *Psychological Science in the Public Interest*, 22(1), 8–43. https://doi.org/10.1177/1529100620973974.

Marra, R. M., Rodgers, K. A., Shen, D. & Bogue, B. (2012). Leaving engineering: A multi-year single institution study. *Journal of Engineering Education*, 101(1), 6–27. https://doi.org/10.1002/j.2168-9830.2012.tb00039.x.

Ministry of Economy, Trade and Industry (2021). Eleven programs certified as FY2021 1st Mathematics, Data Science and AI Smart Higher Education Programs (Literacy Level). News release, 30 June. https://www.meti.go.jp/english/press/2021/0630_003.html. Accessed 28 December 2023.

National Research Council (2012). *Discipline-Based Education Research: Understanding and improving learning in undergraduate science and engineering*. Washington, DC: National Academies Press. https://nap.nationalacademies.org/download/13362. Accessed 27 December 2023 (requires free account setup).

Ng, O.-L., Ting, F., Lam, W. H. & Liu, M. (2020). Active learning in undergraduate mathematics tutorials via cooperative problem-based learning and peer assessment with interactive online whiteboards. *Asia-Pacific Education Researcher*, 29(3), 285–94. https://doi.org/10.1007/s40299-019-00481-1.

Nieswandt, M. (2007). Student affect and conceptual understanding in learning chemistry. *Journal of Research in Science Teaching*, 44(7), 908–37. https://doi.org/10.1002/tea.20169.

OECD (2022). Share of women graduates in STEM fields: % of tertiary graduates in science, technology, engineering and mathematics, 2019. https://web.archive.org/web/20220303224801/https://www.oecd.org/coronavirus/jp/data-insights/did-someone-say-women-in-science. Accessed 28 December 2023.

Ogasawara, M. (2007). Teaching of basic sciences in research universities and the role of the teaching assistant. *Nagoya Journal of Higher Education*, 7, 249–67. (In Japanese.) https://doi.org/10.18999/njhe.7.249.

Ohmori, F., Saito, J. & Suzuki, H. (2022). Active learning and traditional lecture in basic science courses: Teaching methods and their effects from the viewpoints of university students and graduates. *Journal of Japan Association for College and University Education*, 44(2), 29–39. (In Japanese.) https://doi.org/10.60182/jacuejournal.44.2_29.

Oki, S. (2019). Bunkei (letters) and rikei (science), division between two cultures in Japan? An attempt of historical description. *Trends in Sciences*, 24(8), 72–7. (In Japanese.) https://doi.org/10.5363/tits.24.8_72.

Partanen, L. (2018). Student-centred active learning approaches to teaching quantum chemistry and spectroscopy: Quantitative results from a two-year action research study. *Chemistry Education Research and Practice*, 19(3), 885–904. https://doi.org/10.1039/C8RP00074C.

Peteroy-Kelly, M. A. (2007). A discussion group program enhances the conceptual reasoning skills of students enrolled in a large lecture-format introductory biology course. *Journal of Microbiology & Biology Education*, 8(1), 13–21. https://doi.org/10.1128/jmbe.8.1.13-21.2007.

President's Council of Advisors on Science and Technology (2012). *Engage to Excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics* (Report to the President). Executive Office of the President. https://files.eric.ed.gov/fulltext/ED541511.pdf. Accessed 28 December 2023.

Rodriguez, M. & Potvin, G. (2021). Frequent small group interactions improve student learning gains in physics: Results from a nationally representative pre-post study of four-year colleges. *Physical Review Physics Education Research*, 17(2), art. no. 020131: 1–11. https://doi.org/10.1103/PhysRevPhysEducRes.17.020131.

Sands, D., Parker, M., Hedgeland, H., Jordan, S. and Galloway, R. (2018). Using concept inventories to measure understanding. *Higher Education Pedagogies*, 3(1), 173–82. https://doi.org/10.1080/23752696.2018.1433546.

Science Council of Japan (2020). Proposal on the promotion of discipline-based education research (DBER) in physics'. (In Japanese.) https://www.scj.go.jp/ja/info/kohyo/pdf/kohyo-24-t295-3.pdf. Accessed 28 December 2023.

Seyranian, V., Madva, A., Duong, N., Abramzon, N., Tibbetts, Y. & Harackiewicz, J. M. (2018). The longitudinal effects of STEM identity and gender on flourishing and achievement in college physics. *International Journal of STEM Education*, 5, art. no. 40: 1–14. https://doi.org/10.1186/s40594-018-0137-0.

Springer, L., Stanne, M. E. & Donovan, S. S. (1999). Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis. *Review of Educational Research*, 69(1), 21–51. https://doi.org/10.3102/00346543069001021.

Stets, J. E., Brenner, P. S., Burke, P. J. & Serpe, R. T. (2017). The science identity and entering a science occupation. *Social Science Research*, 64, 1–14. https://doi.org/10.1016/j.ssresearch.2016.10.016.

Stout, J. G., Ito, T. A., Finkelstein, N. D. & Pollock, S. J. (2013). How a gender gap in belonging contributes to the gender gap in physics participation. *American Institute of Physics Conference Proceedings*, 1513(1), 402–5. https://doi.org/10.1063/1.4789737.

Tanner, K. & Allen, D. (2005). Approaches to biology teaching and learning: Understanding the wrong answers – teaching toward conceptual change. *Cell Biology Education*, 4(2), 112–17. http://dx.doi.org/10.1187/cbe.05-02-0068.

Tashiro, J., Parga, D., Pollard, J. & Talanquer, V. (2021). Characterizing change in students' self-assessments of understanding when engaged in instructional activities. *Chemistry Education Research and Practice*, 22(3), 662–82. https://doi.org/10.1039/D0RP00255K.

Tien, L. T., Roth, V. & Kampmeier, J. A. (2002). Implementation of a peer-led team learning instructional approach in an undergraduate organic chemistry course. *Journal of Research in Science Teaching*, 39(7), 606–32. https://doi.org/10.1002/tea.10038.

Trujillo, G. & Tanner, K. D. (2014). Considering the role of affect in learning: Monitoring students' self-efficacy, sense of belonging, and science identity. *CBE – Life Sciences Education*, 13(1), 6–15. https://doi.org/10.1187/cbe.13-12-0241.

Veilleux, N., Bates, R., Allendoerfer, C., Jones, D., Crawford, J. & Floyd-Smith, T. (2013). The relationship between belonging and ability in computer science. In *SIGCSE '13: Proceedings of the 44th ACM technical symposium on computer science education*, pp. 65–70. New York: Association for Computing Machinery. https://doi.org/10.1145/2445196.2445220.

Wallace, C. S., Chambers, T. G. & Prather, E. E. (2018). Item response theory evaluation of the Light and Spectroscopy Concept Inventory national data set. *Physical Review Physics Education Research*, 14(1), art. no. 010149: 1–19. https://doi.org/10.1103/PhysRevPhysEducRes.14.010149.

Wilson, D., Jones, D., Bocell, F., Crawford, J., Kim, M. J., Veilleux, N., Floyd-Smith, T., Bates, R. & Plett, M. (2015). Belonging and academic engagement among undergraduate STEM students: A multi-institutional study. *Research in Higher Education*, 56(7), 750–76. https://doi.org/10.1007/s11162-015-9367-x.

Wilton, M., Gonzalez-Niño, E., McPartlan, P., Terner, Z., Christoffersen, R. E. & Rothman, J. H. (2019). Improving academic performance, belonging, and retention through increasing structure of an introductory biology course. *CBE – Life Sciences Education*, 18(4), art. no. 53: 1–13. https://doi.org/10.1187/cbe.18-08-0155.

Yadav, A., Vinh, M., Shaver, G. M., Meckl, P. & Firebaugh, S. (2014). Case-based instruction: Improving students' conceptual understanding through cases in a mechanical engineering course. *Journal of Research in Science Teaching*, 51(5), 659–77. https://doi.org/10.1002/tea.21149.

13

Belonging in the ecotone: a case study from a STEM higher education context

Luke McCrone

Introduction

We live and learn in a physical world which has immense impact on how we behave, feel, interact and relate. Personal, social, institutional and political factors shape the power and agency we feel in any given 'space'. To better understand belonging, we might study these spaces and develop methods for understanding the meaning people make of them.

This chapter introduces a mixture of traditional, redesigned, timetabled and non-timetabled learning space case studies, and draws upon my experiences representing, researching and partnering with students at a science, technology, engineering and mathematics (STEM), research-intensive university. These findings comprise my doctoral research, which investigated undergraduate student engagement with transitions between formal, timetabled and informal, non-timetabled learning. Studying these transitional spaces aided the identification and understanding of spaces in which students feel they have a sense of ownership in their learning, and of how this sense of ownership can support a sense of belonging.

Applying these empirical findings in practice informed a series of student partnership-driven projects which converted informal departmental areas (adjacent to lecture theatres) into functional transitional spaces. One such transitional space was evaluated before and after the renovation, in conjunction with its adjacent redesigned lecture theatre, to investigate how transforming each physical space supported the institution's strategic move to student-centred, discovery-based learning. Reflecting on these institutional case studies and on my student representation experience as Deputy President (Education) in the student union, I explore the implications of partnering with students in the space (re)design process for their sense of ownership and belonging, including in the redesigned spaces. I adopt socio-spatial theories to acknowledge the significance of space as a social product that shapes social activity, whilst later introducing an ecological concept that provides an alternative, critical way of conceptualising sense of belonging in learning space. I argue that belonging between spaces, processes and disciplines requires increasing attention in a complex and evolving higher education ecosystem.

The chapter focus is inspired by literature which increasingly acknowledges that students' sense of belonging is linked to positive academic outcomes (Osterman, 2000), higher student engagement (Furrer & Skinner, 2003), well-being (Allen et al., 2018) and ownership of learning (du Toit-Brits, 2022). Whilst belonging to university is multidimensional, Ahn and Davis (2020) found 'surroundings' to be one of four important domains of belonging, which is defined as students' 'living space, and geographical and cultural location' (p. 1). Ecological metaphors can reveal tensions between spaces and potentially empower an increasingly diverse group of learners, including students who – intentionally or unintentionally – do not belong (see also Kandiko Howson & Kingsbury, Chapter 1 in this volume).

The focus is also influenced by a growing recognition that didactic transmission lecturing is a less effective pedagogical approach than more student-centred, discovery-based learning in STEM fields (Freeman et al., 2014; see also Ohmori et al., Chapter 12 in this volume). With hybridisation increasing the ubiquity of learning (Deed & Alterator, 2017), most students own or have access to personal devices like phones and laptops and thereby have a greater perceived ownership of their formal and informal learning (Wut et al., 2022). Students therefore increasingly find themselves operating at the boundary of spaces, in a state of transition and tension.

As this tide of change continues to sweep us away from traditional conceptions of learning as a classroom-bound phenomenon towards more holistic conceptions of the student experience, the question of belonging has been brought into focus. Hybrid learning poses challenges and opportunities for designers, educators and students, and creates a need to rethink and redesign university campuses for improved belonging, well-being and learning. However, our understanding of the role of the physical university in supporting the development of belonging remains limited and requires further attention (Temple, 2018).

Background and context

My anecdotal and empirical experiences as an undergraduate student in the geosciences, as Deputy President (Education) in Imperial College Union, and most recently as a PhD student who explored student engagement with learning spaces (McCrone, 2021), have given me a unique insight into the evolving institutional context. This collective experience has afforded me direct exposure to a variety of learning spaces, disciplinary contexts and committees in the institution, which have shaped my ontological positioning.

The institution's main campus is located in an urban part of London and is highly international; 60 per cent of the students are from outside the UK. Its ongoing commitment to a Learning and Teaching Strategy, which I was involved in co-creating as a student representative, aims to make the university more student-centred, evidence-based, inclusive, diverse, outward-looking and technology-enhanced (Imperial College London, 2017). These strategic aspirations arguably require a careful evaluation and development of educational infrastructure such as campus spaces and timetables to better reflect the changing needs of the learner and society. Whilst the institution has invested in the maintenance and modernisation of this infrastructure, a joined-up dialogue between space practitioners and those engaging with and improving education has arguably been lacking (Carnell, 2017). The fragmented constitution of research-intensive universities can make this joined-up dialogue even more difficult (Brew, 2010).

The anecdotes introduced in this chapter represent unique case studies in which I employed my experiences and research findings to partner with students, educators and design practitioners to redesign campus learning spaces. The role and impact of these learning spaces on student sense of belonging are explored, as are the ways in which students were engaged in the participatory processes.

The case for 'space'

'Space' is not merely a neutral physical container, it is socio-political, imbued with functional and symbolic messages which indicate how people should behave and interact (Temple, 2019). Hence, whilst different individuals experience the same space differently, shared physical, cognitive and social spaces influence an individual's behaviours, feelings and ways of thinking (see also Kandiko Howson & Kingsbury, Chapter 1 in this volume). In our striving for a stronger sense of belonging, space should therefore be at the centre of our purview. Furthermore, with the average cost of UK education space nearing £200 per square metre, and with the ongoing maintenance of this physical capital approaching £3 billion annually – only exceeded by staff budgets (Temple, 2018) – it is in the sector's best interest to garner knowledge about the impact of space on social activity to inform future investments.

This chapter assumes that space is a social product which shapes social relations and practice (Lefebvre, 1991), and that space is relational with an inherent power-geometry dictated by economic, political and cultural influences and resources (Massey, 2005). By focusing on people's 'use of space and the meanings they associate with different spaces' (Samura, 2018, p. 19), we can better decode their experience and sense of belonging. This chapter looks closely at the interplay between what Sennett (2019) calls the *cité* and *ville*, the former describing social life and the latter the physical location and form of a place. Temple (2019) argues that once the infrastructural *ville* elements 'become ends in themselves, rather than a means towards supporting some wider, broadly agreed, social purpose' (p. 224), they become unsatisfactory for their users, whatever their architectural merits. The relationship between people and spaces, and their sense of ownership in those spaces, can therefore influence their sense of belonging.

Introducing ecotones

Having adopted these socio-spatial theories in the institutional case studies, this chapter presents an ecological way of conceiving learning space – popularised by Barnett and Jackson (2019) in their book *Ecologies for Learning and Practice: Emerging ideas, sightings, and possibilities* – to provide an alternative, critical way of understanding student sense of belonging in space.

The question of where students belong is arguably a question of space and place. This question was historically shaped by a teacher-centred learning paradigm and the absence of the internet and ubiquitous learning. With students' belonging in an increasingly hybrid world, the learning spaces they engage with are increasingly transitional, contested and flexible. The way we conceptualise learning space is therefore changing from binary divides like 'formal' and 'informal' (Middleton, 2019) to metaphors which can more aptly capture both these defined learning spaces and the spaces and tensions in between.

‘Ecotones’ are ecological zones ‘where two distinct ecosystems overlap or grade into one another’ (Pendleton-Jullian, 2019, p. 112). The word ‘ecotone’ etymologically means ‘ecologies in tension’, and, like estuaries in the natural world, they are zones of tension between tidal (e.g., classroom space) and river (e.g., informal space) forces in which a more diverse group of species (students) can potentially thrive. Furthermore, ecotones are spaces at the edge which can reinforce, challenge and develop territorialised ideologies and identities, transforming the adjoining core spaces by feeding changes back into the entire ecosystem. Belonging in the ecotone between spaces, processes and disciplines can promise new ways of thinking and richer flows of knowledge than being at the core, given ‘progress is made at the interface’ (Epstein, 2021, p. 279). This chapter introduces the ecotone concept as a flexible metaphor, in a similar way to Pendleton-Jullian (2019), who explored innovative educational environments, to conceptualise the transitional space and tensions between timetabled and non-timetabled learning, between different pedagogical spaces, and between the design and use of those spaces.

(Re)designing space for belonging

Our efforts to redesign space in the future will likely centre on bringing people together to think and interact in non-traditional ways. This is because the world is changing, and so too are the problems we face in STEM and society. It is abundantly clear from Covid-19, for example, that an interdisciplinary approach is needed for addressing complex real-world issues (Moradian et al., 2021). Developing spaces with flexible power-geometries (Massey, 2005) in which students can think inside and outside the traditional bounds of their discipline is therefore increasingly needed. Whilst on the one hand formal disciplinary spaces like classrooms and labs can develop disciplinary belonging, on the other they can stifle creativity and collaboration across disciplines (Becher & Trowler, 2001).

Contemplating the implication of these changes for belonging encourages us to abstract implicit assumptions about learning space. For instance, to what extent do alterations made to formal, timetabled spaces like classrooms lead to desired changes in learning behaviour (Imms & Kvan, 2021)? How do these changes influence the development of disciplinary belonging? Which dilemmas exist between the enhancement of this disciplinary belonging and that of interdisciplinary collaboration when we are designing learning spaces? How will these questions remain relevant as our theoretical and physical conceptions of learning space develop into metaphors which more aptly capture the complexity of hybrid, discovery-based learning?

Since space is socially constructed and people's interactions are affected by space, changes made to space inevitably lead to changes in people's intent and interactions (Samura, 2018). However, since architectural space is not necessarily deterministic by virtue of its inbuilt intentionality, we fundamentally have agency in how we choose to act within space (Oolbekkink-Marchand et al., 2017). This chapter argues that, whilst redesigning space can shift what Ravelli and Stenglin (2008) call the 'social distance', that is, a participant's physical position and perceived power relative to other interactants, the sense of ownership which teachers and students have in a space influences how empowered they feel within it. I explored these transitions in and relationships between space and behaviour in more detail in my doctoral thesis (McCrone, 2021).

The learning space case studies in this chapter demonstrate how ownership can arise incidentally, such as when students find themselves in more flexible in-between spaces in which they can direct their own learning, or more explicitly when users shape the design of space to suit their own and others' needs. Burke et al. (2016) argued that the objectives of redesigning a learning space will only be fully realised if the users of that space support the pedagogical principles informing it. Exploring student engagement with these transitional spaces, both as users of space and as agents in shaping that space, has assisted a unique understanding of the conditions for belonging.

Transforming the lecture theatre

Traditional learning spaces like raked lecture theatres crystallise patterns of behaviour in which the teacher is in control and the students listen (Finkelstein et al., 2016; Imms & Kvan, 2021). Whilst this in-person timetabled teaching is an increasingly rare opportunity for student cohorts to engage with shared ways of thinking, the 'sage on the stage' approach in which teachers transmit knowledge is being supplemented with 'guide on the side' approaches, in which students discover things for themselves with teacher guidance (Jones, 2006). The evolving role of teachers and students is changing how they interact and perceive one another, changing the type of belonging and identity which is possible.

Amid this pedagogical transition, formal learning spaces must become more flexible in their design to accommodate both traditional and interactive pedagogical approaches (Lam et al., 2019). The relationship between this design and pedagogical flexibility was directly investigated through the pre-renovation exploration, the redesign and the post-renovation evaluation of a raked lecture theatre (see Figure 13.1) in the Department of Physics at Imperial College London during the doctoral research. The intent of the redesign was to retain the original rake and transmission function of the space, whilst converting the row-by-row seating into fixed connect-booth seating with accessible walkways and enhanced audio-visual technology. Each booth could accommodate up to five students, so that group-based learning was more easily achievable.

The doctoral research showed that both teachers and students found it easier to transition between segments of transmission teaching and group-directed learning activities than in the pre-renovation space. The new design provided teachers, particularly those who had pre-existing intent to use alternative pedagogies, with more pedagogical options and agency (see also Horsburgh, Chapter 11 in this volume). Furthermore, reconfiguration of furniture from row-by-row seating to shared booths enabled students to form small distinct learning groups in which they

Figure 13.1 Photograph of refurbished raked lecture theatre showing connect-booth seating converted from original row-by-row seating. Photograph by Thomas Angus, Imperial College London. © Luke McCrone.

could share their learning; interestingly, this was the case during both transmission-based and interactive instances of teaching. Student sense of belonging transitioned from feeling like an individual member of a cohort, to belonging to a learning group with which they could share the challenges inherent to learning. These peer-to-peer relationships prevailed beyond the timetabled session, providing students with more opportunity and agency to work through misunderstanding and its associated emotion, both inside and outside their formal learning (see also Ohmori et al., Chapter 12 in this volume).

Despite challenges with cooperation and team management when they were being required to solve task-problems in booth groups, students developed a shared ownership of their learning, and underwent transitions in perception and behaviour and in their expectation of that learning. This shared ownership of learning resulted in a sense of ownership of the space, evident from the increased use of the space for independent and collaborative study during non-timetabled periods. Hence, whilst the overall capacity of the renovated space was reduced in comparison to its row-by-row configuration, the potential 'transitional space' for both teachers and students was broadened.

The implications of this broader transitional space and heightened ownership, arising from a change in space design and pedagogical intent, for student sense of belonging provide fertile ground for further research. However, concepts that can aptly frame the transitions and tensions inherent in the (re)design and use of innovative learning spaces in STEM higher education are arguably lacking. This is particularly important as the institution in the case study (among others in the sector) strategically 'share' learning spaces like the transformed lecture theatre in Figure 13.1 between departments.

Thinking about this lecture theatre as an ecotone helped the institution to find a balance between supporting the development of disciplinary belonging in the Department of Physics (for example by retaining chalkboard writing surfaces for physics notation) and accommodating potential for interdisciplinary usage and collaboration. Furthermore, the ecotone metaphor allowed me to be more holistic in looking at the informal spaces adjacent to and connected to the lecture theatre, which led to the redesign of one such informal space (explored in the next section) to support transitions into and out of timetabled learning. Having this broader awareness of learning space beyond the formal, timetabled space is important given the increase in hybrid learning, and the transitions students navigate between virtual and physical learning.

Developing the spaces in between

Students now have greater agency about how they choose to engage with hybrid learning and the physical and virtual spaces available to them. This is shifting the perceived significance and utility of formal learning spaces like lecture theatres – which are timetabled and institutionally controlled – in relation to informal learning spaces which students colonise of their own accord. Understanding and nurturing the spaces in between is of growing importance as discovery-based learning and research play a greater role in shaping the higher education experience (Carnell, 2017).

In addition to my proactive involvement in the redesign and evaluation of the lecture theatre in Figure 13.1, I partnered with students and staff to redesign the informal learning space adjacent to that lecture theatre (see also Kinchin et al., Chapter 17 in this volume). This action was motivated by my doctoral research findings, which discovered the potential of these fringe informal learning spaces for supporting transition and discovery-based learning. Because of its position adjacent to the lecture theatre, the pre-renovation informal space was unfurnished and mainly used as a method of ingress to and egress from surrounding spaces. Nonetheless, my observations established that there were subtle changes in student behaviour as they transitioned between this space and the lecture theatre. This raised the question of whether the lecture theatre and the adjacent space could be treated as distinct entities between which students transitioned, or whether these physical and temporal spaces blended into one another (when considered in the context of the timetable) to result in a separate transitional space. This question was able to be conceptualised and addressed using the ecotone metaphor. The informal space possessed potential for the formation of departmental and cross-cohort community as students transitioned into and out of timetabled learning in the lecture theatre.

Through the addition of suitable furniture like sofas, high tables and chairs (see Figure 13.2), the space's altered affordance allowed students to develop a greater sense of ownership in the periods just before and after lectures, as well as during lunchtime and other non-timetabled periods. The addition of writing surfaces (in this case chalkboards) physically and conceptually extended the physics lecture space, so that teachers and students could transition questions and interactions at the end of the timetabled session into a space more permissible of informal, discovery-based discussion. The ambiguous designation of this transitional space also allowed students to colonise it for independent study and collaborative learning not directly associated with timetabled learning.

Figure 13.2 Photograph of refurbished informal learning space adjacent to the lecture theatre in Figure 13.1, entered through the door on the right, showing a variety of furniture types and writing surfaces. Photograph by Luke McCrone, Imperial College London. © Luke McCrone.

The transformation of both the lecture theatre and the adjacent transitional space, in tandem with the broader strategic context, led to changes in how students perceived not only the spaces, but their peers and teachers. Students went from describing their teachers as 'guardians of credit' in the pre-renovation context to 'approachable helpers' in the new spaces. This transition seemed to be due to the negotiation of a more co-constructive relationship between students, their peers and their teachers, which was found to impact how they interacted outside of the timetabled sessions, that is, when approaching teachers with questions. These lasting changes in cohort culture impacted student sense of belonging to the department, supported transitions into online group work during Covid-19, and more broadly contributed to the strategically desired transition to discovery-based learning.

Repeated transitions into and out of any space – including spaces with more neutral designation, expectation and power-geometry like the redesigned transitional space – can lead to increased familiarity, trust, safety and other preconditions for belonging. These shared familiar spaces, which can range from departmental spaces to hall-of-residence kitchens, provide students with a collective purpose such as timetabled learning or eating, and can broaden the potential space for community and belonging. Developing underutilised foyers and corridors, which act as 'both buffer space and physical link' (Nassar & Hosam, 2014, p. 8306), has been proved to increase student ownership of and belonging to their department and discipline. The extent to which the contrasting power-geometry and tension between these transitional spaces and their connecting 'oppressive' lecture theatre (Freire, 2020) can empower students to regain a sense of ownership and agency in their learning is worthy of further investigation. The involvement of students as partners in the redesign of these transitional spaces deepened their sense of ownership and worth in the spaces and departmental community, a relationship which is equally worthy of further investigation.

Partnership: creating space ownership

My own belonging to the institution shifted when I was given the opportunity to contribute meaningfully to improving the student experience in representation roles like Deputy President (Education). This involved me collecting authentic student voice to inform and shape institutional strategy and practice, which shaped my belonging and even my decision to transition from a STEM discipline into the educational research community. However, even with an elected representation title, I at times found it difficult to enact change and was only successful in doing so when provided with the right tools and opportunities. Furthermore, whilst I felt comfortable participating in these formalised representation structures, the same cannot be said for all students. This has prompted an ongoing reflection about how students might be engaged productively and sensitively in shaping their learning experience.

I later partnered with undergraduate students and staff under the institution's StudentShapers partnership programme to convert an underutilised departmental area into the transitional learning space in Figure 13.1 (see Streule et al., 2022). This research-informed, participatory-design approach involved student partners using mixed methods like surveys and sandpit-style focus groups (Casanova et al., 2018) to consult their peer user groups to reimagine the spatial design. An open call for student partner applications was made to the department to ensure inclusive selection of the design team. As a doctoral researcher with experience of social science methods, the pre-renovation space and its transitional potential, I acted as what Norman (2010) calls a ‘translational designer’ by bridging the gap between research and practice. Students were engaged meaningfully, from the conceptualisation of space designs up to the implementation of those designs when products were selected from furniture suppliers. The depth of this involvement gave users a greater stake in the learning environment, both directly, for the student partners, and less directly for consulted staff and student groups.

Perhaps more interestingly, the participatory approach impacted how the space was later perceived and colonised. Whilst changing the physical space had intentionally changed its affordance (Gibson, 1977), the partners and the consulted user group also reflected on their preconceptions of the space and what Pantidi (2013) calls their ‘legibility’. The participatory approach impacted their sense of ownership of and behaviour within the space, as well as their sense of belonging in the space and in the department.

Several researchers have theorised similarly in other contexts, including Temple (2019), who uses common-pool resource (CPR) theory to argue that the collective management of tangible and intangible resources, like physical and social space, can maximise sustainable output and help to create ‘place’ in universities. Likewise, Lefebvre’s (1991, p. 33) ‘conceptual triad’ distinguishes between ‘conceived’ space, which is formally determined by conceptual design, ‘lived’ space, which relates to the meaning assigned to space as influenced by symbolic messages and cultural values, and ‘perceived’ space, which links the two former categories and is revealed through the daily use of space. Temple (2019) argues that, if we are to create place, as many spaces in the university should be moved from the conceived to the perceived category as possible through a greater understanding of which spaces in the institution are valued by staff and students.

Participatory approaches to space redesign arguably transform students from being users of an institutionally conceived space to designers with agency over the physical form and social capital of that space; this changes the meaning students make of those spaces. The participatory approach allowed several other departments to redesign their learning spaces in a way that was more effective, both educationally and in terms of cost, than traditional approaches. The literature does, however, lack theories and terminology which conceptualise this transition in student role and sense of ownership (Martens et al., 2019). The ecotone metaphor may help to conceptualise this tension and transitional space between design and usage, in a similar way to Lefebvre’s (1991) conceptual triad, to explore how students’ participation in shaping their own learning environment impacts their sense of belonging in and ownership of that environment.

Ecological metaphors for space and belonging

The ecotone metaphor has been introduced to help with conceptualising and understanding some of the learning spaces introduced in this chapter. For example, the transitions between the transformed, timetabled lecture theatre and the adjacent informal, non-timetabled space gave rise to a separate ecotone space in which students were less constrained by expectation or code of conduct. Within these ecotones exist tensions between opposing forces, between old and new behaviours and ways of thinking, and between existing and potential identities (see also Kandiko Howson & Kingsbury, Chapter 1 in this volume). The flexible power-geometry of these fringe ecotones offers new situations and possibilities for students and teachers to manage these tensions.

The ecotone metaphor has helped to reveal the potential of the transformed lecture theatre, firstly via the introduction of connected seating booths which might be thought of as 'micro-ecotones' between student groups and teachers, and secondly by understanding the transitions and tensions in power and ownership between different interactants. Using this metaphor helped me to understand how the lecture theatre redesign had broadened the potential ecotone for transitions in behaviour, ownership and different ways of belonging, compared to the pre-renovation space. It also encouraged a redefinition of the classroom from a demarcated lecture theatre to an ecological zone, which includes the fringe informal spaces and potential ecotones in between; this conceptualisation has had powerful implications for design and practice (McCrone, 2021).

Thinking ecologically about space and belonging can help us to think more holistically about where students learn and belong (Barnett & Jackson, 2019). Ecotones are a versatile ecological metaphor which can be used to conceptualise not only the space between formal and informal learning, but those between teacher and student, between physical and virtual learning, between liminality and understanding, and between disciplines. Pendleton-Jullian (2019), for instance, used the concepts of ecotones, elasticity and agency for designing environments of innovation. This application may extend to how we understand the space and opportunity between management (conceived space) and user (perceived space) in the context of the student partnership redesign work. Involving students as end users in the redesign process provides them with more agency in shaping the ecotone and their sense of belonging in the subsequent renovated space. Furthermore, the ecotone metaphor could be applied to campus-scale design and planning in more holistic thinking about student belonging in 'distal' living spaces like halls of residence, 'proximal' learning spaces like lecture theatres, and the spaces in between.

As students unpredictably colonise new learning spaces as hybrid learning increases, we need to develop methods which more aptly capture how exactly spaces are being used and perceived (McCrone & Kingsbury, 2023). This development will allow us to identify and develop ecotones like informal transitional spaces, in which a diverse group of students can thrive and shape their own conditions for belonging.

Conclusion

If we are to create a strong sense of belonging and support discovery-based learning, we must understand how ownership of space can be transitioned to students in ways that enable them to freely enact different ways of thinking and interacting. This chapter has introduced case studies, firstly to argue that transitional spaces like foyers and corridors at the fringe of lecture theatres possess flexible power-geometries within which students can engage in this learning interaction. Secondly, I have argued that the involvement of users in the redesign of these spaces can support a deeper sense of ownership and agency in those spaces. For student partners to reap these benefits, however, they must feel valued in the redesign process and be equipped with methods and tools which allow them to reimagine the spaces effectively; a translational designer who has researched the spaces can help to guide student partners towards a purposeful design.

The complex relationships between space, ownership and belonging are requiring us to rethink the traditional socio-spatial theories alluded to in this chapter. Ecotones are ecological zones at the boundary of two ecosystems (learning spaces) which provide a useful metaphor for this evolving complexity, given that they can capture the transitions and tensions between the lecture theatre and adjacent informal space, as well as the transitional space between those who design space and those who use it. Ecotones might also help us to identify and design not only spaces which enhance disciplinary belonging, like the transformed lecture theatre, but also spaces in between that promote interdisciplinary collaboration, innovation and new ideas from the interaction of different perspectives and approaches.

The dilemma between disciplinary belonging and interdisciplinary collaboration requires us to find a balance by looking at the ecotones between formal, disciplinary spaces in which students and teachers have a shared agency to discover new ideas and possibilities. Furthermore, these ecological metaphors and holistic conceptions of learning space might help us to incorporate flexibility, connectivity and inclusivity into an increasingly hybrid learning experience. However, as hybrid, discovery-based learning poses challenges and opportunities for designers, educators and students, we must think carefully about which spaces students are learning in, and how these spaces can support the formation of belonging. This is particularly important in the STEM higher education context.

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References

Ahn, M. Y. & Davis, H. H. (2020). Four domains of students' sense of belonging to university. *Studies in Higher Education*, 45(3), 622–34. https://doi.org/10.1080/03075079.2018.1564902.

Allen, K., Kern, M. L., Vella-Brodrick, D., Hattie, J. & Waters, L. (2018). What schools need to know about fostering school belonging: A meta-analysis. *Educational Psychology Review*, 30(1), 1–34. https://link.springer.com/article/10.1007/s10648-016-9389-8.

Barnett, R. & Jackson, N. (eds). (2019). *Ecologies for Learning and Practice: Emerging ideas, sightings, and possibilities*. Abingdon: Routledge.

Becher, T. & Trowler, P. (2001). *Academic Tribes and Territories: Intellectual enquiry and the cultures of disciplines*, 2nd edn. Milton Keynes: McGraw-Hill Education.

Brew, A. (2010). Imperatives and challenges in integrating teaching and research. *Higher Education Research & Development*, 29(2), 139–50. https://doi.org/10.1080/07294360903552451.

Burke, P. J., Crozier, G. & Misiaszek, L. I. (2016). *Changing Pedagogical Spaces in Higher Education: Diversity, inequalities and misrecognition*. Abingdon: Routledge.

Carnell, B. (2017). Connecting physical university spaces with research-based education strategy. *Journal of Learning Spaces*, 6(2), 1–12.

Casanova, D., Di Napoli, R. & Leijon, M. (2018). Which space? Whose space? An experience in involving students and teachers in space design. *Teaching in Higher Education*, 23(4), 488–503. https://doi.org/10.1080/13562517.2017.1414785.

Deed, C. & Alterator, S. (2017). Informal learning spaces and their impact on learning in higher education: Framing new narratives of participation. *Journal of Learning Spaces*, 6(3), 54–8.

du Toit-Brits, C. (2022). Exploring the importance of a sense of belonging for a sense of ownership in learning. *South African Journal of Higher Education*, 36(5), 58–76. http://dx.doi.org/10.20853/36-5-4345.

Epstein, D. (2021). *Range: Why generalists triumph in a specialized world*. New York: Riverhead Books.
Finkelstein, A., Ferris, J., Weston, C. & Winer, L. (2016). Research-informed principles for (re) designing teaching and learning spaces. *Journal of Learning Spaces*, 5(1).
Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H. & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, 111(23), 8410–15. https://doi.org/10.1073/pnas.1319030111.
Freire, P. (2020). Pedagogy of the oppressed. In J. Beck, C. Jenks, N. Keddie & M. F. D. Young (eds), *Toward a Sociology of Education*, pp. 374–86. Abingdon: Routledge.
Furrer, C. & Skinner, E. (2003). Sense of relatedness as a factor in children's academic engagement and performance. *Journal of Educational Psychology*, 95(1), 148–62. https://doi.org/10.1037/0022-0663.95.1.148.
Gibson, J. J. (1977). The theory of affordances. In R. Shaw & J. Bransford (eds), *Perceiving, Acting, and Knowing: Toward an ecological psychology*, pp. 67–82. Hillsdale, NJ: Lawrence Erlbaum Associates.
Imms, W. & Kvan, T. (eds) (2021). *Teacher Transition into Innovative Learning Environments: A global perspective*. Singapore: Springer.
Imperial College London (2017). Innovative teaching for world class learning: Learning and teaching strategy. https://web.archive.org/web/20220520111847/https://www.imperial.ac.uk/learning-and-teaching-strategy/. Accessed 30 December 2023.
Jones, A. N. (2006). From the sage on the stage to the guide on the side: The challenge for educators today. *ABAC Journal*, 26(1), 1–18.
Lam, E. W. M., Chan, D. W. M. & Wong, I. (2019). The architecture of built pedagogy for active learning: A case study of a university campus in Hong Kong. *Buildings*, 9(11), art. no. 230, 1–13. https://doi.org/10.3390/buildings9110230.
Lefebvre, H. (1991). *The Production of Space*, trans. D. Nicholson-Smith. Oxford: Blackwell Publishing.
Martens, S. E., Meeuwissen, S. N. E., Dolmans, D. H. J. M., Bovill, C. & Könings, K. D. (2019). Student participation in the design of learning and teaching: Disentangling the terminology and approaches. *Medical Teacher*, 41(10), 1203–5. https://doi.org/10.1080/0142159X.2019.1615610.
Massey, D. (2005). *For Space*. London: SAGE Publications.
McCrone, L. (2021). Transitional space in active learning: Perspectives from an undergraduate STEM education context. PhD thesis, Imperial College London.
McCrone, L. & Kingsbury, M. (2023). Combining worlds: A mixed method for understanding learning spaces. *International Journal of Qualitative Methods*, 22. https://doi.org/10.1177/16094069231173781.
Middleton, A. (2019). *Reimagining Spaces for Learning in Higher Education*. London: Bloomsbury Academic.
Moradian, N., Moallemian, M., Delavari, F., Sedikides, C., Camargo, C. A., Jr, Torres, P. J., ... & Rezaei, N. (2021). Interdisciplinary approaches to COVID-19. In N. Rezaei (ed.), *Coronavirus Disease – COVID-19*, pp. 923–36. Cham: Springer.
Nassar, U. A. & El-Samaty, H. S. (2014). Transition space in higher-education buildings as an efficient 'behavior setting' model. *International Journal of Innovative Research in Science, Engineering and Technology*, 3(1), 8304–19.
Norman, D. A. (2010). The research–practice gap: The need for translational developers. *Interactions*, 17(4), 9–12. https://doi.org/10.1145/1806491.1806494.
Oolbekkink-Marchand, H. W., Hadar, L. L., Smith, K., Helleve, I. & Ulvik, M. (2017). Teachers' perceived professional space and their agency. *Teaching and Teacher Education*, 62, 37–46. https://doi.org/10.1016/j.tate.2016.11.005.
Osterman, K. F. (2000). Students' need for belonging in the school community. *Review of Educational Research*, 70(3), 323–67. https://doi.org/10.3102/00346543070003323.
Pantidi, N. (2013). An ethnographic study of everyday interactions in innovative learning spaces. PhD thesis, Open University.
Pendleton-Jullian, A. (2019). Education and innovation ecotones. In R. Barnett & N. Jackson (eds), *Ecologies for Learning and Practice: Emerging ideas, sightings*, pp. 112–28. Abingdon: Routledge.

Ravelli, L. J. & Stenglin, M. (2008). Feeling space: Interpersonal communication and spatial semiotics. In G. Antos & E. Ventola (eds), *Handbook of Interpersonal Communication*, pp. 355–93. Berlin: Walter de Gruyter.

Samura, M. (2018). Understanding campus spaces to improve student belonging. *About Campus*, 23(2), 19–23. https://doi.org/10.1177/1086482218785887.

Sennett, R. (2018). *Building and Dwelling: Ethics for the city*. New York: Farrar, Straus and Giroux.

Streule, M., McCrone, L., Andrew, Y. & Walker, C. (2022). Engaging with students as partners in education-space design. *International Journal for Students as Partners*, 6(2), 79–90. https://doi.org/10.15173/ijsap.v6i2.5024.

Temple, P. (2018). Space, place and institutional effectiveness in higher education. *Policy Reviews in Higher Education*, 2(2), 133–50. https://doi.org/10.1080/23322969.2018.1442243.

Temple, P. (2019). University spaces: Creating cité and place. *London Review of Education*, 17(2), 223–35. http://dx.doi.org/10.18546/LRE.17.2.09.

Wut, T. M., Xu, J., Lee, S. W. & Lee, D. (2022). University student readiness and its effect on intention to participate in the flipped classroom setting of hybrid learning. *Education Sciences*, 12(7), art. no. 442, 1–15. https://doi.org/10.3390/educsci12070442.

14
Can science be inclusive? Belonging and identity when you are disabled, chronically ill or neurodivergent

Jennifer Leigh, Julia Sarju and Anna Slater

Introduction

Belonging and identity in any aspect of science, technology, engineering and maths (STEM) education must be addressed intersectionally. The barriers and challenges that an individual experiences from any one protected characteristic (such as disability, chronic illness, neurodivergence, race, ethnicity, religion, sexuality or gender) cannot be considered in isolation. In this chapter we present a series of case studies, and focus on how STEM laboratories can and should be managed to ensure that they are inclusive of students and staff who are disabled, chronically ill, neurodivergent or a combination of those. If greater diversity in STEM is to encouraged, it is vital that students feel that they have a place in the discipline and that they belong. This demands that they witness people like them succeeding and progressing in STEM careers (Babalola et al., 2023). Disabled students cannot truly belong in spaces from which disabled staff are excluded; in this chapter we address inclusivity for both students and staff.

Disabled people are part of every large and diverse community, and all the multifaceted (or intersectional) aspects of their identity must be taken into consideration. The proportion of disabled people has increased since Covid-19: for example, in 2017/18 they made up only 18 per cent of the working population in the UK and by 2020/21 the proportion had risen to 21 per cent (Department for Work & Pensions, 2022, Table 4.1). The number of disabled people with a degree is rising; however, the proportion is still much smaller (the number of disabled people with a degree is only about one-third of the number of non-disabled people who have one) (Office for National Statistics, 2022a), and they still face many barriers to access (Office for National Statistics, 2022b).

Within academia, the number of undergraduate students with a known disability increased from 14 per cent in 2018 to 17 per cent in 2021 (Higher Education Statistics Authority, 2022a). During the same period the numbers of postgraduate students with a known disability also increased, from 9 per cent to 11 per cent (Higher Education Statistics Authority, 2022a). However, the number of academic staff with a known disability only increased from 4 per cent to 5 per cent (Higher Education Statistics Authority, 2022b), even though the prevalence of disability increases with age, which might lead us to expect a greater increase in the number of staff with a disability than in the number of students (Department for Work & Pensions, 2022, Table 4.3). It is easy to conclude that within academia there is widespread underrepresentation of disabled people (N. Brown & Leigh, 2018), and that this underrepresentation is increased in disciplines where there is greater gender inequality, such as those in STEM (Higher Education Statistics Authority, 2022b).

Professional societies such as the Royal Society, the Institute of Physics (IOP) and the Royal Society of Chemistry (RSC) are investigating the extent and consequences of underrepresentation and looking at ways to address the lack of diversity in science and the marginalisation of certain groups. These include reports that examine:

- the diversity landscape (Royal Society of Chemistry, 2018),
- women's retention, progression and barriers to publishing success (Royal Society of Chemistry, 2019a, 2019b),
- the experiences of lesbian, gay, bisexual, trans, queer, intersex and asexual (LGBTQIA+) scientists (Institute of Physics, Royal Astronomical Society and Royal Society of Chemistry, 2019),
- the lack of racial and ethnic diversity (Royal Society, 2021; Royal Society of Chemistry, 2022),
- the lack of progression for disabled scientists (Careers Research & Advisory Centre, 2020), and
- the lack of accessibility for disabled students (Joice & Tetlow, 2021).

Underrepresentation, and being and feeling marginalised, at study or work, impact on the degree to which an individual feels they belong there (Royal Society of Chemistry, 2021).

The STEM laboratory environment, and its inclusivity and accessibility or lack thereof, can exacerbate feelings of belonging or exclusion for disabled students (Egambaram et al., 2022). It must be noted that not all laboratories look or feel the same, and that not all STEM studies require practical laboratory time. For this chapter we are focusing on chemistry laboratories. A chemistry degree accredited by a learned society such as the Royal Society of Chemistry requires a considerable amount of time spent on practical learning within a laboratory environment, which conventionally would include a range of equipment for conducting organic, inorganic and physical chemistry experiments.

How much an individual feels they belong is multifaceted and subject to change (May, 2011). There are many theories of belonging (Halse, 2018). Pierre Bourdieu understood it in terms of habitus, field and capital (1977):

> Habitus describes the individual's way of seeing, interpreting and acting in the world, in accordance with their social position. It is internalised and consolidated in childhood through family and educational structures and circumstances. Bourdieu's field conceptualises structured social space within which social agents – individuals, groups, institutions – act[,] i.e. employ strategies to hold or enhance their position. Their position is determined by capital, a concept fundamental to Bourdieu's project of demonstrating how social inequality is reproduced in both economic and symbolic spheres. Cultural capital is acquired over time and through exposure to a particular habitus and is embodied in the practices of social agents. It can enable an individual to navigate a field, knowing the 'rules of the game'. (Thomas, 2015, p. 41)

Within higher education, Bourdieu's model of belonging has been used to understand marginalised students' internalised feelings of not belonging or exclusion (Thomas, 2018). Feelings of not belonging in students are associated with student attrition, which is more common in those who are marginalised in one or more aspect of their identity (see also Murray et al., Chapter 4 in this volume). It is necessary to consider inclusion and belonging within the wider context of society and academia (N. Brown & Leigh, 2020).

In academia, support or adjustments for an individual have historically relied on 'disclosing' or 'declaring' a disability, so that reasonable adjustments can be put into place (Inckle, 2018). This places the burden on the individual to disclose, and to be identified as needing support. This can be particularly challenging for those who have conditions that are not visible, that fluctuate, or that are stigmatised (for example mental ill-health), as there can be a fear of how that disclosure will be received (Finesilver et al., 2020). In addition, access to diagnosis, particularly of non-visible disabilities and neurodivergences such as attention deficit hyperactive disorder (ADHD), is gendered and racialised (Allan & Harwood, 2016).

Although science is historically associated with objectivity (Popper, 1959), scientific work and career development for scientists rely on the development of relationships, collaborations and reputations. A fear of disclosure or of being seen as lesser or vulnerable can impede disabled scientists from developing individual professional identities, which impacts the ways they are seen by themselves and others. It is also vital to consider disability through an intersectional lens (Crenshaw, 1989). This means that the impact of disability is considered cumulatively with marginalisations or feelings of not belonging that are due to discrimination on the basis of gender, race or other minoritised identity characteristics. These feelings lead to students reporting a 'chilly environment' in chemistry and other STEM subjects (Stockard et al. 2018; see also Al Arefi, Chapter 10 in this volume).

Although habitus is consolidated in childhood, marginalised students, particularly those who are disabled, chronically ill or neurodivergent, are likely to have already internalised feelings of not belonging in STEM, which may be reinforced by their experiences. It is vital to be proactive and to address the feelings of not belonging and exclusion that STEM environments, particularly laboratories, can create for disabled, chronically ill and neurodivergent staff and students. The lived experiences of those marginalised within STEM demonstrate the impact on the individual scientist (Leigh, Hiscock, McConnell et al., 2022).

Diversity and inclusion in the laboratory

It is well recognised that inequalities and systemic and structural barriers face those who are marginalised, and that, as we have indicated, these are intersectional and compound (Crenshaw, 1989). In the words of Audre Lorde, 'We operate in the teeth of a system for which racism and sexism are primary, established, and necessary props of profit' (Lorde 2017, p. 27). Within academia certain bodies are deemed out of place (Ahmed, 2012), diversity is seen as something to be celebrated rather than just expected as the norm (Fryberg & Martinez, 2014), and ableism is endemic (N. Brown & Leigh, 2020). Neither academia nor science is diverse or representative of the wider community, and this is reflected in data on the distribution of research funding (UK Research and Innovation, 2020). This lack of diversity 'may allow unintentional, undetected flaws to bias … research' (Rosser, 2012, p. 182). Disabled academics are underrepresented in the work force (N. Brown & Leigh, 2018) and 'we live in a world where disability is used as "inspiration porn" (a term coined in 2014 by the late comedian and journalist Stella Young)' (Leigh, Caplehorne & Slowe, 2023, p. 6).

Vignette: Medical versus social model of disability

Disabled people face many barriers and microaggressions (Harris, 2017), and these continue throughout education (Leicester & Lovell, 1997) and in society (Mackelden, 2019). Within academia, these discriminations can come from external funding bodies (Brock, 2021) or arise internally within institutions, and the culmination of such discrimination and barriers is the absence of academics with disabilities, chronic illnesses, or neurodivergences (Careers Research & Advisory Centre, 2020). In part, this can be explained by a predominance within science of the medical model of disability, which describes a disability as a deficit of the individual (Leonardi et al., 2006). In contrast, the social model of disability (Oliver, 2013) would label the environment or society as disabling. For example, an individual in a wheelchair is only disabled when the ramps and lifts are not in place to let them get where they need and want to go. The medical model allows able-bodied and neurotypical people to see those with disabilities as 'lesser', and less human. It is common for those who are 'out' about their disability, neurodivergence, or chronic illness, or who are in a minority because of their religion, sexuality, gender or other protected characteristic, to become involved in work that supports equality, diversity and inclusion (EDI). However, this work is not always recognised in formal progression processes by the institutions (Ahmed, 2012), and can in fact rebound negatively on the individuals involved (Colwell & Bertsch McGrayne, 2020; Leigh, Hiscock, McConnell et al., 2022, p. 57).

EDI work often falls to those who are themselves marginalised, and, while necessary within academia, and time-consuming, it is not valued or recognised in the same way as other academic tasks such as research (Ahmed, 2012). In STEM, other time-consuming tasks that carry little formal esteem, such as pastoral and administrative duties, are often delegated to women and other marginalised groups (Babcock et al., 2022). This situation results in marginalised staff spending time on tasks that are not rewarded by promotion, which contributes to and compounds the lack of diversity at more senior levels (McGee & Robinson, 2020).

Focusing on the chemical sciences, while the field is still grappling to address EDI issues more broadly (Ackerman-Biegasiewicz, Rias-Rotondo & Biegasiewicz, 2020; Ball, 2020; Bordiga et al., 2020; Caltagirone et al., 2021), it might seem a 'hard ask' to tackle mental health, disability and accessibility. There is a lot to fix in terms of the culture in STEM. For example, in the chemical sciences and other disciplines, many argue that first we need to address the lack of women and the lack of Black and brown people (Coughlan, 2021; Vaughan, 2020). The Covid-19 pandemic showed that those with caring responsibilities face a disproportionate burden (Leigh, Hiscock, Koops et al., 2022), and there is a lack of support for parents and prospective parents in the lab (Leigh, Busschaert et al. 2022; Leigh, Smith et al., 2022; Slater et al., 2022). Then consider the postdoc system and the predominance of precarious and short-term contracts (Grinstein & Treister, 2018; Powell, 2015; Spina et al., 2020). But what about when these barriers combine, for example for Black and brown disabled chemists, or postdocs who want families (Lee et al., 2017)? These issues are all intersectional, and to address one EDI issue we must look at them all. So, where to start if we want people to feel as though they belong and not to feel excluded?

The first step is to acknowledge and embrace the ideology of 'nothing about us without us' (Sarju, 2021). To address disability, mental health, or any other EDI issue, we need to involve the people who have lived experience of it. This will build trust, reward effort and explicitly acknowledge the power imbalances in this work and the risk individuals take when they engage in it. Too often, EDI work is undertaken by those on precarious or more junior contracts. Within academia, there is a visible negative impact on the experiences and progression of those disabled, chronically ill or neurodivergent academics that remain (N. Brown, 2021). This can be rationalised as the inevitable consequence of an impairment or neurodivergence feeding into internalised ableism. To address this, the contributions of these academics must be sought out, recognised and rewarded. For example, when a list of recommendations to address ableism and increase inclusivity and accessibility is compiled, whether they are for academia in general (N. Brown & Leigh, 2020) or for the chemistry laboratory in particular (Egambaram et al., 2022), it must be compiled by and with those whom it affects.

The second step is to acknowledge that if individuals are marginalised, isolated or excluded, or their reasonable adjustments (Inckle, 2018) or accessibility (Sweet, Gower & Heltzel, 2018) needs in the laboratory are not met, their mental health and sense of belonging will be impacted negatively. For example, imagine the additional energy and resources needed by an individual who has to struggle to access their building and laboratory because there are no automatic doors, who has to negotiate a journey of two flights down every time they need an accessible toilet, who has to ask for help each time they need to run a routine experiment because the machine is too high for them to reach and they are too unsteady to balance on a footstool; or consider someone who has endured numerous microaggressions (Ahmed, 2012, 2017) because of their gender, disability, sexuality or race. Will they feel they have a place in the lab, and belong there? No. Will it affect their mental health? Yes. They are much more likely to have poor mental health than an individual who does not have to negotiate these challenges (Rolle et al., 2021). Making a healthier and safer laboratory environment means making the culture more welcoming and inclusive for everyone, a place as free from bullying, harassment, ableism and racism as possible (Wellcome, 2020).

Here, we share a selection of case studies comprised of reflections and insights from several research projects concerned with inclusion and accessibility in the kind of chemistry education of which laboratories are an essential component. These case studies are linked but were conducted separately. They all had the necessary ethical approvals in place and were co-produced by teams that included students and staff who were in UK and international higher education, and who had lived experience of disability, chronic illness or neurodivergence, and of other marginalisations, related to race, religion, sexuality or other characteristics. There is a focus on the laboratory environment, because, to facilitate belonging for disabled, chronically ill or neurodivergent students in science, we must make practical learning environments such as labs accessible (Egambaram et al., 2022).

Our case studies are focused on things that facilitate or create barriers to belonging in the laboratory. There is a dearth of literature on the lived experience of disabled students and staff in the laboratory; most of it focuses on learning, assessment or safety (see for example Ayi & Hon, 2018; Galloway & Bretz 2015a, 2015b; Sarju & Jones, 2022; Sweet et al., 2018). We centre on particular aspects of lived experiences of disability, chronic illness, and neurodivergence: what it means, who gets to belong, who is out in the cold, and what it is like to feel a chilly environment in science:

> Autism in science is not talked about or welcome. (PhD student)
>
> Labs can be intimidating – there is such a focus on stuff like memory, vision etc. … This is hard if you have brain fog! You wear glasses if you need them, but you don't get the same for cognitive issues. (Principal investigor (PI))
>
> Rest and quiet spaces are really important if you have to work for long periods of time. (PI)
>
> I can feel impaired in the lab space, but others assume normality. My mobility aids are seen as an inconvenience. (PhD student)
>
> Different doesn't mean less productive. (PhD student)

The case studies cover digital accessibility, adjustments to physical spaces, upskilling students and staff in relation to embedding EDI, and the importance of inclusive cultures and discipline-specific networks or communities to achieve this embedding. One aspect of embedding EDI in scientific and laboratory spaces with regard to disability is moving away from the predominant focus on the individual, their deficits, and what they cannot do, rather than the skills and talents they have brought with them into the space. There are often unachievable or ableist expectations in STEM and while, there may be adjustments for physical disabilities, there is often a lack of awareness of the importance of rest and quiet, or of the need for adjustments for cognitive issues such as poor working memory.

Case study 1: Amplifying chemistry students' voices

This case study describes an example of genuinely listening to and amplifying diverse students' voices and respecting their lived expertise. The RSC first funded work carried out by Dr Julia Sarju, Dr Jennifer Leigh, Dr Maria Turkenberg, Dr Lizzie Wheeldon and Dr Joy Debgupta in 2021 which aimed to listen to and amplify 'chemistry students' voices in higher education' (the name given to the project). This project is ongoing. It used (social) media, such as an accessible Google site (Inequalities in Chemistry Education, 2021a) and Twitter (Inequalities in Chemistry Education, 2021b), to share students' experiences, and incorporated a free online event at which students and staff were invited to discuss inequalities in chemistry education and shared ideas and recommendations to tackle them. The students explained how disability was perceived by others, particularly when a disability was 'invisible':

> I feel like assumptions are sometimes made about what is a 'normal'-looking person who is perceived as 'healthy'.
>
> They reported a lack of appropriate adjustments.
>
> Support is available but often the impact is wider than 1:1 lab support.

Students described their lack of trust in and the lack of transparency of decision-making groups in higher education:

> Give students greater insight [in]to high-up decision makers like Mitigating Circumstances committees. This way we would have better understanding of decisions that were being made, even if we don't agree with them. At the moment, because it's so nebulous, and seems inconsistent when you ask among pupils, it gets harder to trust.

This case study demonstrates that, if we want disabled students to feel they belong, it is vital that they feel supported and connected. Furthermore, trust is key to forming meaningful connections with peers and instructors and allows students to take more advantage of critical feedback and other opportunities to learn (A. Brown & Campione, 1998). Ongoing work in this area includes expanding the listening project to other higher education institutions, and further analysis of the initial data generated.

Case study 2: International Women in Supramolecular Chemistry network's Disability/Chronic Illness/Neurodivergence Cluster

Loneliness and isolation are common in higher education (Banadene & Down, 2023; Wonkhe, 2022). Marginalised individuals are more likely than others to feel excluded and unwelcome because of intersecting aspects of their identity (Prasad, 2021; Sundberg et al., 2022; Vasquez, 2020). Loneliness can exacerbate and induce mental health challenges (Ayres, 2022). One way to ameliorate loneliness is through feeling belonging by being part of the discipline, and part of a like-minded community within the discipline. Belonging increases both science capital (Archer et al., 2015) and social capital (Bourdieu, 1977).

Women in Supramolecular Chemistry (WISC) is an international network which provides support for women and other marginalised groups at all career stages working in this area. The network has a broad aim of building a sense of community and kinship for women and other marginalised groups (WISC, 2020). WISC is area-specific and community-led (Caltagirone et al., 2021). WISC offers mentoring, resources and community research on topics such as managing research through Covid-19 (Leigh, Hiscock, McConnell et al., 2022), and also provides community support clusters for those who are further marginalised: one of these clusters is for those who are disabled, chronically ill or neurodivergent (Leigh, Hiscock, Koops et al. 2022).

Finding 'like-minded' and supportive people is vital for those who are marginalised (O'Leary & Mitchell, 1990). WISC's Disability/Chronic Illness/Neurodivergence Cluster, which is headed by Anna Slater and Jennifer Leigh, began as a regular virtual meeting open to anyone with an interest in sharing a safer space or learning more. One meeting resulted in an application to the RSC's Inclusion & Diversity Fund to imagine the future accessible lab (see Case Study 6). The project began with focus groups from disabled chemists, who reiterated the need for community:

> Find like-minded people where you don't feel crazy for doing things differently – you need support to get through stigma. (PhD student)
>
> Identify your village. Find your allies, sponsors, advocates and mentors. Find them quickly. … Build rapport. They don't have to be your university academics – it could be people in admin, your medical team, or from Twitter. (PhD student)
>
> Find other people going through the same things. Find other disabled scientists or academics as it is easy to feel isolated. You need a support network. (PhD student)

These comments and this case study underline the importance of community and safer spaces for those marginalised because of disability, who are more likely to suffer from imposter syndrome and to be victims of discrimination and internalised and structural ableism, and who are less likely to feel they belong in the lab.

Case Study 3: Embedding equality, diversity, and inclusion into chemistry skills training for undergraduate students

Upskilling students and staff is imperative to maximise the benefits of an inclusion initiative. This project, funded by the RSC, introduced training for undergraduate chemistry students as part of the chemistry curriculum at the University of York, framing EDI awareness as a core professional chemistry skill (Jones et al., 2022). The training was developed and introduced in 2020 to set clear expectations of departmental culture with respect to inclusion, and to train chemistry students to challenge the status quo and adopt inclusive practices.

A series of short videos featuring a diverse range of authentic voices from staff and others were created for the project, covering inequities in science and including topics such as how students could access support, act as allies and respect diverse peers. The materials and resources were made available to York chemistry students in their course 'Supporting Information'. They were also shared publicly on YouTube to support and encourage wider implementation. The training and content were embedded into a compulsory 10-credit 'Skills for Chemists' module designed to provide students with a range of vital skills required for their degree programme. In addition to the EDI training, it offered a foundation in mathematics, physics, biology and computer programming, and content on becoming a professional chemist.

This case study demonstrates a practical way to engage STEM students with EDI and connect students with the experiences and values of staff within their departments. York's Employability and Diversity Officer, Dr Leonie Jones, reflected: 'Hearing staff talk about their own experiences, or their professional insights into EDI, supported by data and evidence, engages students with the subject and allows them to see its practical relevance in the real world.'

Making changes to curricula requires senior buy-in, and embedding EDI within core course content in this way can illustrate the importance a department or an institution places on equity and inclusion. York's head of department, Professor Caroline Dessent, reflected:

> In the longer term, transforming the culture of chemistry requires the next generation of scientists to be aware of cultural issues and committed to equity, inclusion and empowerment. We believe that providing formal training in these aspects enables our students to go on to be agents for change. We also hope that other chemistry departments [will] develop EDI training programmes for their students and are making materials available to help them in doing so.

Students are an integral part of higher education STEM communities. Raising their awareness of and engaging them in discussions of EDI challenges and good practices has the potential to impact departmental cultures significantly and positively. In addition, it has potential to empower students to be agents of change both in their departments and in wider society.

Case Study 4: Inclusive teaching training for chemistry graduate teaching assistants

Similarly to the previous one, this case study aims to ensure that all staff who interact with students are upskilled around inclusivity and accessibility. Graduate teaching assistants (GTAs) are important partners in practical teaching and learning in chemistry. In order to increase equity and address problems such as gender bias from GTAs towards male students there is a need for 'improved TA training programs that teach a host of equitable teaching strategies to enhance the climate of the classrooms and consequently, improve learning' (Neill et al., 2019). The University of York wanted to acknowledge the importance of the role GTAs play in supporting the delivery and assessment of undergraduate chemistry learning and teaching, particularly practical teaching in the lab, and responded by developing a bespoke in-house training unit on equitable teaching and demonstration for all chemistry GTAs, which launched in 2018.

The unit is delivered through a combination of workshops, lab shadowing, mentoring and self-reflection exercises. It focuses on inclusive and accessible practical chemistry teaching and is aimed at building instructors' empathy with students and increasing their awareness of EDI issues. It was designed to model good inclusion and accessibility practice, create a safe space for individual reflection, and be flexible towards and responsive to participants' priorities, ongoing learning about inclusion, and the wider societal context. GTAs can reflect on their teaching practices and their experiences of learning. Discussions are facilitated so that all participants feel valued and listened to.

Empowering chemistry teaching assistants has a positive impact on them and their students (Flaherty et al., 2017). In this training unit the GTAs are empowered to explore and adopt inclusive teaching practices and compassionate pedagogies rather than given a list to learn by rote. They are also encouraged to support their peers to develop their inclusive practices, which can be put into three broad categories: behaviours and traits, inclusive communication, and specific practical advice (Sarju & Jones, 2022). Topics covered in the unit include 'adapting to people's needs', 'ensur[ing] lips are visible when speaking', 'using inclusive language', '[avoiding] making assumptions', and '[recognising that] barriers are not always obvious'. As with the previous case study embedding EDI into York's undergraduate chemistry curriculum, this unit for GTAs clearly demonstrates the department's values and commitment to EDI.

Case Study 5: Digital accessibility student partnership

An important aspect of inclusion and accessibility is digital accessibility. This project utilised a student and staff partnership to address the digital accessibility of chemistry teaching materials at the University of York, which evolved over four summers (2019–22). It began with the electronic and printed resources for the teaching lab, then expanded to include:

- resources to support small group teaching;
- auditing and transforming lecture resources and making recommendations for inclusive lecturing practices (Bennett, 2021);
- accessibility of assessments;
- assessment of accessibility; and
- development of resources aimed at students.

The project produced a variety of outputs, including accessible templates, staff and student guides (both written and on video), changes to instructor practices and a book chapter reviewing co-creation with student partners in chemistry online education (Curtin & Sarju, 2021). Three of the student partners were supported and encouraged to present their work at the Digital Creativity Conference, which raised their profiles and amplified their voices within the academy.

Student and staff partnerships are not inclusive by default. Partners must plan for the equitable inclusion of team members so that everyone can contribute and develop meaningfully (see also Kinchin et al., Chapter 17 in this volume). In this accessibility project it was essential that the student partners felt their lived experiences were valid and valued, so that they could constructively and honestly audit teaching materials and set recommendations for accessible chemistry resources. They reported:

> Accessibility benefits everyone. We need to be actively inclusive [and] listen to diverse voices. Student partnerships allow students to feel their voices are being heard and making change. Remote internships allow for students to have an accessible space to be heard and make a difference.

Working in partnership with students is either underused, or underreported in chemistry education literature (Curtin & Sarju, 2021), which results in students' voices not being heard. Everyone at York benefited from working in partnership: the students shared their skills and experiences to transform learning resources and upskill staff, many of whom now have a greater understanding of *why* it is important to create accessible resources, not just how. In addition to the direct accessibility benefits for students and staff, increasing empathy and understanding between students and staff brought huge cultural benefits.

Case Study 6: The future accessible laboratory

The physical space of a laboratory can be either exclusionary or inclusive. This project, initiated by the WISC Disability/Chronic Illness/Neurodivergence Cluster and again funded by the RSC, used a series of focus groups to explore people's lived experiences of chemistry laboratories. Participants were asked for recommendations to make labs more inclusive and accessible; the research team would use the recommendations to create a model for the future accessible lab. The groups were highly emotional as people recounted their experiences, including a fear of and lack of trust in health and safety processes, experiencing them as a means of keeping them out of the lab.

> I would really struggle to stay studying in a lab now. (Senior clinical scientist)
>
> I stayed at the same university because of support, but will there be consequences for that? Yes. (Post-doctoral research assistant)
>
> I had to go part-time because of health reasons. (PhD student)
>
> Ivory tower ableism is not accepting of illnesses, and there is a culture of not taking holidays or sick leave. (PhD student)
>
> I'm getting screened for ASD [autism spectrum disorder]. Sensory processing is hard. I'm not looking forward to that conversation. (PhD student)

The WISC cluster worked with Sarju and others to form a collaborative autoethnography group around accessible laboratory spaces. The findings from the focus groups and data from the autoethnography were combined to create a tangible set of recommendations for inclusive laboratory spaces (Egambaram et al., 2022). The Accessible Labs project will continue with a 360° Virtual Reality Accessible Lab designed to raise awareness of barriers, and the implementation of an accessibility library pilot scheme at the University of Liverpool (see Case Study 7).

Case Study 7: Lab accessibility library

Finally, for inclusion and accessibility to be embedded within an environment they must become normalised. In addition to the significant attitudinal barriers faced by disabled science students, there is often a dearth of suitable assistive tools to allow them to learn practical chemistry on an equitable basis with their non-disabled peers. In 2023, another RSC-funded project, led by Amy Lunt, a PhD researcher at the University of Liverpool, aimed to purchase tools to provide a library of resources which would benefit and assist disabled students in practical teaching laboratories.

Examples of assistive items that will be part of the library include a Braille labeller, large-display calculators, a scanning pen label reader, bottle and jar openers, liquid dispenser pumps, coloured overlays for computer monitors and coloured nonreflective lab glasses. As well as physical items the library will include assistive software and accessible teaching resources.

Discussion

The case studies highlighted several strands that are vital to addressing intersectional belonging for disabled students in STEM. Here, we call attention to these as action points for institutions, departments, and individual staff and students. We believe there is a need for a revolution within scientific culture that will normalise inclusivity and accessibility and allow easy and quick access to individual accommodations.

You can't be what you can't see

There is a need to address the lack of diversity, and the systemic ableism, racism, gender and other inequities, in science. Belonging is intersectional. For cultural change to happen, there needs to be a top-down and bottom-up approach to sharing best practices. This demands senior-level buy-in, resources and support, as demonstrated in the case studies from York. It includes raising awareness of how disabled, chronically ill and neurodivergent people are cut out of spaces by their inaccessibility. Normalising accessibility and inclusivity, working in partnership with students, using communications that champion different types of people working in labs, calling attention to what needs to be changed and improved and stressing the benefits for everyone, and combating negative perceptions of and stereotypes about disability, are all part of the necessary culture change.

Disabled students will not feel they belong if they experience negative attitudes towards their disability: 'Disabled students often get demoralized when the academic culture surrounding them holds a conventional wisdom that indicates they are unlikely to succeed, and if they do succeed, it means that it is unlikely that they are truly disabled and so should not have had accommodations' (Egambaram et al. 2022, p. 3816). Similarly, if a building is inaccessible, they will not feel welcome:

> I'm a wheelchair user. It takes a lot of energy just to open doors. The building is accessible in the main but the hallways are close [together] and no other doors are accessible. Shelves are unreachable. (PhD student)

It is vital to collaborate with professional societies such as the RSC, the IOP and the Royal Society to share best practice and raise awareness.

Support

A comprehensive list of recommendations for increasing inclusivity and accessibility for disabled people within the chemistry lab can be found in Egambaram et al. (2022). Ideally these would be implemented in all teaching and research labs. Additional health and safety considerations must be taken into consideration in a 'wet' lab, for example potential exposure to chemical, biological and physical hazards (Ayi & Hon, 2018). However, good practice in health and safety should mitigate and minimise risk, and health and safety should be a transparent process rather than being used as a means of keeping disabled people out of the lab.

> I wish people would speak up when they are struggling. There is a lack of communication and things are kept within groups. (Health and safety officer)
>
> For a lot of issues there are fairly easy solutions. It's not about removal of risk, it's risk mitigation. Most things are situational. We need to build labs with accessibility in mind. We could design facilities and processes that make it easier for everyone. (Health and safety officer)

One example of health and safety processes being used to either include people or act as a barrier is the use of noise-reduction or noise-cancelling headphones for those with sensory processing issues. Labs are noisy spaces, yet it is common for such headphones to be banned.

> Headphones are seen as a H&S [health and safety] risk, so would they ban d/Deaf people? There are ways to communicate – writing, signing, buttons to switch lights on, stamping feet to get attention. (Independent researcher)

In addition to ways to communicate, visual and vibrating alarms to alert people to fire and other hazards can be put in place. One reason for banning headphones is the 'buddy' system, where one lab worker is responsible for another's safety and must listen out for them if they are working at the other end of the room. Wearing headphones would prevent this; however, the risk can be mitigated simply by having people work side by side or in eyeshot, or instigating a lab trio instead so that the individual who requires headphones is not responsible for someone else.

Systems and processes to identify and access accommodation need to be simple, speedy and transparent, and there must be adequate resources:

> A lack of budget for accessibility/equipment leads to a lack of willingness to take on disabled students. (PhD student)
>
> Universities need to look at funding models to resource accessibility and adjustments and processes. (Staff disability officer)

If the individual adjustments a student needs to support them in the lab are absent, insufficient or not put in place in a timely way they will not feel they belong.

Belonging

Marginalised students face additional barriers in STEM, to their work, to their success, and to aspects of their mental health such as their feelings of self-worth. They may encounter gatekeepers who question their right to be there (Egambaram et al., 2022). When asked what advice they would like to have heard, the focus groups of disabled scientists told us:

> Don't give up. (PhD student)
>
> You are enough. (PhD student)
>
> You are worthy of being where you are. You are not alone, and you are worthy. (Senior clinical scientist)

> You are able – you are here because you are able. Your ability has brought you here. Life with a chronic illness sucks but it doesn't have to stop you living your dream. (Master's student)
>
> Keep fighting and don't let other people define your limits. (Post-doctoral researcher)

These comments give an insight into just how challenging the lab and the scientific environment are for disabled scientists. Addressing belonging is not just about hitting metrics for various excellence frameworks (teaching, research, retention, etc.) so that an institution can move up league tables: it directly impacts finances. There needs to be buy-in from extrinsically motivated budget holders as well as intrinsically motivated academics and technicians who understand the moral imperative to address inclusion. This chapter is a call for institutions to proactively address these issues, and for individuals to confront their own complacency and complicity in the status quo. Inclusive attitudes and access to accommodation and resources make all the difference: 'My professor said, "Tell me what you need to do science", and got it done' (PhD student).

Small changes can impact on an individual's sense of belonging. Such changes might be as simple as being asked what accommodations they need, being informed about networks and communities they can access, and seeing that EDI is valued within the department, as in York. Unfortunately, these things do not always happen; much EDI work is undertaken by marginalised groups and not formally recognised or rewarded (Ahmed, 2012). 'EDI is always over and above and unrewarded' (independent researcher). If we want students to feel they belong, we need change.

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References

Ackerman-Biegasiewicz, L. K. G., Arias-Rotondo, D. M., Biegasiewicz, K. F., Elaqua, E., Golder, M. R., Kayser, L. V., Lamb, J. R., Le, C. M., Romero, N. A., Wilkerson-Hill, S. M. & Williams, D. A. (2020). Organic chemistry: A retrosynthetic approach to a diverse field. *ACS Central Science*, 6(11), 1845–50. https://doi.org/10.1021/acscentsci.0c01138.

Ahmed, S. (2012). *On Being Included: Racism and diversity in institutional life*. Durham, NC: Duke University Press.

Ahmed, S. (2017). *Living a Feminist Life*. Durham, NC: Duke University Press.

Allan, J. & Harwood, V. (2016), The risk factors for psy-diagnosis? Gender, racialization and social class. In E. Bendix Petersen & Z. Millei (eds), *Interrupting the Psy-Disciplines in Education*, pp.185–202, London: Palgrave Macmillan.

Archer, L., Dawson, E., DeWitt, J., Seakins, A. & Wong, B. (2015), 'Science capital': A conceptual, methodological, and empirical argument for extending Bourdieusian notions of capital beyond the arts. *Journal of Research in Science Teaching*, 52(7), 922–48. https://doi.org/10.1002/tea.21227.

Ayi, H.-R. & Hon, C.-Y. (2018). Safety culture and safety compliance in academic laboratories: A Canadian perspective. *Journal of Chemical Health and Safety*, 25(6), 6–12. https://doi.org/10.1016/j.jchas.2018.05.002.

Ayres, Z. (2022). *Managing Your Mental Health during Your PhD: A survival guide*. Cham: Springer.

Babalola, O. O., du Plessis, Y. & Babalola, S. S. (2023). Power of shared success: How can sharing success and roles of others motivate African women in STEM? *International Journal for Educational and Vocational Guidance*, 1–27. https://doi.org/10.1007/s10775-023-09583-1.

Babcock, L., Peyser, B., Vesterlund, L. & Weingart, L. R. (2022). Saying 'no' in science isn't enough: When women refuse requests to do unrewarded tasks, another female colleague often gets asked instead. *Nature*, 10 November.

Ball, P. (2020). Prejudice persists, *Chemistry World*, 9 June.

Banadene, L. & Down, J. (2023). The heart of the matter: Student loneliness and belonging, *HEPI* blog, 10 February. https://www.hepi.ac.uk/2023/02/10/the-heart-of-the-matter-student-loneliness-and-belonging/. Accessed 1 January 2024.

Bennett, K. (2021). A guide to inclusive lecturing practices., National Teaching Repository, Educational Resource. https://doi.org/10.25416/NTR.16574312.v1.

Bordiga, S., Chang, S., Chen, J., Crudden, C., Dey, A., Fornasiero, P., Gunnoe, T. B., Jones, C. W., Linic, S., Ma, D., Maseras, F., Ooi, T., Cuenya, B. R., Sautet, P., Scott, S. L., Stamenkovic, V., Wang, Y., Yoon, T. P. & Zhao, H. (2020). Excellence *versus* diversity? Not an either/or choice. *ACS Catalysis*, 10(13), 7310–11. https://doi.org/10.1021/acscatal.0c02590.

Bourdieu, P. (1977). *Outline of a Theory of Practice*, trans. R. Nice. Cambridge: Cambridge University Press.

Brock, J. (2021). 'Textbook case' of disability discrimination in grant applications, *Nature Index*, 19 January.

Brown, A. & Campione, J. (1998). Designing a community of young learners: Theoretical and practical lessons. In N. M. Lambert & B. L. McCombs (eds), *How Students Learn: Reforming schools through learner-centered education*, 153–86. Washington, DC: American Psychological Association.

Brown, N. (ed.) (2021). *Lived Experiences of Ableism in Academia: Strategies for inclusion in higher education*. Bristol: Policy Press.

Brown, N. & J. Leigh (2018). Ableism in academia: Where are the disabled and ill academics?. *Disability & Society*, 33(6), 985–9. https://doi.org/10.1080/09687599.2018.1455627.

Brown, N. & Leigh, J. (eds) (2020). *Ableism in Academia: Theorising experiences of disabilities and chronic illnesses in higher education*. London: UCL Press.

Caltagirone, C., Draper, E. R., Hardie, M. J., Haynes, C. J. E., Hiscock, J. R., Jolliffe, K. A., Kieffer, M., McConnell, A. J. & Leigh, J. (2021). An area-specific, international community-led approach to understanding and addressing equality, diversit, and inclusion issues within supramolecular chemistry. *Angewandte Chemie International Edition*, 60(21), 11572–9. https://doi.org/10.1002/anie.202015297.

Careers Research & Advisory Centre (2020). Qualitative research on barriers to progression of disabled scientists. Cambridge: Careers Research & Advisory Centre.

Colwell, R. & Bertsch McGrayne, S. (2020). *A Lab of One's Own: One woman's personal journey through sexism in science*. New York: Simon & Schuster.

Coughlan, S. (2021). Only 1% of UK university professors are black, *BBC News*, 19 January. https://www.bbc.co.uk/news/education-55723120. Accessed 1 January 2024.

Crenshaw, K. (1989). Demarginalizing the intersection of race and sex: A Black Feminist Critique of Antidiscrimination Doctrine, Feminist Theory, and Antiracist Politics. *University of Chicago Legal Forum*, 1989(1), 139–67.

Curtin, A. & Sarju, J. (2021). Students as partners: Co-creation of online learning to deliver high quality, personalized content. In E. Pearsall, K. Mock, M. Morgan & B. A. Tucker (eds), *Advances in Online Chemistry Education*, pp. 135–63. Washington, DC: American Chemical Society.

Department for Work & Pensions (2022). *Family Resources Survey: Financial year 2020 to 2021*. London: Department for Work & Pensions.

Egambaram, O., Hilton, K., Leigh, J., Richardson, R., Sarju, J., Slater, A. & Turner, B. (2022). The future of laboratory chemistry learning and teaching must be accessible. *Journal of Chemical Education*, 99(12), 3814–21. https://doi.org/10.1021/acs.jchemed.2c00328.

Finesilver, C., Leigh, J. & Brown, N. (2020). Invisible disability, unacknowledged diversity. In N. Brown & J. Leigh (eds), *Ableism in Academia: Theorising experiences of disabilities and chronic illnesses in higher education*, pp. 143–60. London: UCL Press.

Flaherty, A. A., O'Dwyer, A., Mannix-McNamara, P. & Leahy, J. J. (2017). The influence of psychological empowerment on the enhancement of chemistry laboratory demonstrators' perceived teaching self-image and behaviours as graduate teaching assistants. *Chemistry Education Research and Practice*, 18(4), 710–36. https://doi.org/10.1039/C7RP00051K.

Fryberg, S. A. & Martinez, E. J. (eds) (2014). *The Truly Diverse Faculty: New dialogues in American higher education*. Basingstoke: Palgrave Macmillan.

Galloway, K. R. & Bretz, S. L. (2015a). Measuring meaningful learning in the undergraduate general chemistry and organic chemistry laboratories: A longitudinal study. *Journal of Chemical Education*, 92(12), 2019–30. https://doi.org/10.1021/acs.jchemed.5b00754.

Galloway, K. R. & Bretz, S. L. (2015b). Measuring meaningful learning in the undergraduate chemistry laboratory: A national, cross-sectional study, *Journal of Chemical Education*, 92(12), 2006–18. http://dx.doi.org/10.1021/acs.jchemed.5b00538.

Grinstein, A. & Treister, R. (2018). The unhappy postdoc: A survey based study. *F1000Research*, 6. https://doi.org/10.12688%2Ff1000research.12538.2

Halse, C. (2018). Theories and theorising of belonging. In C. Halse (ed.), *Interrogating Belonging for Young People in Schools*, pp. 1–28. Cham: Palgrave Macmillan.

Harris, L. (2017). Exploring the effect of disability microaggressions on sense of belonging and participation in college classrooms. Ed.S. thesis, Utah State University.

Higher Education Statistics Authority (2022a). Characteristics of HE students. Higher Education Statistics Authority.

Higher Education Statistics Authority (2022b). Who's working in HE? Higher Education Statistics Authority.

Inckle, K. (2018). Unreasonable adjustments: The additional unpaid labour of academics with disabilities. *Disability & Society*, 33(8), 1372–6. https://doi.org/10.1080/09687599.2018.1480263.

Inequalities in Chemistry Education (2021a). Resources. https://sites.google.com/york.ac.uk/in-chemistry-education/resources. Accessed 25 March 2024.

Inequalities in Chemistry Education (2021b). https://twitter.com/InChemEducation. Accessed 25 March 2024.

Institute of Physics, Royal Astronomical Society and Royal Society of Chemistry (2019). Exploring the workplace for LGBT+ physical scientists. Institute of Physics, Royal Astronomical Society and Royal Society of Chemistry.

Joice, W. & Tetlow, A. (2021). Disability STEM data for students and academic staff in higher education 2007/08 to 2018/19, Royal Society.

Jones, L. C., Sarju, J. P., Dessent, C. E. H., Matharu, A. S. & Smith, D. K. (2022). What makes a professional chemist? Embedding equality, diversity, and inclusion into chemistry skills training for undergraduates. *Journal of Chemical Education*, 99(1), 480–6. https://doi.org/10.1021/acs.jchemed.1c00500.

Lee, J., Williams, J. C. & Li, S. (2017). Parents in the pipeline: Retaining postdoctoral researchers with families, The Pregnant Scholar in partnership with the National Postdoctoral Association, San Francisco, CA.

Leicester, M. & Lovell, T. (1997). Disability voice: Educational experience and disability. *Disability & Society*, 12(1), 111–18. https://doi.org/10.1080/09687599727506.

Leigh, J. S., Busschaert, N., Haynes, C. J. E., Hiscock, J. R., Hutchins, K. M., Krbek, L. K. S. von, McConnell, A. J., Slater, A. G., Smith, D. K. & Draper, E. R. (2022). Planning a family. *Nature Reviews Chemistry*, 6(10): 673–7. https://doi.org/10.1038/s41570-022-00427-0.

Leigh, J., Caplehorne, J. & Slowe, S. (2023). Ableism and exclusion: Challenging academic cultural norms in research communication. *Journal of Research Management and Administration*, 2(1), 030220232. https://doi.org/10.18552/jorma.v2i1.764.

Leigh, J. S., Hiscock, J. R., Koops, S., McConnell, A. J., Haynes, C. J. E., Caltagirone, C., Kieffer, M., Draper, E. R., Slater, A. G., Hutchins, K. M., Watkins, D., Busschaert, N., Krbek, L. K. S. von, Jolliffe, K. A. & Hardie, M. J. (2022). Managing research throughout COVID-19: Lived experiences of supramolecular chemists. *Chem*, 8(2), 299–311. https://doi.org/10.1016/j.chempr.2022.01.001.

Leigh, J., Hiscock, J., McConnell, A., Haynes, C., Caltagirone, C., Kieffer, M., Draper, E., Slater, A., Krbrek, L. von, Hutchins, K., Watkins D. & Busschaert, N. (2022). *Women in Supramolecular Chemistry: Collectively crafting the rhythms of our work and lives in STEM*. Bristol: Policy Press.

Leigh, J. S., Smith, D. K., Blight, B. A., Lloyd, G. O., McTernan, C. T. & Draper, E. R. (2022). Listening to fathers in STEM. *Nature Reviews Chemistry*, 7, 67–8. https://doi.org/10.1038/s41570-022-00459-6.

Leonardi, M., Bickenbach, J., Ustun, T. B., Kostanjsek, N., Chatterji, S. & MHADIE Consortium (2006). The definition of disability: What is in a name?. *The Lancet*, 368(9543), 1219–21. https://doi.org/10.1016/s0140-6736(06)69498-1.

Lorde, A. (2017). *The Master's Tools Will Never Dismantle the Master's House*. Milton Keynes: Penguin Random House.

Mackelden, A. (2019). Being disabled is exhausting. Online. https://clarissaexplainsfa.com/blog/2019/2/1/being-disabled-is-exhausting. Accessed 29 September 2019.

May, V. (2011). Self, belonging and social change. *Sociology*, 45(3), 363–78. https://doi.org/10.1177/0038038511399624.

McGee, E. O. & Robinson, W. H. (eds) (2020). *Diversifying STEM: Multidisciplinary perspectives on race and gender*. New Brunswick, NJ: Rutgers University Press.

Neill, C., Cotner, S., Driessen, M. & Ballen. C. J. (2019). Structured learning environments are required to promote equitable participation. *Chemistry Education Research and Practice*, 20(1), 197–203. https://doi.org/10.1039/C8RP00169C.

Office for National Statistics (2022a). Outcomes for disabled people in the UK: 2021. Office for National Statistics. https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/disability/articles/outcomesfordisabledpeopleintheuk/2021#main-points. Accessed 1 January 2024.

Office for National Statistics (2022b). Disabled people's experiences with activities, goods and services, UK: February to March 2022. Office for National Statistics. https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/disability/bulletins/disabledpeoplesexperienceswithactivitiesgoodsandservicesuk/februarytomarch2022. Accessed 1 January 2024.

O'Leary, V. E. & Mitchell, J. M. (1990). Women connecting with women: Networks and mentors in the United States. In S. Stiver Lie & V. E. O'Leary (eds), *Storming the Tower: Women in the academic world*, pp. 58–73. London: Kogan Page.

Oliver, M. (2013). The social model of disability: Thirty years on. *Disability & Society*, 28(7): 1024–6. https://doi.org/10.1080/09687599.2013.818773.

Popper, K. (1959). *The Logic of Scientific Discovery*. London: Routledge & Kegan Paul.

Powell, K. (2015). The future of the postdoc. *Nature*, 520, 144–7. https://doi.org/10.1038/520144a.

Prasad, A. (2021). Why are there still so few black scientists in the UK? *The Observer*, 10 April.

Rolle, T., Vue, Z., Murray, S. A., Shareef, S. A., Shuler, H. D., Beasley, H. K., Marshall A. G., & Hinton, A., Jr (2021). Toxic stress and burnout: John Henryism and social dominance in the laboratory and STEM workforce. *Pathogens and Disease*, 79(7), ftab041. https://doi.org/10.1093/femspd/ftab041.

Rosser, Sue V. (2012). *Breaking into the Lab: Engineering progress for women in science*. New York: New York University Press.

Royal Society (2021). Ethnicity in STEM academic communities: Reports commissioned by the Royal Society. Royal Society, London. https://royalsociety.org/topics-policy/publications/2021/trends-ethnic-minorities-stem/. Accessed 1 January 2024.

Royal Society of Chemistry (2018). Diversity landscape of the chemical sciences. Royal Society of Chemistry, London. https://www.rsc.org/globalassets/02-about-us/our-strategy/inclusion-diversity/cm-044-17_a4-diversity-landscape-of-the-chemical-sciences-report_web-2.pdf. Accessed 1 January 2024.

Royal Society of Chemistry (2019a). Breaking the barriers: Women's retention and progression in the chemical sciences. Royal Society of Chemistry, London. https://www.rsc.org/globalassets/02-about-us/our-strategy/inclusion-diversity/womens-progression/media-pack/v18_vo_inclusion-and-diversity-_womans-progression_report-web-.pdf. Accessed 1 January 2024.

Royal Society of Chemistry (2019b). Is publishing in the chemical sciences gender biased? Driving change in research culture. Royal Society of Chemistry, London. https://www.rsc.org/globalassets/04-campaigning-outreach/campaigning/gender-bias/gender-bias-report-final.pdf. Accessed 1 January 2024.

Royal Society of Chemistry (2021). A sense of belonging in the chemical sciences. Royal Society of Chemistry, London. https://www.rsc.org/globalassets/22-new-perspectives/talent/belonging-in-the-chemical-sciences/rsc-belonging-in-chemical-sciences-report.pdf. Accessed 1 January 2024.

Royal Society of Chemistry (2022). Missing elements: Racial and ethnic inequalities in the chemical sciences. Royal Society of Chemistry, London. https://www.rsc.org/globalassets/22-new-perspectives/talent/racial-and-ethnic-inequalities-in-the-chemical-sciences/missing-elements-report.pdf. Accessed 1 January 2024.

Sarju, J. P. (2021). Nothing about us without us: Towards genuine inclusion of disabled scientists and science students post pandemic. *Chemistry – A European Journal*, 27(4), 10489–94. https://doi.org/10.1002/chem.202100268.

Sarju, J. P. & Jones, L. C. (2022). Improving the equity of undergraduate practical laboratory chemistry: Incorporating inclusive teaching and accessibility awareness into chemistry graduate teaching assistant training. *Journal of Chemical Education*, 99(1): 487–93. https://doi.org/10.1021/acs.jchemed.1c00501.

Slater, A., Caltagirone, C., Draper, E., Busschaert, N., Hutchins K. & Leigh J. (2022). Pregnancy in the lab. *Nature Reviews Chemistry*, 6, 163–4. https://doi.org/10.1038/s41570-022-00362-0.

Spina, N., Harris, J., Bailey, S. & Goff, M. (2020). *'Making It' as a Contract Researcher: A pragmatic look at precarious work*. Abingdon: Routledge.

Stockard, J., Greene, J., Richmond, G. & Lewis, P. (2018). Is the gender climate in chemistry still chilly? Changes in the last decade and the long-term impact of COACh-sponsored workshops. *Journal of Chemical Education*, 95(9), 1492–9. https://doi.org/10.1021/acs.jchemed.8b00221.

Sundberg, T., Boyce, P. & Ryan-Flood, R. (2022). Challenging LGBT+ exclusion in UK higher education. University and College Union. https://www.ucu.org.uk/media/11495/Challenging-LGBT-exclusion-in-UK-higher-education/pdf/LGBT__exclusion_May2021.pdf. Accessed 1 January 2024.

Sweet, E., Gower, W. S. & Heltzel, C. E. (2018). *Accessibility in the Laboratory*. Washington, DC: American Chemical Society.

Thomas, K. (2015). Rethinking belonging through Bourdieu, diaspora and the spatial. *Widening Participation and Lifelong Learning*, 17(1), 37–49. http://dx.doi.org/10.5456/WPLL.17.1.37.

Thomas, K. C. (2018). *Rethinking Student Belonging in Higher Education: From Bourdieu to borderlands*. Abingdon: Routledge.

UK Research and Innovation (2020). UKRI diversity data for funding applicants and awardees. UK Research and Innovation, London.

Vasquez, K. (2020). Disabled scientists excluded from the lab. *Chemistry World*, 8. December. https://www.chemistryworld.com/opinion/disabled-scientists-excluded-from-the-lab/4012695.article. Accessed 1 January 2024.

Vaughan, A. (2020). Only 10 senior Black researchers awarded UK science funding last year. *New Scientist*, 15 December. https://www.newscientist.com/article/2262849-only-10-senior-black-researchers-awarded-uk-science-funding-last-year/. Accessed 1 January 2024.

Wellcome (2020). What researchers think about the culture they work in. Wellcome Trust, London. https://wellcome.org/sites/default/files/what-researchers-think-about-the-culture-they-work-in.pdf. Accessed 1 January 2024.

WISC (2020). WISC: Women in supramolecular chemistry, https://www.womeninsuprachem.com/. Accessed 1 January 2024.

Wonkhe (2022). Students' perceptions of belonging and inclusion at university. Pearson/Wonkhe. https://wonkhe.com/wp-content/wonkhe-uploads/2022/02/Belonging-and-inclusion-survey-Wonkhe-Pearson-Feb-22.pdf. Accessed 1 January 2024.

15

Exploring students' sense of belonging to engineering in authentic interdisciplinary project-based teamwork

Lillian Y. Y. Luk, Inês Direito, Kate Roach and John Mitchell

Introduction

Through the lens of Engeström's (1999, 2006) activity theory, this chapter explores how teamwork may encourage a sense of belonging to a specific engineering discipline and to the wider engineering community. Using qualitative data in the form of short interviews with students collected during project-based learning activities in interdisciplinary settings, the authors find that teamwork creates a space for students to reflect on disciplinary differences, constructing and describing 'my' discipline in comparison with 'others' while making references to knowledge and skills, work approaches and curriculum structure. Such comparisons draw students' attention to their disciplinary identity and enhance their sense of belonging to a specific engineering discipline. The authors also find that teamwork supports the formation of a community of practice which fosters a sense of belonging to the broader engineering community.

In 2014 the University College London (UCL) Faculty of Engineering Sciences launched a revision of its undergraduate curriculum entitled the Integrated Engineering Programme (IEP) (Mitchell et al., 2021). While entry to distinct engineering disciplines remained, the programme brought in, among other things, a thread of authentic project work and supporting professional skills instruction (Hailes et al., 2021). The design of the curriculum drew heavily on Vygotsky's (1978) theory of social constructivism and its application to engineering as imagined by engineering education pioneers such as Felder (2012) and Froyd and Ohland (2005). Fundamental to this learner-centred teaching approach is the aspiration that engagement in authentic project-based learning activities will lead to a heightened sense of belonging which will spur a sense of identity as a professional engineer (Roach et al., 2018). This sense of belonging was foregrounded by the curriculum development team because of its relationship to self-efficacy and intrinsic motivation (Andrews et al., 2021), which were seen as key factors in the learning process.

The IEP consists of a core set of modules that were designed to deliver learning outcomes common to all engineering disciplines. The emphasis is on active learning that supports the development of both technical and non-technical skills. These include engineering design and mathematical modelling, alongside a whole suite of professional skills such as communication, team working, critical thinking, creative problem solving and ethical reasoning. The IEP modules are largely concentrated in the first two years of undergraduate studies. These modules are interwoven with discipline-specific courses from eight different engineering departments, allowing students to gain both broad engineering knowledge and focused expertise in a specific field. Nine project-based learning (PjBL) activities of different forms are interspersed through the first two years of undergraduate study. These are connected with other elements of the IEP and with disciplinary learning. The aim is to provide opportunities for students to draw on their theoretical knowledge (technical and non-technical) in practical real-world engineering contexts that also activate their professional skills.

Discipline-specific theoretical knowledge is taught within students' home departments, while the IEP delivers first- and second-year modules, such as Design and Professional Skills (D&PS) and Mathematical Modelling and Analysis (MMA), that aim to provide the underlying theory required by all the PjBL elements. The learning outcomes for these modules link into the active learning elements of the programme, where students have an opportunity to put their newly developed knowledge and skills into practice.

In the redesign of the programme, an explicit connection was made between the taught material and its practical application through project work. Taking Kolmos and Graaff's (2014) definitions of problem-based and project-based learning, our implementation is very specifically project-based learning, as differentiated from problem-based learning (PBL). This produces a curriculum in which project-based learning is central to the learning experience and engages students in design activities that build predominantly, although not exclusively, on prior technical knowledge which is applied in order to deliver a defined technical goal. Most importantly, and in contrast to some implementations of PjBL, all activities are in teams. Group size varies for the different projects, but groups of four or five are typically favoured, and groups change between projects.

As part of D&PS curriculum, specific support is given to students to scaffold their teamwork. We have observed a wide variation in the teamwork experience of our students upon entry to the programme, in part because of the diversity of the student cohort, which includes many international students. We have also seen that, while some have well-developed teamwork and team communication skills, in the main this is down to experience rather than to any formal instruction. We know that these skills are much sought after by the industry as core employability skills, but we were also conscious that with increased teamwork comes an increased responsibility to ensure that inclusive practices are embedded in our teaching approach.

To support the development of inclusive teamwork we developed a programme of interventions, including an evaluation of team members' strengths, direct instruction on teamwork and reflection on team performance (Peters et al., 2019). CliftonStrengths, a positive psychology tool, was offered to first-year students, on a voluntary basis, with the purpose of promoting reflection and giving them the vocabulary to talk about different approaches to thinking and working in group project settings. Formative feedback was given in debrief sessions one week after the project's completion, and students were encouraged to complete self-reflection activities.

Project-based learning is delivered in various forms. It begins with two five-week projects called the Engineering Challenges that span the first term of the first year and serve as an orientation to the engineering faculty and an introduction to active learning methods. Compared with school curricula, these projects position the responsibility for learning more squarely on students than on staff. The projects in this first module map onto a typical engineering design cycle in that the first project involves early design tasks such as needs assessment, ideation and design proposal, and the second project involves technical interdisciplinary problem solving and prototyping.

The interdisciplinary aspect of the second engineering challenge should be specially noted, as the teams are formed by drawing together members of different engineering disciplines, with an emphasis on discipline-based roles and expertise within the project. Subsequently, most of the project experiences are within the students' chosen discipline of mechanical, chemical, electronic, civil, computing, biomedical or biochemical engineering. The learning outcomes of all the project-based activities aim to achieve a balance between the development of generic skills and the development of technical and disciplinary knowledge and skills (Johnson & Ulseth, 2016; Lahiff et al., 2019).

Earlier research in engineering education (e.g., Geisinger & Raman, 2013; Striolo et al., 2021) has found that students who do not identify with any engineering discipline or maintain a sense of belonging to engineering are more likely to leave their engineering programmes or leave the profession in the future. Students who participated in recent studies conducted by Cohen and Viola (2022) and by Ahn and Davis (2020) consistently pointed out teamwork, or group work, as words which come to mind when they think about belonging. However, it is unclear from these two studies which aspects of teamwork bring about a sense of belonging. As teamwork is a key component of the engineering curriculum at UCL, we investigated its role in developing students' sense of belonging to engineering, using Engeström's activity theory as our theoretical framework. We provide an overview of studies of identity in engineering and of sense of belonging, and a literature review of activity theory and its implications for engineering education.

Identity and sense of belonging

Sense of belonging can be defined as an emotional connection of feeling safe in a social or physical space, culture, profession or other type of community (Macmillan & Chavis, 1986; Strayhorn, 2018). In educational contexts, sense of belonging can be described as 'a generalized sense of membership that stems from students' perception of their involvement in a variety of settings and the support they experience from those around them' (Tinto, 2012, p. 66). Research with university students conceptualised sense of belonging in four domains: academic (educational engagement with university, curriculum and lecturers), social (participation in societies and informal social spaces, friendship and solidarity, communication), surroundings (living space as well as broad geographical and cultural location) and personal space (subjective interests, attitudes and identities) (Ahn & Davis, 2020). See also Chapter 1 in this volume for other definitions of belonging and identity in STEM higher education.

Engineering is embedded in and interacts with a complex range of systems and activities, which leads to the experience of multiple subjectivities which are 'crucial resources for developing a self-identity'

(Williams et al., 2007, p. 3). Research on participation in authentic learning activities in which students work together to solve real-world problems that are found in their community of practice (engineering) has shown a positive impact on students' self-awareness and self-esteem (Roach et al., 2018). Students' self-beliefs are crucial to engineering identity formation (Godwin, 2016).

Several studies on engineering identity found that it is related to retention and persistence in the field (Jones et al., 2014; Matusovich et al., 2010; Meyers et al., 2012; Pierrakos et al., 2009), as well as to belonging to academic and workplace spaces (Faulkner, 2007; Paretti & McNair, 2012; Tonso, 2006). In the same way, domain identification with engineering, 'the extent to which an individual defines the self through a role of performance in a particular domain' (Osborne & Jones, 2011, p. 132), is related to engineering career goals (Jones et al., 2014).

In Tonso's words, 'referring to someone as an engineer signals their having an engineering identity – marking that person as belonging to a group of people who practice engineering' (Tonso, 2014, p. 267). A key aspect of an engineer's identity is technical competence (Hatmaker, 2013), which is developed by becoming involved with disciplinary knowledge and having a shared vocabulary, tools and methods. Disciplinary identity is defined as the connection to a particular academic discipline (Davis & Wagner, 2019). Research has found that there is disciplinary variation in graduate engineering identity (Bahnson et al., 2021). For example, computer science students reported generally lower engineering identity; this may reflect the interdisciplinary background of this discipline, which is influenced by non-engineering fields such as mathematics and business.

Engineers are traditionally educated in their own discipline (e.g. mechanical, civil, chemical), but seldom work solely or exclusively with colleagues with the same disciplinary background. In cross-disciplinary teamwork, engineering students not only apply their disciplinary knowledge but also develop common ground with colleagues from other engineering disciplines (Forin et al., 2012). This cross-disciplinary work can generate tensions between participants in discussion and prioritisation of tasks, ways of thinking, rules and codes between disciplines. The participants' response to the tensions, according to Forin et al. (2012, p. 18) allows them 'to understand where they stand in regards to their peers' view of their work'. This capacity to negotiate experiences with colleagues from different engineering disciplines, and feeling included as an actor in the solution to a common problem, are determinants of belonging and professional development.

Activity theory

Rooted in sociocultural approaches to situated learning, activity theory conceives the human activity system as a complex model that includes subjects, mediating artefacts, objects, rules, communities, division of labour and outcomes (Engeström, 1999, 2006). The subjects are agents of action who relate to other individuals and objects. Subjects make decisions and regulate their actions in pursuance of their objects. Objects are the goals that subjects are motivated to achieve. An object must go through multiple transformations informed by personal sense and cultural meaning to produce a new outcome(s). This is only possible using mediating artefacts, which are the resources used in the activity, such as tools and signs, which can be jointly created by subjects. The community is the social group involved in the activity, of which the subject is a member. Within this community, the members establish and negotiate the division of labour, or how the tasks of a specific activity are shared among the members, and operate according to a set of explicit and implicit rules (including conventions and codes of conduct).

In activity theory, human cognitive development is a socially mediated process. The integration of intra-psychological (within the subject) and inter-psychological (between people) learning takes place in activity systems (Newstetter & Svinicki, 2014; Vygotsky, 1978). According to Engeström and Miettinen (1999, p. 9), 'the internal tensions and contradictions of such a system are the motive force of change and development'. Activity theory also has a focus on identity formation, as it theorises that a person is constantly shaping and being shaped by their social contexts (Roth & Lee, 2007). Identity 'is both product and by-product of activity, as are relevant structures of the community where identity constructions occur' (Tonso, 2006, p. 274).

Identity is a 'dialectical feature' (Roth & Lee, 2007, p. 215) which is continually made and remade in practical activity (Hand & Gresalfi, 2015; Roth et al., 2004). Given that social interaction is the unit of analysis for activity theory (Engeström, 1999), this framework has been adopted in studies that explore engineering student collaborations (De Costa et al., 2022; Hite & Thompson, 2019) and cultural forms for engineering identity (Tonso, 2006).

Through active learning methodologies, such as PjBL, undergraduate students learn engineering professional practice(s) in collaboration with others. These specific learning environments are designed to stimulate interactive engagement and provide students with resources for their thinking and their learning and enactment of professional skills. In these settings, learning is a process of social participation, and engagement in 'communities of practice' provides learning with a social context (Wenger, 1998; see also Horsburgh, Chapter 11 in this volume). In collaborative learning, the learner acquires and develops new social identities 'as a result of a process of social recognition by the community' (Williams et al., 2007, p. 2). These interactions with, and recognition by, the community transcend physical learning spaces, as suggested by recent research on online PBL and on the sense of belonging to engineering during emergency remote teaching (Liu, Yang & Ho, 2022).

This chapter explores the ways in which pedagogies of active learning may encourage a sense of belonging in two distinct ways: belonging as a personal connection, a sense of 'being at home' with an activity, a profession or a discipline, and belonging as a dialectic resource used to construct, describe or defend 'my' group or discipline against 'others'. We define belonging as a relational, fluid and situated practice (Gravett & Ajjawi, 2022), a process ongoing across time and emerging through co-constructed learning spaces and activities, involving a connection with engineering in general and with a specific engineering discipline.

Investigating the impact of teamwork on students' sense of belonging to engineering

As part of a pilot study, our research team interviewed five engineering undergraduates on their experiences of teamwork in project-based learning in the Integrated Engineering Programme (IEP). As summarised in Table 15.1, the interviewees consisted of four mechanical engineering students and one chemical engineering student, who are either Year 1 or Year 2 students.

Activity theory was adopted as a conceptual lens to guide data analysis; it provided a framework for us to analyse and understand how

Table 15.1 Student demographics

Identifier	Department	Year of Study	Local/ International
A	Mechanical Engineering	2nd year	International
B	Mechanical Engineering	1st year	International
C	Mechanical Engineering	1st year	Local
D	Chemical Engineering	2nd year	International
E	Mechanical Engineering	1st year	International

teamwork in interdisciplinary project-based learning promotes a sense of belonging in engineering. In this study, elements of activity theory were reflected in the following ways (see Figure 15.1):

- Subjects: students who bring with them different knowledge and skills
- Object: teamwork in project-based learning which requires authentic problem solving
- Tools/mediating artefacts: communication
- Community: team members
- Rules/norms: curriculum structure, approaches to work
- Roles/division of labour: division of work within the team
- Outcome: sense of belonging to engineering

In the following subsections, we investigate what opportunities teamwork offers for students to develop a sense of belonging to the engineering discipline and to the broader engineering community. We found that teamwork in interdisciplinary project-based learning promotes a sense of belonging in engineering by:

- promoting reflection on disciplinary differences, and
- supporting the formation of a community of practice.

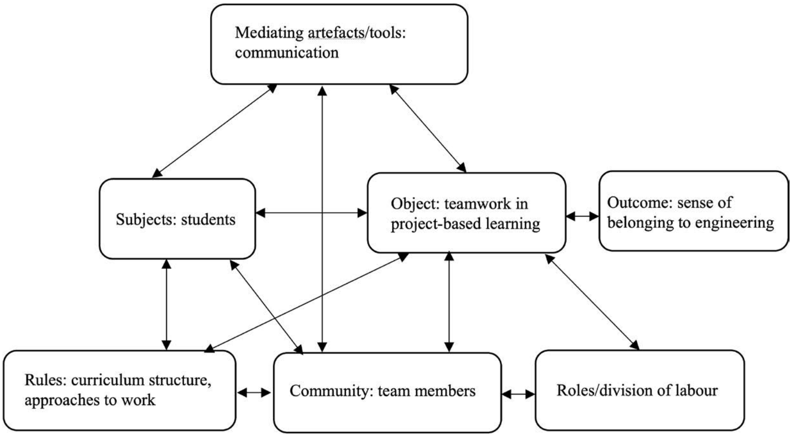

Figure 15.1 Adaptation of activity theory. Adapted from Engeström (1999, 2006).

Promoting reflection on disciplinary differences

Evidence from our study suggests that interdisciplinary teamwork provides opportunities for students to reflect on differences between engineering disciplines in terms of knowledge and skills, work approaches and curriculum structure, which seem to strengthen their disciplinary identity. Our findings suggest that students' sense of belonging to their engineering discipline is reinforced when their disciplinary identity is made salient to them as they make constant references to and comparisons with students from another engineering disciplines during teamwork.

First, we identified instances in which students compare their knowledge and skills with students from another engineering discipline as they work together. Such comparison occurred when students had to draw upon the knowledge of all team members and leverage the unique knowledge and skills of each member to solve real-world problems. For example, Student B, who is a mechanical engineering student, shared that his teammates from civil engineering brought his attention to a geological factor that influenced the building of a dam, which he would not have considered:

> So what made me feel like I belong [to engineering] was the opportunity to apply my learning and understanding to a real-world problem in Engineering Challenges. So that's where I got to try and see if I completely understand what the problem is and to see if my solution is going to be effective or not by collaborating with students from civil engineering who have different skills, knowledge and area of expertise. We had to consider the geology of the lands which we had to construct the dam on, so we wanted to check if there is any risk of landslides and this was something that I would not have considered myself initially. So yeah, I definitely felt that I could properly belong and cooperate with the civil engineers. (Excerpt 1, Student B)

The underlying comparison of disciplinary knowledge he made between himself and peers from another engineering major suggests engagement in discovery of his own identity as a mechanical engineering student. This is evident from the way he described his experience in the Engineering Challenges module, where he had the opportunity to see whether his solution (based on 'his' disciplinary knowledge) was going to be effective, and realised how peers from civil engineering can contribute 'their' disciplinary knowledge.

Second, there were instances in which students compared their work approaches with peers from another engineering discipline during interdisciplinary teamwork. For example, Student B noticed differences in working style when he encountered difficulty communicating with students from civil engineering because they were slow in responding to emails:

> Well, basically with my team, the main problems we faced were communication problems because some of the civil engineering students usually replied very late and so we had to manage with only the mechanical engineering students sometimes. (Excerpt 2, Student B)

Similarly, Student D, who is a chemical engineering student, observed that his teammates from biomedical engineering worked in a less organised manner than peers from his own discipline. He associated his observation with possible differences in training, stressing that chemical engineers are trained to work in a step-by-step structured way:

> In our courses like chemical engineering, we do things very structurally. So, we put them in blocks because it's kind of [the] same as the type of work we do as chemical engineers. We organise things, and then do them step by step. Very often, they become very organised and become very structural. But for biomedical students, they do not have this kind of working routine, and so sometimes the work they spin out is very spontaneous and so, sometimes we have to help them structure their work and give reminders on what to bring. (Excerpt 3, Student D)

Student B's and Student D's ways of bringing out the contrast in work approaches indicate an attempt to differentiate themselves from students from another engineering discipline, which seems to have reinforced their sense of identity as a mechanical and chemical engineering student respectively.

Third, there was an instance in which a student noticed disciplinary differences in curriculum structure as they work with students from another discipline. Student C, who is a mechanical engineering student, explained that he had to exclude the civil engineering students in his team because of differences in schedule and workload:

> I think the civil engineering students had a lot of deadlines when we had to put in work. And we didn't because we had different

> courses. So they couldn't work at the same time as us. And then they just didn't provide much work. … I accepted the fact that they couldn't work as much as us sometimes because they just simply had too many assignments. They had an exam when we had none. So, we just tried to put in work. I just tried to organise work with the mechanical engineers. (Excerpt 4, Student C)

He put his identity as a mechanical engineering student in the limelight when he stressed that the civil engineering students did not make much contribution to the project because they were unable to work at the same time as them (the mechanical engineering students), and he ended up having to coordinate work.

Supporting the formation of a community of practice

Findings from our study suggest that interdisciplinary teamwork offers opportunities for friendship development, division of labour and authentic engagement with engineering practice which supported the organic formation of a community of practice among the students. Students' sense of belonging to engineering is reinforced when they engage in the emerging community of practice that is developed through teamwork. For example, Student E described how a community of practice began to emerge through an increase in communication among team members as they distributed work among themselves. He went on to describe how a greater sense of community developed naturally as conversations moved on smoothly from work-related to more personal topics, leading to the flourishing of friendship:

> In a team, we have a lot of tasks, and we distribute the tasks to individual members of the team. I am in the team because I have a task assigned to me by the team. And we started to communicate because a lot of tasks overlap with each other or my task is related to others as well, and that is the point where you start to increase communication, and it just naturally starts from very academic and project-related stuff to other stuff as well, when we talk about life and we become friends in the end. (Excerpt 5, Student E)

The development of friendship among team members serves to boost the sense of belonging to the engineering community, which can be further built on trust and respect. For instance, student D shared that his feeling of belonging comes from mutual trust and respect in a friendly team environment:

> I would say [the sense of belonging] mainly come[s] from respect and trust. You respect the other person and the other person respects you. And also there is a friendly working environment, and you are not having an argument with someone. And the second thing is trust. I mean when other people delegate their work to you, if there's trust, they do feel that you are reliable and can hand in the work on time. And you will just naturally feel that you belong to this team. (Excerpt 6, Student D)

Student E also noted that the division of labour allowed him to see how work in different engineering disciplines is related and could be integrated, thus strengthening the sense of community. While Student E's experience suggests that the sense of community is strengthened when students can see similarities between different engineering disciplines, another student's experience suggests that the sense of community can also be strengthened when students are able to see differences between different engineering disciplines. As illustrated by Excerpt 1, Student B shared that having the opportunity to work with civil engineering students to solve real-world problems reinforced the sense of being part of an engineering community in which engineers from different backgrounds work collaboratively, contributing their own area of expertise to solve a problem. Student B's comment also suggests that working in an interdisciplinary team increases their engagement with and confidence in their disciplinary knowledge, which further stimulates a sense of belonging to the engineering community.

Discussion

Through the lens of Engeström's activity theory, students' sense of belonging to engineering emerges when interaction of the different elements in the activity model situates teamwork in a social system. This happens when students make comparisons between students from 'my discipline' and students from 'the other discipline', and build a community of practice. Students use the shared activities and the social systems that they build around projects as a means of discovering what gives them a sense of 'being at home' in the engineering discipline. While activity theory proposes that tools (e.g., communication) mediate the process of teamwork, findings from our study suggest that communication also serves as a foundation for effective division of labour and successful friendship development in the community. These are the key factors supporting the development of a community of practice, and subsequently a sense of belonging to the engineering community.

While one of the main aims of the IEP is 'to provide an "integrated view of engineering" as a multi-disciplinary and creative activity that draws experts from key disciplinary areas and requires them to collaborate in identifying and designing innovative solutions to problems' (Mitchell et al., 2021, p. 52), interdisciplinary teamwork in the programme might unintentionally draw students' attention to their disciplinary identity, leading to an 'us' versus 'them' division. However, our findings suggest that students' disciplinary identity is likely to be diluted when they can see how the work of different engineering disciplines is interrelated, and how each discipline can offer its expertise to solve a common problem. In other words, effective interdisciplinary collaboration can shift students' attention away from their disciplinary identity and extend their sense of belonging to a specific engineering discipline to the larger engineering community.

Limitations

We acknowledge, however, that different aspects of social identity, socioeconomic status and academic background – which were not explored in our study – might impact students' sense of belonging to engineering and teamwork in more nuanced ways. We also acknowledge that belonging can be a challenging and negative experience for historically underrepresented students and non-traditional students (see Hussain & Jones, 2021; Lewis et al., 2021). Also, it is important to note that the views about engineering identity and belonging to engineering presented in this study were based on only five interviews with students from two subdisciplines (four mechanical engineering students and one chemical engineering student) in the same higher education institution.

Another limitation of this study is that we do not have a baseline with which to compare students' sense of belonging before they took part in the team project. In other words, we do not know whether students were already affiliated with their engineering discipline before they took part in project-based learning. Thus, in future research, we will invite students to actively reflect on how they perceived their sense of belonging to have developed before and after their team project. We will also invite them to share challenges that might have hindered their sense of belonging and what helped them overcome them.

Conclusion

This chapter demonstrates that pedagogies of active learning can be used to encourage a sense of belonging to the engineering profession as well as to specific engineering disciplines. This suggests that project-based learning activities in disciplinary and interdisciplinary settings provide an opportunity to build communities of practice within the student cohort and foster a sense of belonging. We argue that this is key to engagement with the education process and a vital component of the development of self-efficacy in students.

However, within the approach we must recognise that the majority of the student cohort described are in a very particular developmental phase of life, late adolescence, when building identity and belonging is a key task in the bridge to adulthood and maturity. While many aspects of this development are positive there is a risk that students will feel required to defend their disciplinary territory, which ideally should be avoided. It was reported that students saw the experience of interdisciplinary teams leading to extended friendship groups outside their home discipline as a benefit. We observed that our students use the shared activities and the social systems that they build around projects as a means of testing out ways of belonging, and of discovering what gives them a sense of 'being at home' in a team or in an engineering discipline. Thus, project-based learning may provide additional impetus to the developmental journey and to the sense of belonging within the shared activities of a profession.

References

Ahn, M. Y. & Davis, H. H. (2020). Four domains of students' sense of belonging to university. *Studies in Higher Education*, 45(3), 622–34. https://doi.org/10.1080/03075079.2018.1564902.

Andrews, M. E., Borrego, M. & Boklage, A. (2021). Self-efficacy and belonging: The impact of a university makerspace. *International Journal of STEM Education*, 8(1), art. no. 24. https://doi.org/10.1186/s40594-021-00285-0.

Bahnson, M., Perkins, H., Tsugawa, M., Satterfield, D., Parker, M., Cass, C. & Kirn, A. (2021). Inequity in graduate engineering identity: Disciplinary differences and opportunity structures. *Journal of Engineering Education*, 110(4), 949–76. https://doi.org/10.1002/jee.20427.

Cohen, E. & Viola, J. (2022). The role of pedagogy and the curriculum in university students' sense of belonging. *Journal of University Teaching & Learning Practice*, 19(4), art. no. 6.

Davis, S. N. & Wagner, S. E. (2019). Social and human capital influences on undergraduate researchers' disciplinary identity: The case of social and natural scientists. *Scholarship and Practice of Undergraduate Research*, 2(3), 35–44. https://doi.org/10.18833/spur/2/3/5.

De Costa, P. I., Lee, J. & Li, W. (2022). Sociocultural influence on engineering students' collaborative design project: An Activity Theory perspective. *Applied Linguistics Review*. https://doi.org/10.1515/applirev-2022-0009.

Engeström, Y. (2006). Activity theory and expansive design. In S. Bagnara & G. C. Smith (eds), *Theories and Practice of Interaction Design,* pp. 3–24. Mahwah, NJ: Lawrence Erlbaum Associates.

Engeström, Y. & Miettinen, R. (1999). Introduction. In Y. Engeström, R. Miettinen & R. Punamäki (eds), *Perspectives on Activity Theory*, pp. 1–16. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511812774.002.

Faulkner, W. (2007). 'Nuts and bolts and people': Gender-troubled engineering identities. *Social Studies of Science*, 37(3), 331–56. https://doi.org/10.1177/0306312706072175.

Felder, R. M. (2012). Engineering education: A tale of two paradigms. In B. McCabe, M. Pantazidou & D. Phillips (eds), *Shaking the Foundations of Geo-engineering Education*, pp. 9–14. Boca Raton: CRC Press.

Forin, T. R., Adams, R. & Hatten, K. (2012). Crystallized identity: A look at identity development through cross-disciplinary experiences in engineering. Paper presented at 2012 ASEE Annual Conference & Exposition, San Antonio, Texas. https://doi.org/10.18260/1-2--21129.

Froyd, J. E. & Ohland, M. W. (2005). Integrated engineering curricula. *Journal of Engineering Education*, 94(1), 147–64. https://doi.org/10.1002/j.2168-9830.2005.tb00835.x.

Geisinger, B. N. & Raman, D. R. (2013). Why they leave: Understanding student attrition from engineering majors. *International Journal of Engineering Education*, 29(4), 914–25.

Godwin, A. (2016). The development of a measure of engineering identity. Paper presented at 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana. https://doi.org/10.18260/p.26122.

Gravett, K. & Ajjawi, R. (2022). Belonging as situated practice. *Studies in Higher Education*, 47(7), 1386–96. https://doi.org/10.1080/03075079.2021.1894118.

Hailes, S., Jones, L., Micheletti, M., Mitchell, J. E., Nyamapfene, A., Roach, K., Tilley, E. & Truscott, F. (2021). The UCL Integrated Engineering Programme. *Advances in Engineering Education*, 9(3), 1–17. https://advances.asee.org/wp-content/uploads/vol09/Issue3/Papers/AEE-Innovative-UCL-2.pdf. Accessed 2 January 2024.

Hand, V. & Gresalfi, M. (2015). The joint accomplishment of identity. *Educational Psychologist*, 50(3), 190–203. https://doi.org/10.1080/00461520.2015.1075401.

Hatmaker, D. M. (2013). Engineering identity: Gender and professional identity negotiation among women engineers. *Gender, Work and Organization*, 20(4), 382–96. https://doi.org/10.1111/j.1468-0432.2012.00589.x.

Hite, R. & Thompson, C. J. (2019). Activity theory as theoretical framework for analyzing and designing global K-12 collaborations in engineering: A case study of a Thai-U.S. elementary engineering project. *Journal of International Engineering Education*, 1(1), art. no. 5. https://digitalcommons.uri.edu/jiee/vol1/iss1/5. Accessed 2 January 2024.

Hussain, M. & Jones, J. M. (2021). Discrimination, diversity, and sense of belonging: Experiences of students of color. *Journal of Diversity in Higher Education*, 14(1), 63–71. https://doi.org/10.1037/dhe0000117.

Johnson, B. & Ulseth, R. (2016). Development of professional competency through professional identity formation in a PBL curriculum. *2016 IEEE Frontiers in Education Conference (FIE)*, Erie, PA, pp. 1–9. https://doi.org/10.1109/FIE.2016.7757387.

Jones, B. D., Osborne, J. W., Paretti, M. C. & Matusovich, H. M. (2014). Relationships among students' perceptions of a first-year engineering design course and their engineering identification, motivational beliefs, course effort, and academic outcomes. *International Journal of Engineering Education*, 30(6), 1340–56.

Kolmos, A. & Graaff, E. de (2014). Problem-based and project-based learning in engineering education: Merging models. In A. Johri & B. M. Olds (eds), *Cambridge Handbook of Engineering Education Research*, pp. 141–61. New York: Cambridge University Press.

Lahiff, A., Tilley, E., Broad, J., Roach, K. & Detmer, A. (2019). Disciplinary learning in project-based undergraduate engineering education: The case for new knowledge. In B. Kloot (ed.), *8th Research in Engineering Education Symposium (REES 2019): Making connections*, pp. 578–87. Research in Engineering Education Network.

Lewis, J. A., Mendenhall, R., Ojiemwen, A., Thomas, M., Riopelle, C., Harwood, S. A. & Browne Huntt, M. (2021). Racial microaggressions and sense of belonging at a historically white university. *American Behavioral Scientist*, 65(8), 1049–71. https://doi.org/10.1177/0002764219859613.

Liu, X., Yang, Y. & Ho, J. W. (2022). Students sense of belonging and academic performance via online PBL: A case study of a university in Hong Kong during quarantine. *International Journal of Environmental Research and Public Health*, 19(3), art. no. 1495. http://dx.doi.org/10.3390/ijerph19031495.

Macmillan, D. W. & Chavis, D. M. (1986). Sense of community: A definition and theory. *Journal of Community Psychology*, 14(1), 6–23. https://doi.org/10.1002/1520-6629(198601)14:1<6::AID-JCOP2290140103>3.0.CO;2-I.

Matusovich, H. M., Streveler, R. A. & Miller, R. L. (2010). Why do students choose engineering? A qualitative, longitudinal investigation of students' motivational values. *Journal of Engineering Education*, 99(4), 289–303. https://doi.org/10.1002/j.2168-9830.2010.tb01064.x.

Meyers, K. L., Ohland, M. W., Pawley, A. L., Silliman, S. E. & Smith, K. A. (2012). Factors relating to engineering identity. *Global Journal of Engineering Education*, 14(1), 119–31.

Mitchell, J. E., Nyamapfene, A., Roach, K. & Tilley, E. (2021). Faculty wide curriculum reform: The integrated engineering programme. *European Journal of Engineering Education*, 46(1), 48–66. https://doi.org/10.1080/03043797.2019.1593324.

Newstetter, W. C. & Svinicki, M. D. (2014). Learning theories for engineering education practice. In A. Johri & B. Olds (eds), *Cambridge Handbook of Engineering Education Research*, pp. 29–46. New York: Cambridge University Press.

Osborne, J. W. & Jones, B. D. (2011). Identification with academics and motivation to achieve in school: How the structure of the self influences academic outcomes. *Educational Psychology Review*, 23(1), 131–58. https://doi.org/10.1007/s10648-011-9151-1.

Paretti, M. C. & McNair, L. D. (2012). Analyzing the intersections of institutional and discourse identities in engineering work at the local level. *Engineering Studies*, 4(1), 55–78. https://doi.org/10.1080/19378629.2011.652120.

Peters, J., Direito, I., Roach, K. & Tilley, E. (2019). Designing inclusive approaches in intensive team-based engineering learning environments. *International Journal of Gender, Science and Technology*, 11(1), 93–107.

Pierrakos, O., Beam, T. K., Constantz, J., Johri, A. & Anderson, R. (2009). On the development of a professional identity: Engineering persisters vs engineering switchers. *2009 39th IEEE Frontiers in Education Conference*, San Antonio, TX, 2009, pp. 1–6. https://doi.org/10.1109/FIE.2009.5350571.

Roach, K., Tilley, E. & Mitchell, J. (2018). How authentic does authentic learning have to be? *Higher Education Pedagogies*, 3(10), 495–509. https://doi.org/10.1080/23752696.2018.1462099.

Roth, W.-M. & Lee, Y.-J. (2007). 'Vygotsky's neglected legacy': Cultural-historical activity theory. *Review of Educational Research*, 77(2), 186–232. https://doi.org/10.3102/0034654306298273.

Roth, W.-M., Tobin, K., Elmesky, R., Carambo, C., McKnight, Y.-M. & Beers, J. (2004). Re/making identities in the praxis of urban schooling: A cultural historical perspective. *Mind, Culture, and Activity*, 11(1), 48–69. http://dx.doi.org/10.1207/s15327884mca1101_4.

Strayhorn, T. L. (2018). *College Students' Sense of Belonging: A key to educational success for all students*, 2nd edn. New York & Abingdon: Routledge.

Striolo, C., Pollock, M. & Godwin, A. (2021). Staying or leaving: Contributing factors for U.K. engineering students' decisions to pursue careers in engineering industry. *European Journal of Engineering Education*, 46(3), 364–88. https://doi.org/10.1080/03043797.2020.1711707.

Tinto, V. (2012). *Completing College: Rethinking institutional action.* Chicago, IL: University of Chicago Press.

Tonso, K. L. (2006). Student engineers and engineer identity: Campus engineer identities as figured world. *Cultural Studies of Science Education*, 1, 273–307. https://doi.org/10.1007/s11422-005-9009-2.

Tonso, K. L. (2014). Engineering identity. In A. Johri & B. Olds (eds), *Cambridge Handbook of Engineering Education Research*, pp. 267–82. New York: Cambridge University Press.Vygotsky, L. S. (1978). *Mind in Society: The development of higher psychological processes*, trans. M. Cole. Cambridge, MA: Harvard University Press.

Wenger, E. (1998). *Communities of Practice: Learning, meaning, and identity*. Cambridge: Cambridge University Press.

Williams, J., Davis, P. & Black, L. (2007). Sociocultural and cultural-historical activity theory perspectives on subjectivities and learning in schools and other educational contexts. *International Journal of Educational Research*, 46(1–2), 1–7. https://doi.org/10.1016/j.ijer.2007.07.001.

16

How to meet students' need for belonging during undergraduate research engagement: a case study within medicine

Belinda W. C. Ommering and Friedo Dekker

Introduction

Medical students are involved in various educational opportunities related to the science, technology, engineering and mathematics (STEM) area. This ranges from physics to biology and evidence-based medicine. Many medical schools aim to educate future physicians who have an academic attitude, and a subgroup of physician-scientists to connect science and clinical practice. To this end, medical schools aspire to, or already do, provide students with research opportunities within the core curriculum to educate future physicians scientifically and stimulate the development of a scientist identity. As students mainly enter medical education to become medical doctors working in a clinical setting, intrinsically motivating them to conduct research is important. However, providing students with authentic research experiences and stimulating motivation within large-scale education is challenging.

Drawing on self-determination theory, we developed a research course aimed at, among other things, intrinsically motivating medical students for research. We learned that 'relatedness' or 'belonging' may be one of the key concepts when we were developing a two-week course in which 300 students could all answer their own authentic research question. Especially when providing students with research opportunities in the early phases of their education, it is important to consider how to shape these experiences so that student belonging, motivation and well-being are fostered. Carefully scaffolded group activities, intentional community building and structured peer activities helped foster students' sense of belonging.

This chapter draws on a case study within medicine, connecting practical examples based on self-determination theory to report on how to meet students' need for belonging within an authentic individual research opportunity in the first year of the undergraduate curriculum. The research showed positive effects from the course in terms of knowledge, motivation and further research involvement.

Medicine and STEM

Internationally, medicine and STEM are perceived as intertwined in different ways. The Higher Education Research Institute (HERI) lists health professions as a STEM discipline (https://www.heri.ucla.edu/PDFs/surveyAdmin/fac/Listing-of-STEM-Disciplines.pdf; accessed 25 March 2024). Uddin and colleagues (2021) report that medical and health sciences are the most common of all STEM disciplines in interdisciplinary research with a focus on STEM. In the US, STEM students can major in medicine or health tracks, although according to Dou and colleagues (2021) this part of the STEM student population is generally omitted from discussions of STEM education. Furthermore, medical students are involved in various STEM-related educational opportunities during medical school. Physics, physiology and chemistry are essential for physicians to understand basic processes in the human body. Maths and statistics are essential for pharmacotherapy and evidence-based medicine. Moreover, medicine is largely based and dependent on scientific progress regarding diagnosis and treatment. Thus, many challenges in teaching science apply equally to the setting of medical education.

The role of research in medical school

Research is imperative for making advances within medicine, the lifelong learning of physicians and ultimately offering optimal patient care (Chang & Ramnanan, 2015; Dekker, 2013; Woolf, 2008). Within medical schools, we aim to deliver future physicians with an academic mindset who are able to use scientific research in daily clinical work. These physicians should be able to practise evidence-based medicine, starting with a recognition of where knowledge is missing when they handle clinical questions and problems. Subsequently, they must be capable of understanding and critically appraising relevant scientific research so that they can apply it within their daily clinical decision making, thereby providing their patients with grounded diagnoses. Physicians should acknowledge that the medical field is dynamic, with frequently adjusted or new insights. Their academic mindset also enables them to contribute to the process of lifelong learning through research (Chang & Ramnanan, 2015; Dekker, 2011; Richardson et al., 2014).

As well as all physicians using research, some physicians should actively contribute to research within their medical discipline. This goes beyond, for example, just asking patients to be subjects in a study conducted by other researchers, or asking for patients' informed consent to share clinical data with other researchers. To keep evolving within medicine, physicians who are themselves structurally involved in both clinical practice and scientific research are needed (Dekker, 2011). Internationally, physicians of this type are called physician-scientists, clinician-scientists or clinical researchers. Physician-scientists have a medical degree and provide daily clinical care, but also substantially devote time to conducting research (Sklar, 2017). Physician-scientists encounter practical clinical questions and problems every day, which can serve as an inspiration for research. Conversely, physician-scientists can translate research outcomes into clinical practice and make sure that research outcomes find their way to patients through clinical application (Roberts et al., 2012).

In order to deliver academically capable physicians and a subset of physicians pursuing a research-oriented career, clinical research was introduced in the undergraduate stages of medical education curricula (National Institutes of Health, 2014). This is in line with the role of the 'scholar' as defined by the Canadian Medical Education Directives for Specialists (CanMEDS), a framework many of the medical education programmes worldwide build upon. Nowadays, many medical schools have implemented – or are starting to implement – undergraduate research opportunities for medical students. These intra- or extracurricular initiatives have the twofold purpose of delivering graduates with an academic mindset and encouraging a subgroup of graduates to pursue careers as physician-scientists (Abu-Zaid & Alkattan, 2013; Havnaer et al., 2017; Scager et al., 2014).

Stimulating feelings of belonging and motivation through research experiences

It is a common belief that conducting research during medical school helps students to understand and apply research as medical professionals. When offered in the right way, undergraduate research experiences can motivate students to conduct research as physicians or, in some cases, physician-scientists (Ommering, van Blankenstein, van Diepen & Dekker, 2021; Ommering, van Blankenstein & Dekker, 2021; Ommering, van Diepen et al., 2020). For both purposes it seems beneficial to put students in a researcher role and stimulate active engagement within authentic research opportunities. Instead of perceiving students as passive consumers of research knowledge (research-informed education), a trend is emerging in which students are actually involved in clinical or laboratory research (research-based education) early on in undergraduate education (Healey et al., 2010). However, many medical students are educated in a medical programme at the same time, especially in the early stages of medical school. Providing students with individual authentic research experiences that intrinsically motivate them towards research in a large-scale education setting is challenging (Kindon & Elwood, 2009; Walkington et al., 2017).

Self-determination theory (SDT) provides a theoretical perspective that underpins the importance of belonging in undergraduate research opportunities to stimulate motivation for research. SDT posits that social conditions support or hinder human flourishing. SDT distinguishes intrinsic motivation (based on enjoyment or pure interest) and extrinsic motivation (driven by external rewards), while stating that intrinsic motivation is related to better academic performances and general well-being (Ryan & Deci, 2017). According to SDT, three basic psychological needs must be fulfilled to promote intrinsic motivation. The need for autonomy is the need to regulate one's own actions, the need for competence is the need to feel effective in dealing with relevant life contexts, and the need for relatedness is the need to feel socially connected to others and cared for by them. In other words, the need for relatedness is similar to a need for belonging (Ryan & Deci, 2017). SDT therefore serves to both design and evaluate the research course.

The notion of relatedness raises the question whether engaging in undergraduate research affects students' sense of belonging. Especially when providing students with research opportunities in early phases of education, it is important to consider how to shape these experiences in such a way that student belonging, motivation and well-being are fostered. Within the Leiden University Medical Center (LUMC), an undergraduate research course was designed and implemented for all students in their first year of medical training. Attention is given to meeting all psychological needs to promote intrinsic motivation and well-being among our students (Ommering, van Diepen et al., 2020), and here we draw out the enabling aspects of the structure of the course.

Leiden University Medical Center's first-year research course

First we provide a short overview of the course, and then focus on elements which particularly fostered feelings of belonging. Our course is integrated into the first year of a three-year medical bachelor's degree and focuses on academic and scientific training. Students individually conduct a short research project within two weeks by (1) gathering patient data, (2) formulating an individual research question, (3) analysing data, (4) writing a research report and (5) presenting the research orally. About 350 students follow the research course each year.

In the same first year, before starting the research course, students serve as interns in nursing homes. As a preparation for the research course, students collect data on three patients in the nursing home. They return to collect follow-up data from the same three patients after three months. All the collected data, on approximately 1,050 patients (350 students × 3 patients), is combined in one large data set that every student can use during the research course to answer their individual research question, which is inspired by their bedside experiences with patients in the nursing home. The research course itself takes place in the first semester, after the nursing internship, and has a duration of two weeks (full-time). During these two weeks, students follow lectures; the whole group focuses mainly on statistics and epidemiology. In addition, students follow three sessions for which they are divided into smaller groups of about 12–15 students. The smaller-group sessions are structured as follows:

1. As preparation for the first smaller-group session, students are asked to formulate ideas on possible research questions for their individual research projects. During the actual session, the students brainstorm on the definition of a good question, after which they discuss and optimise their individual questions in groups of three or four students. The aim of the first smaller-group session is to make sure that every student has formulated a research question for their project.

2. The second smaller-group session focuses on critically appraising existing literature. This helps students to get a sense of the way research is reported and the dos and don'ts within this process. Also, it helps to clarify that critical appraisal of research is always necessary and that careful consideration is needed of what might be transferred to one's own specific context.
3. The third and last smaller-group session simulates a conference session with oral research presentations. Students present their research, provide others with constructive feedback and actively participate in group discussion.

Effective mentoring is imperative if undergraduate research experiences are to be successful (Shanahan et al., 2015). Therefore, the three smaller-group sessions are led by one and the same teacher to foster continuity. Teachers do their best to create a safe environment and stimulate students to ask questions. In our course, the smaller-group sessions are provided by PhD students and physician-scientists. They can serve as role models and establish a 'low threshold' culture or a safe space to acknowledge and help with difficulties in conducting research, in which they can also take on the role of mentor. As well as alternating between the large- and smaller-group sessions, students follow sessions in which they practise with statistics. A safe learning environment in which students are closely monitored and mentored can enhance feelings of belonging ('relatedness' in SDT).

Students work towards writing a professional academic piece: they need to write an extended abstract on their research which accounts for 20 per cent of their final grade for the course. Students also present their research orally, which accounts for another 20 per cent of their grade. The research report and presentation are graded by the teacher of the smaller-group sessions, using a rubric. To conclude, students take part in an official exam. Feedback on the extended abstract and the oral presentation reflects a 'stepped preparation' in which the feedback may help to prepare for the official exam. The exam represents 60 per cent of the grade for the course and focuses on statistical and epidemiological knowledge and understanding.

Practical examples of fostering the need for belonging within a research course

Undergraduate research experiences have the potential to contribute to motivation and student well-being through feelings of belonging. We provide a description of the design choices that were made with the intention of stimulating feelings of belonging and therefore motivation, based on SDT. As our course was implemented in the first year of our medical programme, most students experienced undergraduate research for the first time, and the students were all novices when it came to conducting research. This offered the opportunity to establish a sense of community right from the start: all the students were thrown in at the 'deep end'; they were in this together.

Feelings of 'not being alone' should be emphasised. This feeling was strengthened through giving students the joint responsibility of constructing one combined data set. Gathering data collectively encourages the development of feelings of social interdependence (Johnson, 2003). Also, it promotes feelings of inclusivity and of being part of a community, as every student's data matters for the data set and the wider project. Indirectly, this feeling of relatedness can support a sense of responsibility for the outcomes of peers, which can strengthen social connectedness among students and underpin the feeling that students are important contributors within their research community.

The small groups of 12–15 students helped to create feelings of community and stimulate feelings of belonging. This is in line with the findings of Oman (2017), who reported that students mentioned that opportunities for mentoring and networking within social spaces were important for well-being. Small-group sessions help to promote connections between peers. Assigning one teacher to one group for all three meetings supports close working relationships between students and research faculty members (Thiry & Laursen, 2011). The teachers can serve as role models and help students gain technical skills and methods regarding conducting research in the medical discipline. In turn, these skills can enable students to form connections to their discipline through research for which they are intrinsically motivated (Walkington & Ommering, 2022). The teachers of the small-group sessions can function as mentors and provide social guidance; for students this can feel as though they are being cared for by others, which is also part of feelings of belonging and relatedness (Shanahan et al., 2015; Ryan & Deci, 2017).

Specific teaching methods and assignments within the smaller-group sessions can be designed so that feelings of belonging are fostered. For instance, in our first smaller-group sessions, students worked on formulating a research question for their project. The smaller-group session is shaped in such a way that plenary discussion, and collaboration in even smaller groups, are alternated. Through this mode of constructing the session, although students work on individual research questions it feels like a group effort to make sure that everyone leaves with a good research question.

Peer discussion is stimulated within the course, which contributes to deep learning of both content and skills (Shanahan et al., 2015). Lastly, simulating a conference setting and asking students to step up as 'critical friends' providing constructive feedback during the oral presentation enables students to learn from each other and to provide feedback and ask critical questions. Feelings of 'being in this together' are enhanced. Through the creation of a culture in which students help each other, though closely monitored by the teacher of the small-group sessions, feelings of belonging are enhanced.

Positive effects of an authentic research course that fosters belonging

After the course was designed and implemented, four studies were conducted to evaluate our initiative and identify its positive effects. In line with SDT, a qualitative grounded-theory study by Ommering and colleagues revealed that feelings of belonging, such as feeling part of a community or a research group, were mentioned as factors contributing to intrinsic motivation for research as well (Ommering, Wijnen-Meijer et al., 2020). Moreover, a strong connection to practice, as pursued within our course, contributes to feelings of relevance and, in turn, to motivation for research. These feelings may also contribute to feelings of belonging in relation to daily practice and patients.

Vereijken and colleagues compared the outcomes of an earlier, traditional course on statistics and epidemiology with the outcomes of our redesigned course, in which active participation is fostered, for a new cohort of first-year medical students. They showed that after three months the new course resulted in relevant, and significantly more, knowledge on the national progress test, better skills in writing a scientific abstract and higher levels of motivation for research (Vereijken et al., 2018). Two other studies by Ommering and colleagues, which were grounded in self-determination theory, indicated that authentic assessment within the course was an essential component of improving intrinsic motivation for research among students. A successful experience of presenting your own research orally was related to both increased feelings of intrinsic motivation for research and research self-efficacy beliefs among undergraduate students (Ommering, van Diepen et al., 2021).

Furthermore, it was established that intrinsic motivation for research is related to conducting research as an undergraduate (Ommering et al., 2019). In this study, we showed that students who were intrinsically motivated for research at the start of medical school were more likely than others to be involved in the extracurricular research programme that the Leiden University Medical Center offers in the second year of medical training. This reinforces the idea that a research experience in which feelings of belonging among students are fostered not only contributes to intrinsic motivation and well-being but might also help to stimulate a subgroup of students to pursue a physician-scientist career.

Conclusion

In medical school a twofold purpose is pursued: deliver future physicians with an academic mindset who can use research in daily clinical practice, and deliver a subset of physician-scientists who are able to connect clinical practice and science and so contribute to advances within the medical domain. To this end, many intra- and extracurricular initiatives are designed and implemented to offer students undergraduate research experiences. Undergraduate research experiences have the potential to contribute to motivation and student well-being, through, for instance, feelings of belonging.

In this chapter we have presented a case study from medicine illustrating how self-determination theory can provide a valuable approach to designing and evaluating a research course in which feelings of belonging can be promoted in a first-year research course embedded in large-scale education. Social interdependence in gathering of data, working with fixed small groups and mentors throughout the course, the promotion of feelings of being part of a community and the implementation of peer discussion and feedback are mentioned as elements in the research course that help to contribute to feelings of belonging in students and, consequently, intrinsic motivation and general well-being. Hopefully, this ultimately contributes to the delivery of graduates who are motivated to use research in their daily practice, and perhaps some graduates who aspire to pursue a physician-scientist career.

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References

Abu-Zaid, A. & Alkattan, K. (2013). Integration of scientific research training into undergraduate medical education: A reminder call. *Medical Education Online*, 18(1), art. no. 22832. http://dx.doi.org/10.3402/meo.v18i0.22832.

Chang, Y. & Ramnanan, C. J. (2015). A review of literature on medical students and scholarly research: Experiences, attitudes, and outcomes. *Academic Medicine*, 90(8), 1162–73. https://doi.org/10.1097/acm.0000000000000702.

Dekker, F. W. (2011). Science education in medical curriculum: Teaching science or training scientists? *Medical Science Educator*, 21(3S), 258–60.

Dekker, F. W. (2013). Achieving research competences through medical education. *Perspectives on Medical Education*, 2(4), 178–80. https://doi.org/10.1007/s40037-013-0084-x.

Dou, R., Cian, H. & Espinosa-Suarez, V. (2021). Undergraduate STEM majors on and off the pre-med/health track: A STEM identity perspective. *CBE – Life Sciences Education*, 20(2), ar24. https://doi.org/10.1187/cbe.20-12-0281.

Havnaer, A. G., Chen, A. J. & Greenberg, P. B. (2017). Scholarly concentration programs and medical student research productivity: A systematic review. *Perspectives on Medical Education*, 6(4), 216–26. https://doi.org/10.1007/S40037-017-0328-2.

Healey, M., Jordan, F., Pell, B. & Short, C. (2010). The research–teaching nexus: A case study of students' awareness, experiences and perceptions of research. *Innovations in Education and Teaching International*, 47(2), 235–46. http://dx.doi.org/10.1080/14703291003718968.

Johnson, D. W. (2003). Social interdependence: Interrelationships among theory, research, and practice. *American Psychologist*, 58(11), 934–45. https://doi.org/10.1037/0003-066X.58.11.934.

Kindon, S. & Elwood, S. (2009). Introduction: More than methods – reflections on participatory action research in geographic teaching, learning and research: Participatory action research in geographic teaching, learning and research. *Journal of Geography in Higher Education*, 33(1), 19–32.

National Institutes of Health (2014). Physician-Scientist Workforce Working Group report. NIH Biomedical Research Workforce Working Group. https://acd.od.nih.gov/documents/reports/PSW_Report_ACD_06042014.pdf. Accessed 2 January 2024.

Oman, S. (2017). Student Experience Survey 2017: Investigating well-being at university. https://www.timeshighereducation.com/student/blogs/student-experience-survey-2017-investigating-well-being-university. Accessed 2 January 2024.

Ommering, B. W. C., van Blankenstein, F. M. & Dekker, F. W. (2021). First steps in the physician-scientist pipeline: A longitudinal study to examine the effects of an undergraduate extracurricular research programme. *BMJ Open*, 11(9), art. no. e048550. https://doi.org/10.1136/bmjopen-2020-048550.

Ommering, B. W. C., van Blankenstein, F. M., van Diepen, M. & Dekker, F. W. (2021). Academic success experiences: Promoting research motivation and self-efficacy beliefs among medical students. *Teaching and Learning in Medicine*, 33(4), 423–33. https://doi.org/10.1080/10401334.2021.1877713.

Ommering, B. W. C., van Blankenstein, F. M., Wijnen-Meijer, M., van Diepen, M. & Dekker, F. W. (2019). Fostering the physician-scientist workforce: A prospective cohort study to investigate the effect of undergraduate medical students' motivation for research on actual research involvement. *BMJ Open*. 9(7), art. no. e028034. https://doi.org/10.1136/bmjopen-2018-028034. PMID: 31340963; PMCID: PMC6661705.

Ommering, B. W. C., van Diepen, M., van Blankenstein, F. M., de Jong, P. G. M. & Dekker, F. W. (2020). Twelve tips to offer a short authentic and experiential individual research opportunity to a large group of undergraduate students. *Medical Teacher*, 42(10), 1128–33. https://doi.org/10.1080/0142159X.2019.1695766.

Ommering, B. W.C., Wijnen-Meijer, M., Dolmans, D. H., Dekker, F. W. & van Blankenstein, F. M. (2020). Promoting positive perceptions of and motivation for research among undergraduate medical students to stimulate future research involvement: A grounded theory study. *BMC Medical Education*, 20(1), art. no. 204, 1–12. https://doi.org/10.1186/s12909-020-02112-6.

Richardson, D., Oswald, A., Lang, E., Harvey, B. & Chan, M. (2014). *The CanMEDS 2015 Scholar Expert Working Group Report*. The Royal College of Physicians and Surgeons of Canada.

Roberts, S. F., Fischhoff, M. A., Sakowski, S. A. & Feldman, E. L. (2012). Perspective: Transforming science into medicine: how clinician-scientists can build bridges across research's 'valley of death'. *Academic Medicine*, 87(3), 266–70. https://doi.org/10.1097/acm.0b013e3182446fa3.

Ryan, R. M. & Deci, E. L. (2017). *Self-Determination Theory: Basic psychological needs in motivation, development, and wellness*. New York: Guilford Press.

Scager, K., Akkerman, S. F., Pilot, A. & Wubbels, T. (2014). Challenging high-ability students. *Studies in Higher Education*, 39(4), 659–79. https://doi.org/10.1080/03075079.2012.743117.

Shanahan, J. O., Ackley-Holbrook, E., Hall, E., Stewart, K. & Walkington, H. (2015). Ten salient practices of undergraduate research mentors: A review of the literature. *Mentoring & Tutoring: Partnership in Learning*, 23(5), 359–76. https://doi.org/10.1080/13611267.2015.1126162.

Sklar, D. P. (2017). We must not let clinician–scientists become an endangered species. *Academic Medicine*, 92(10), 1359–61. https://doi.org/10.1097/ACM.0000000000001870.

Thiry, H. & Laursen, S. L. (2011). The role of student-advisor interactions in apprenticing undergraduate researchers into a scientific community of practice. *Journal of Science Education and Technology*, 20(6), 771–84. https://doi.org/10.1007/s10956-010-9271-2.

Uddin, S., Imam, T. & Mozumdar, M. (2021). Research interdisciplinarity: STEM versus non-STEM. *Scientometrics*, 126(1), 603–18. https://doi.org/10.1007/s11192-020-03750-9.

Vereijken, M. W. C., van der Rijst, R. M., van Driel, J. H. & Dekker, F. W. (2018). Student learning outcomes, perceptions and beliefs in the context of strengthening research integration into the first year of medical school. *Advances in Health Sciences Education*, 23(2), 371–85. https://doi.org/10.1007%2Fs10459-017-9803-0.

Walkington, H., Griffin, A. L., Keys-Mathews, L., Metoyer, S. K., Miller, W. E., Baker, R. & France, D. (2017). Embedding research-based learning early in the undergraduate geography curriculum. In M. J. Haigh, D. Cotton & T. Hall (eds), *Pedagogic Research in Geography Higher Education*, pp. 291–306. Abingdon: Routledge.

Walkington, H. & Ommering, B. W. C. (2022). How does engaging in authentic research at undergraduate level contribute to student well-being? *Studies in Higher Education*, 47(12), 2497–507. https://doi.org/10.1080/03075079.2022.2082400.

Woolf, S. H. (2008). The meaning of translational research and why it matters. *JAMA*, 299(2), 211–13. https://doi.org/10.1001/jama.2007.26.

17

Fostering belonging through student–staff research partnerships

Ian M. Kinchin, Karen Gravett, Cathy Derham and Alfred Thumser

Introduction

In their review of science, technology, engineering and mathematics (STEM) teacher development, Winberg et al. (2019) highlight the complexities of developing STEM pedagogy to complement STEM content and the tensions that may develop between a social science perspective of education and a natural science perspective of content, and the epistemological abyss that can separate the two. In their review, the fixed nature of these opposing views appears to be embedded in implicit assumptions that emerge from a grounded philosophy of being in which pedagogical competence is separated from mastery of the discipline. Within this chapter, we offer an alternative lens through a nomadic philosophy of becoming in which identities are not static, but always on the move, becoming something different. In this situation, neither side of the abyss is 'settled', each being disrupted by an acknowledgement of 'other knowledges' (Correia, 2023) that can typically be found within an 'institutional natural history' (Kinchin, 2022).

Rather than being introduced to members of the faculty through the traditional medium of staff workshops, these complex and challenging ideas were seen to emerge through extended participation in a student–staff research partnership programme (SSRPP). This was not a forced emergence, and there were no targets for the project that determined it as a desired outcome or endpoint for development. Here we explore what spaces student–staff partnerships might offer to create new openings for connections and belonging within teaching and learning. How does working in partnership with students make teachers feel? What changes can happen as a result of student–staff partnerships, in terms of colleagues' experiences of belonging, connection and community? What can working in partnership with our students enable us to do, to create? Indeed, we need to ask what it is that academics belong to: is it the institution, the discipline, the teaching community? Or is it a unique mixture of all these for each academic? By adopting a situated, institution-centred approach, the SSRPP evaluated the potential for the University of Surrey to develop a culture of partnership, and demonstrated the different kinds of partnerships that might evolve.

Context

Although we aimed to include the student participants in as much of the process as possible, timings meant that we were forced to undertake some activities before the student involvement, in particular acquiring the internal funding to support the activities, obtaining ethical approval to undertake the research and securing the book contract to publish the outputs. The publishing contract seemed to be an important component of the proposed work for the recruitment of staff partners, conferring a level of academic credibility to the work. Once students were recruited, the window for activity during the academic year appeared very narrow, as we had to ensure that student activity was completed before the exam season got under way at the end of the academic year. When the Christmas and Easter holidays were taken into account, it was clear that the partnership element would be restricted to a few weeks in which the student–staff pairing would undertake a unique piece of pedagogical research within their own academic context.

One of the aims of the project was to make the research as authentic as possible, and this meant publishing the outcomes through an externally recognised channel. In the end, the two rounds of research activity (completed in 2018 and 2019) were published in two volumes (Gravett et al., 2020; Heron et al., 2021). The length of the publication cycle extended the process in ways that were beyond our control (to accommodate peer review, corrections to proofs and so on), with the result that publication did not happen until after most of the students had already left the institution. This would make any long-term follow-up with students very difficult. However, the staff partners were still working here at the university. Initial evaluation of the programme was carried

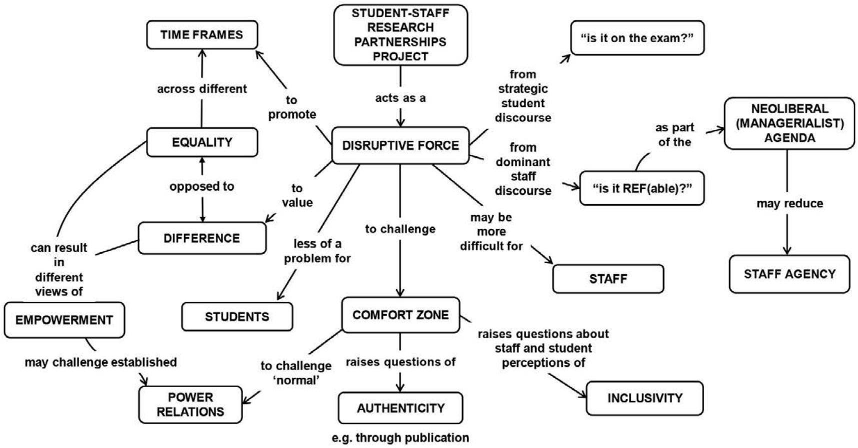

Figure 17.1 A concept map to summarise the main findings of an evaluation of a student–staff research partnership project. From Ali et al., 2021. © Ian Kinchin.

out in the autumn immediately after the second cycle of research activity was complete. The evaluation was undertaken in partnership with two of the students who had been research partners in the second cycle of projects and had subsequently taken up posts as interns within the academic development unit (Ali et al., 2021). A key finding of this initial evaluation was that partnership projects were considered 'disruptive' to both students and staff (Figure 17.1).

To cope with the disturbance created by the partnership project, considerable support was given to the researchers (staff and students) by the academic development team. This support included numerous one-to-one discussions about the projects and how to proceed, and workshops that dealt with research methods, such as how to conduct an interview or how to run a focus group. In addition, we had to address issues to do with writing and referencing so that we could ensure some consistency of style across the book, even though the partnerships were working in different disciplinary contexts (arts and sciences) where writing and referencing practices varied enormously. Most of the staff partners had not previously conducted any pedagogical research and so felt uneasy about working outside their usual disciplinary boundaries. Most had never authored a book chapter; nor had they engaged in any small-scale qualitative research, and so they were not familiar with the supporting literature. In combination this meant that many of the partners needed support and reassurance about the process, as well as feedback on drafts of their chapters from the book editors.

In all, 29 projects were published across the two volumes. These represented all the faculties across the university. Some of the projects were focused on a disciplinary area such as engineering (e.g., Eslahi et al., 2020) or nutritional sciences (e.g., Kwong & Collins, 2020), while others focused on cross-disciplinary teaching issues such as feedback (e.g., Balloo & Vashakidze, 2020) or curriculum design (e.g., Khan et al., 2021). At the end of each of the published chapters, the authors were encouraged to include a 'reflective vignette' in which they could comment on the process they had undertaken. This was offered from the student and the staff perspectives.

Belonging

Partnership is both an idea and a practice. It involves a change in mindset as well as a change in practice. Partnership work can therefore be powerful. It can be thought of – and enacted – as a move against the conditions of the neoliberal university (Gravett, Kinchin & Winstone, 2020). It can serve to create something new, something meaningful. Memorably, participants involved in the SSRPP commented that, for them, partnership makes 'the university a lot more productive, a lot more fair and just a nicer place to learn and work' (Ali et al., 2021, p. 18). However, these potentially positive aspects of relational practices should not blind us to the fact that teaching in inclusive, engaging and meaningful ways remains complex and may become problematic. Moreover, the link between partnership work and fostering a sense of belonging is not straightforward.

Belonging has become a common area of inquiry in recent years as educators seek to understand how to foster student belonging to increase attainment, progression and student well-being (Meehan & Howells, 2019; Strayhorn, 2012). In post-Covid-19 times, even greater attention has been placed on conceptualising and supporting student belonging. The concept of belonging and its utility as a means for understanding academics' experiences of working in the academy also is also emerging as an important focus of attention. Transformative changes have reoriented academic work and continue to do so as we grapple with what it means to work and live in a post-digital, post-Covid-19 world.

However, research is also beginning to expose the complexity of belonging as an idea: the connections, relations and boundaries of belonging that sit uncomfortably alongside common conceptions of belonging as fixed and measurable or as a simple emotion (Gravett & Ajjawi, 2022; Guyotte et al., 2021). Belonging is not the static and linear concept many depictions might suggest. It cannot be easily fostered and, once created, cannot be described as 'achieved'. We do not belong to a singular space, or time, and the narrative of 'belonging to the university' fails to stand up to critical scrutiny when we begin to unpack the difficulties inherent in describing even where the university is located, within a hybrid and post-digital learning environment. Rather, belonging is a mobile and messy concept. Processual, dynamic and situated, it evades simple definitions that can be generalised (Gravett & Ajjawi, 2022; Guyotte et al., 2021). There is a need to handle belonging with care and to consider the concept with greater granularity than is commonly adopted: to ask how and where is belonging made? And what does belonging do, and is this desirable?

In this chapter, we adopt this nuanced definition of belonging as situated and processual (Gravett & Ajjawi, 2022) and we use these questions to consider whether partnership praxis may offer situated spaces for connections and belonging to be created. We consider the impact these sites of belonging may have upon STEM staff experiences of working in higher education, and we consider what the effect of these experiences upon colleagues' work and identities has been.

Case studies

In this chapter, we consider two case studies of academics to comment on the impact of the SSRPP on their professional belonging. We have invited these staff participants (Cathy and Alfred) to be co-authors of this chapter and have used sections of their personal reflection (presented as first-person narratives) as a basis for our objective discussion and analysis. This is in line with arguments presented by Smagorinsky et al. (2006, p. 100), who concluded that

> sharing authorship requires the sharing of much more than ownership. It also requires a shared perspective on the part of university-based teachers and researchers on how classroom-based teachers and researchers experience their work. Sharing authorship is rhizomatic rather than arborescent – it involves, as we conceive it, the reterritorialization of cultural practices as part of a new and mutual process of becoming.

This 'mutual process of becoming' is a way to perceive the academic developer role, and fits with the ideas of 'research as pedagogy' (Kinchin, Kingsbury & Buhmann, 2018) and 'researcher-led academic development' (Kinchin, Heron et al., 2018),

Case study 1: Cathy

Cathy's partnership project was designed to explore 'the experiences of student nurses to determine the quality of the feedback they receive and the extent to which this promotes sustainable feedback practices' (Panzieri & Derham, 2020, pp. 237–8). The method for this study involved three focus groups, with a total of 28 participating students, with whom the authors explored four themes as determinants of high-quality feedback (based on Johnson et al., 2016):

1. The learner has to do the learning;
2. the learner is autonomous;
3. the learner–educator relationship needs to be based on trust and mutual respect;
4. the feedback has to be supported by collaborative dialogue.

Evidence for each of these themes was supported in the published chapter by quotes from the focus groups. The authors concluded that students could identify the factors that determine high-quality feedback, but that their experiences were inconsistent and there is a need to develop student skills for dealing with feedback, encouraging them to regulate their own learning and 'reduce their current dependency on others for direction' (Panzieri & Derham, 2020, p. 250). At the end of their chapter, the authors each included a personal commentary. This was followed by a joint comment that was offered 'in partnership':

> For us both the true value of partnership working was gained via the process of engagement. Our partnership was characterised by our ways of working. This was a collaborative process where we both felt able to contribute equally, but in different ways. Our relationship … was based upon dialogue, mutual trust and respect. Although great satisfaction was gained from developing mutually constructed knowledge through the completion of our work, the greatest pleasure was in realising that our engagement truly represented partnership working. (Panzieri & Derham, 2020, p. 251)

Here the authors appear to be considering 'engagement' in the sense of 'agentic engagement' as developed by Reeve (2013) – as engagement that influences the flow of learning by both partners – and may therefore represent a rather aspirational relational pedagogy. This is reinforced by the idea of 'mutually constructed knowledge' that is rather different from the typical 'transmission of knowledge' that might be observed in a traditional STEM lecture.

Cathy offers further reflection on the process:

> Key to the concept of students as partners and creating a sense of belonging for both the student and staff member, is that this a reciprocal relationship in which both parties have essential expertise and things to contribute. Creating mutually constructed knowledge in this way required an authentic partnership where trust was fundamental (Bovill et al., 2016). Small scale research projects have the advantage of enabling the development of relationships and open dialogue, so each party feels their contribution is valued and respected, which creates a sense of valued involvement (Asher & Weeks, 2014). Without this, there is potential for tension between different frames of reference, which may result in students feeling they need to say what we want them to say or agree with our suggestions.
>
> Creating an environment which enables the mutual construction of knowledge depended upon my student partner feeling she could influence decision making. I needed to be prepared for some for the vulnerabilities and uncertainty which may have occurred, as this way of working challenges the traditional hierarchal relationships we have in a university setting. This might cause some anxiety in relation to the quality of outputs, but the process of working together was more important and afforded benefits in terms of developing the sense of belonging.

By creating opportunities and space for partnership working, relationships and experiences can be created which contribute to a sense of belonging (Cook-Sather & Felten, 2017). Within higher education institutions, it may be challenging for both staff and students to alter the way they view their roles and ways of working. The fact that attempts to promote partnerships with students often come from staff as a means of enhancing the student experience and sense of belonging could be interpreted as something which is 'done to students' rather than 'done with students'. In health care there is an expectation that patients will be involved in their own care (NHS England, 2017), and yet there are challenges in transferring that approach to the education setting. We need to move from a top-down approach and encourage an approach which enables students to identify projects they want to work on, and afford them a greater sense of ownership and autonomy, with scaffolding in place to support as required.

The key concept of care (central to Cathy's home discipline of nursing) has subsumed her concept of teaching, so that 'care' and 'teaching' have become indistinguishable (Derham, 2018). Therefore, Cathy appears to have strengthened her sense of belonging to nursing while also being able to demonstrate integration with the teaching community. This has been helped by the availability of a supporting language within the educational discourse (e.g., Noddings, 2012) that complements the disciplinary language and aligns with the professional values of the nursing profession.

Case study 2: Alfred

Alfred's partnership project 'sought to consolidate an appropriate understanding of how teaching methods and student experiences in the Biosciences influence student perceptions' (Matyjasiak & Thumser, 2021, p. 24). The method for this study was an online survey of undergraduate bioscience students. Analysis of responses from 132 students revealed two broad response clusters. The primary cluster was linked by the authors to traditional didactic lectures in which 'clarity of lecture content' was rated most highly by the respondents. A secondary cluster of responses was identified which was linked to ideas such as the laboratory, IT and library facilities, the campus environment, mental health and career support. The authors concluded that 'Excellence is a process of growth and development, not an endpoint' (Matyjasiak & Thumser, 2021, p. 29). The authors then reflected:

> During this work our own perspectives were challenged: what is important was questioned – is it teaching excellence, excellent teaching, student learning or a nuanced interaction and overlap of all three perspectives? On a personal level, there are several positive outcomes from this student–staff partnership, including our personal development, a greater appreciation of student and staff perspectives and a substantially enhanced knowledge base and understanding of educational reforms and processes required to develop a curriculum that makes students more workplace ready and reflective learners.

The increased sophistication in the authors' acknowledgment of the complexity inherent in the concept of teaching excellence, and the recognition of the potential value of overlapping different perspectives, offer a parallel to the education research literature, where teaching excellence is continually discussed and redefined (e.g., Gravett & Kinchin, 2020; Skelton, 2009). Student–staff projects had been an interest of Alfred's for some time before he undertook this project, as part of the migration from a typical bioscientist, as discussed below. At the end of the chapter, Matyjasiak and Thumser (2021) reflect on their learning. Alfred offers further reflection with the benefit of hindsight and time travelled:

> I was extremely naïve at the start of the partnership and most of my learning probably took place through the process of writing when I engaged more extensively with the broader literature, and I would now start with a literature review. Power dynamics are an important and continuous consideration during a student–staff partnership, and it takes years, rather than months, to develop an adequate ethos and environment. Further considerations are to consider the reasons for the project from the outset, and explicitly use this rationale to continuously inform the project and keep it on track, while agreeing clear objectives and expectations with the student partner.
>
> In hindsight, I probably had more of a top-down approach than was ideal. Student time and input can be random, depending on their timetable and assessments. Thus, I would probably recruit several students and set overlapping objectives, i.e. include some redundancy in allocated tasks. Further, a range of perspectives would be facilitated that would strengthen the project as a whole. As regards colleagues, I would try to develop a community-of-practice to cross-fertilise in terms of ideas and facilitate dissemination.

By daring to remove the disciplinary blinkers imposed by the positivist epistemology of science, Alfred has been able to appreciate alternative ways of knowing, and recognises the potential of a diverse 'ecology of knowledges' (*sensu* Santos, 2014) that extends beyond the scientific approach of his home discipline. This has been seen by some commentators to generate an 'epistemological shudder' (Charteris, 2014) that may present an impenetrable barrier to understanding. However, working with Alfred over a number of years on various teaching and learning initiatives (e.g., Aguiar et al., 2019) has helped to create a sense of mutual trust to the extent that Alfred is willing to 'suspend his disbelief' when presented with an idea that contradicts his disciplinary heritage.

The difficulty that Alfred has discovered is that of working across disciplines, in this case biochemistry and education. His home discipline of biochemistry can be considered to be based on representational assumptions that include, for example, the view that data is 'given', 'waiting to be found', 'inert in and unaffected by the knowing process' (Code, 2006, p. 41), relying somewhat on foundational, representational and 'spectator epistemologies' that actively exclude the observer from the data (Code, 2006, p. 26), he is willing to work alongside colleagues who are engaged in educational research that employs narrative, qualitative and post-qualitative approaches that are increasingly guided by feminist and eco-social imaginaries of knowledge making (e.g., Barad, 2007; St. Pierre, 2015). It would be easy for Alfred to dismiss these approaches as 'non-scientific' and so avoid the complication of considering diverse ways of knowing.

To suggest that Alfred has found himself caught in a state of liminality between the comforting orthodoxy of science and the discomfort created by entertaining alien ideas would be to fall into the trap of considering professional development as a linear transition from one point to another in which one world view has to be rejected to accept another. We argue that this is not the case and that an acceptance of plurality is something that is commonplace in the sciences. For example, in physics light is considered a wave and a particle, and an electron is considered a quantum and a classical particle, depending on the context. A biochemical analogy has been offered to illustrate this by Kinchin and Correia (2021), comparing the different perspectives of protein structure (1°, 2°, 3° and 4°) with different perspectives of knowledge, and the accompanying epistemological flexibility needed to accommodate this. In this analogy, knowledge can be seen as linear and unidirectional (1°), linear and bidirectional (2°), rhizomatic and epistemologically singular (3°) or rhizomatic and epistemologically plural (4°), depending on context. While biochemists accept the multiple representations of a protein, the multiple representations of knowledges seem more problematic.

It has been shown by Skopec et al. (2021) that academics working in STEM subjects have difficulty recognising knowledge that is constructed outside of their own epistemic community. They describe this reaction against introducing ideas and narratives that might challenge the dominant view as 'epistemic fragility'. While the networks of knowledge-based experts that inhabit an epistemic community might engage in intense debates, this is different from the tensions created by the acknowledgement of other epistemic communities, whose beliefs might be seen to undermine the shared beliefs of the STEM community.

However, adoption of epistemological plurality is seen by Alfred to be a necessary step in his professional development (Kinchin & Thumser, 2021) as he moves towards a greater appreciation of knowledges that exist outside the boundaries of his home discipline of biochemistry. Indeed, this situation resonates with Barnett's view that 'If we are not in the presence of *some* destabilisation, then we are not in the presence of a genuine higher education' (Barnett, 2022, p. 2), which means taking on a nomadic being – always on the move.

Conclusions

In this chapter we have explored two situated experiences of partnership and the potential for belonging created within those spaces. This potential is opened up by engaging in an extended dialogue between student and staff that goes beyond the scope of the typical tutorial exchange and may include input from academic development staff, who may challenge disciplinary perspectives and encourage a consideration of alternative frameworks and different research sources. It would be too simplistic to state that engagement in staff–student research partnerships will inevitably lead to the development of academics' sense of belonging, or that a sense of belonging can be permanently developed and achieved. The relationship between these notions is complex and non-linear, precluding measurement of the straightforward cause-and-effect relationship so beloved by senior managers. However, it is possible to suggest that partnership work, and the relational connections that can develop within a partnership, hold the potential to offer spaces where belonging can be made and explored.

The role of staff partner within this partnership project is complex and can require the member of staff to operate beyond the usual boundaries of their disciplinary knowledge as they grapple with the unfamiliar approaches to research and to the supporting literature. It requires a particular approach, akin to the 'ecopedagogy' described by Misiaszek (2021), an approach that recognises the value of othered epistemologies (Kinchin & Thumser, 2021). The balancing act of concurrently engaging with the traditions of disciplinary practices and theories, while navigating new situations and shaping oneself, is highly complex during any career transition (Fitzmaurice, 2013), akin to being simultaneously nomadic and grounded: Cathy and Alfred are grounded within their own disciplinary expertise, but simultaneously embrace the status of novitiate within educational research. A willingness to occupy this space and to accept the challenges it may offer may be a prerequisite to a successful partnership programme.

Cathy had already been thinking about teaching using various theoretical lenses before engaging in the student partnership programme, as evidenced in her chapter on pedagogical frailty (Derham, 2018). The focus on partnership and mutually constructed knowledge that she mentions above then helped her to engage in further collaborative work with teachers in other faculties in the university (Kinchin, Derham et al., 2021) to help cement her role as an ecological leader (*sensu* Allen et al., 1999) within the university teaching community. Similarly, Alfred emphasises the importance of a community practice in developing a disciplinary pedagogy and had previously engaged in a collaborative project with peers to develop a common understanding of professional development within the teaching team (Aguiar et al., 2019). This supported deeper theoretical reflection on his own development after the partnership work had been completed (Kinchin & Thumser, 2021). Thus, the partnership work is only one component in a wider approach to professional development undertaken by both Cathy and Alfred.

We need to be mindful of the complexity surrounding the idea of belonging: belonging to what? When considering teachers of STEM disciplines, we would argue that it is insufficient to belong to the disciplinary community without also acknowledging overlaps with the disciplinary teaching community. This wider perspective on belonging requires teachers to acknowledge the ecology of knowledges that exist within the university and may facilitate a more sophisticated appreciation of disciplinary knowledge that can enrich STEM teaching (Kinchin & Correia, 2021). The concept of an ecology of knowledges challenges the current monocultural focus on scientific knowledge by instead locating scientific knowledge within a broader assemblage of knowledge systems. Hall and Tandon (2017, p. 7) summarise the situation by explaining that

> what is generally understood as knowledge in the universities of our world represents a very small proportion of the global treasury of knowledge. University knowledge systems in nearly every part of the world are derivations of the Western canon, the knowledge system created some 500 to 550 years ago in Europe by white male scientists. The contemporary university is often characterized

as working with colonized knowledge, hence the increasing calls for the decolonization of our universities. The epistemologies of most peoples of the world, whether Indigenous, or excluded on the basis of race, gender or sexuality are missing. But evidence of other epistemologies and other ways of representing knowledge exist. Without a much deeper analysis of whose knowledge, how that knowledge was gathered and how transformative change is encouraged through deeper attention to knowledge democracy, public engagement in knowledge sharing simply reinforces the existing colonized relations of knowledge power.

Belonging to the STEM teaching community requires an additional level of epistemological flexibility that transcends the STEM community and entails a recognition of the dynamic nature of knowledges within a nomadic philosophy of becoming. In essence, 'the reductionist visions promoted by instrumental reason may not account for the parallel epistemologies employed by teachers and students, so they do not appear to react in rational and predictable ways to the evidence provided – evidence they see as divorced from everyday experience' (Kinchin, 2022, p. 686).

Within the case studies highlighted here, we can see that the small-scale research projects reported by the participants will not be universally generalisable and would fail to show any statistical significance for practice within the wider teaching community. But that does not reduce their potential for local impact within the particular context studied, or their potential to provoke questions, and to stimulate ideas and discussions for others. Nor can we quantify the satisfaction or pleasure reported by the partners in the projects. But that makes it no less real, and no less influential in supporting a sense of belonging among the students and staff involved.

References

Aguiar, J. G., Thumser, A. E., Bailey, S. G., Trinder, S. L., Bailey, I., Evans, D. L. & Kinchin, I. M. (2019). Scaffolding a collaborative process through concept mapping: A case study on faculty development. *PSU Research Review*, 3(2), 85–100. http://dx.doi.org/10.1108/PRR-10-2018-0030.

Ali, X., Tatam, J., Gravett, K. & Kinchin, I. M. (2021). Partnership values: An evaluation of student-staff research projects at a UK higher education institution. *International Journal for Students as Partners*, 5(1), 5–25. https://doi.org/10.15173/ijsap.v5i1.4354.

Allen, K. E., Stelzner, S. P. & Wielkiewicz, R. M. (1999). The ecology of leadership: Adapting to the challenges of a changing world. *Journal of Leadership Studies*, 5(2), 62–82. https://doi.org/10.1177/107179199900500207.

Asher, S. R. & Weeks, M. S. (2014). Loneliness and belongingness in the college years. In R. J. Coplan & J. C. Bowker (eds), *The Handbook of Solitude: Psychological perspectives on social isolation, social withdrawal, and being alone*, pp. 283–301. Chichester: Wiley Blackwell.

Balloo, K. & Vashakidze, A. (2020). Facilitating students' proactive recipience of feedback with feedback portfolios. In K. Gravett, N. Yakovchuk & I. M. Kinchin (eds), *Enhancing Student-Centred Teaching in Higher Education: The landscape of student–staff research partnerships*, pp. 255–72. Cham: Palgrave Macmillan.

Barad, K. (2007). *Meeting the Universe Halfway: Quantum physics and the entanglement of matter and meaning.* Durham, NC: Duke University Press.

Barnett, R. (2022). The homeless student – and recovering a sense of belonging. *Journal of University Teaching & Learning Practice*, 19(4), art. no. 2. https://ro.uow.edu.au/jutlp/vol19/iss4/02.

Bovill, C., Cook-Sather, A., Felten, P., Millard, L. & Moore-Cherry, N. (2016). Addressing potential challenges in co-creating learning and teaching: Overcoming resistance, navigating institutional norms and ensuring inclusivity in student–staff partnerships. *Higher Education*, 71(2), 195–208. https://doi.org/10.1007/s10734-015-9896-4.

Charteris, J. (2014). Epistemological shudders as productive aporia: A heuristic for transformative teacher learning. *International Journal of Qualitative Methods*, 13(1), 104–21. https://doi.org/10.1177/160940691401300102.

Code, L. (2006). *Ecological Thinking: The politics of epistemic location*. Oxford: Oxford University Press.

Cook-Sather, A. & Felten, P. (2017). Where student engagement meets faculty development: How student-faculty pedagogical partnership fosters a sense of belonging. *Student Engagement in Higher Education Journal*, 1(2), 3–11. https://sehej.raise-network.com/raise/article/view/cook. Accessed 3 January 2024.

Correia, P. R. M. (2023). Building a bridge from chemistry to educational leadership: Overcoming the valley between the two cultures. In A. Hosein, N. Rao & I. M. Kinchin (eds), *Narratives of Becoming Leaders in Disciplinary and Institutional Contexts*: *Leadership identity in learning and teaching in higher education*, pp. 139–52. London: Bloomsbury Academic.

Derham, C. (2018). Nursing. In I. M. Kinchin & N. E. Winstone (eds), *Exploring Pedagogic Frailty and Resilience: Case studies of academic narrative*, pp. 61–75. Leiden: Brill Sense.

Eslahi, A., Chadeesingh, D. R., Foreman, C. & Alpay, E. (2020). 3D printers in engineering education. In K. Gravett, N. Yakovchuk & I. M. Kinchin (eds), *Enhancing Student-Centred Teaching in Higher Education: The landscape of student–staff research partnerships*, pp. 97–112. Cham: Palgrave Macmillan.

Fitzmaurice, M. (2013). Constructing professional identity as a new academic: A moral endeavour. *Studies in Higher Education*, 38(4), 613–22. https://doi.org/10.1080/03075079.2011.594501.

Gravett, K. & Ajjawi, R. (2022). Belonging as situated practice. *Studies in Higher Education*, 47(7), 1386–96. https://doi.org/10.1080/03075079.2021.1894118.

Gravett, K. & Kinchin, I. M. (2020). Revisiting 'A "teaching excellence" for the times we live in': Posthuman possibilities. *Teaching in Higher Education*, 25(8), 1028–34. https://doi.org/10.1080/13562517.2020.1807497.

Gravett, K., Kinchin, I. M. & Winstone, N. E. (2020). Frailty in transition? Troubling the norms, boundaries and limitations of transition theory and practice. *Higher Education Research and Development*, 39(6), 1169–85. https://doi.org/10.1080/07294360.2020.1721442

Gravett, K., Yakovchuk, N. & Kinchin, I. M. (eds) (2020). *Enhancing Student-Centred Teaching in Higher Education: The landscape of student–staff research partnerships*. Cham: Palgrave Macmillan.

Guyotte, K. W., Flint, M. A. & Latopolski, K. S. (2021). Cartographies of belonging: Mapping nomadic narratives of first-year students. *Critical Studies in Education*, 62(5), 543–58. https://doi.org/10.1080/17508487.2019.1657160.

Hall, B. L. & Tandon, R. (2017) Decolonization of knowledge, epistemicide, participatory research and higher education. *Research for All*, 1(1), 6–19. https://doi.org/10.18546/RFA.01.1.02.

Heron, M., Barnett, L. & Balloo, K. (eds) (2021). *Exploring Disciplinary Teaching Excellence in Higher Education: Student–staff partnerships for research*. Cham: Palgrave Macmillan.

Johnson, C. E., Keating, J. L., Boud, D. J., Dalton, M., Kiegaldie, D., Hay, M., McGrath, B., McKenzie, W. A, Nair, K. B. R.,, Nestel, D., Palermo, C. & Molloy, E. K. (2016). Identifying educator behaviours for high quality verbal feedback in health professions education: Literature review and expert refinement. *BMC Medical Education*, 16(1), 1–11. https://doi.org/10.1186/s12909-016-0613-5.

Khan, J., Yuqing, T., Yue, Y. & Yuheng, Z. (2021). Co-creating teaching excellence in curriculum design through leadership and entrepreneurship. In M. Heron, L. Barnett & K. Balloo (eds), *Exploring Disciplinary Teaching Excellence in Higher Education: Student–staff partnerships for research*, pp. 163–82. Cham: Palgrave Macmillan.

Kinchin, I. M. (2022). Exploring dynamic processes within the ecological university: A focus on the adaptive cycle. *Oxford Review of Education*, 48(5), 675–92. https://doi.org/10.1080/03054985.2021.2007866.

Kinchin, I. M. & Correia, P. R. M. (2021). Visualizing the complexity of knowledges to support the professional development of university teaching. *Knowledge*, 1(1), 52–60. https://doi.org/10.3390/knowledge1010006.

Kinchin, I. M., Derham, C., Foreman, C., McNamara, A. & Querstret, D. (2021). Exploring the salutogenic university: Searching for the triple point for the *becoming-caring-teacher* through collaborative cartography. *Pedagogika*, 141(1), 94–112. https://doi.org/10.15823/p.2021.141.5.

Kinchin, I. M., Heron, M., Hosein, A., Lygo-Baker, S., Medland, E., Morley, D. & Winstone, N. E. (2018). Researcher-led academic development. *International Journal for Academic Development*, 23(4), 339–54. https://doi.org/10.1080/1360144X.2018.1520111.

Kinchin, I. M., Kingsbury, M. and Buhmann, S. Y. (2018). Research as pedagogy in academic development: A case study. In E. Medland, R. Watermeyer, A. Hosein, I. M. Kinchin & S. Lygo-Baker (eds), *Pedagogical Peculiarities: Conversations at the edge of university teaching and learning*, pp. 49–67. Rotterdam: Brill Sense.

Kinchin, I. M. & Thumser, A. E. (2021). Mapping the 'becoming-integrated-academic': An autoethnographic case study of professional becoming in the biosciences. *Journal of Biological Education*, 57(4), 715–26, https://doi.org/10.1080/00219266.2021.1941191.

Kwong, K. & Collins, A. (2020). Student perspectives on a nutrition curriculum. In K. Gravett, N. Yakovchuk, & I. M. Kinchin (eds), *Enhancing Student-Centred Teaching in Higher Education: The landscape of student–staff research partnerships*, pp. 201–16. Cham: Palgrave Macmillan.

Matyjasiak, J. & Thumser, A. (2021). What teaching excellence means to undergraduate students on a STEM programme. In M. Heron, L. Barnett & K. Balloo (eds), *Exploring Disciplinary Teaching Excellence in Higher Education: Student–staff partnerships for research*, pp. 21–37. Cham: Palgrave Macmillan.

Meehan, C. & Howells, K. (2019). In search of the feeling of 'belonging' in higher education: Undergraduate students transition into higher education. *Journal of Further and Higher Education*, 43(10), 1376–90.

Misiaszek, G. W. (2021). *Ecopedagogy: Critical environmental teaching for planetary justice and global sustainable development.* London: Bloomsbury Academic.

NHS England (2017). Involving people in their own health and care: Statutory guidance for clinical commissioning groups and NHS England. https://www.england.nhs.uk/publication/involving-people-in-their-own-health-and-care-statutory-guidance-for-clinical-commissioning-groups-and-nhs-england/. Accessed 3 January 2024.

Noddings, N. (2012). The caring relation in teaching. *Oxford Review of Education*, 38(6), 771–81. https://doi.org/10.1080/03054985.2012.745047.

Panzieri, J. & Derham, C. (2020). Student nurses' experiences of receiving verbal feedback within the clinical learning environment: To what extent does this promote sustainable feedback practices? In K. Gravett, N. Yakovchuk & I. M. Kinchin (eds), *Enhancing Student-Centred Teaching In Higher Education: The landscape of student–staff research partnerships*, pp. 237–53. Cham: Palgrave Macmillan.

Reeve, J. (2013). How students create motivationally supportive learning environments for themselves: The concept of agentic engagement. *Journal of Educational Psychology*, 105(3), 579–95. https://doi.org/10.1037/A0032690.

Santos, B. de S. (2014). *Epistemologies of the South: Justice against epistemicide*. London: Routledge.

Skelton, A. M. (2009). A 'teaching excellence' for the times we live in? *Teaching in Higher Education,* 14(1), 107–12. https://doi.org/10.1080/13562510802602723.

Skopec, M., Fyfe, M., Issa, H., Ippolito, K., Anderson, M. & Harris, M. (2021). Decolonization in a higher education STEMM institution: Is 'epistemic fragility' a barrier? *London Review of Education*, 19(1), 1–21. https://doi.org/10.14324/LRE.19.1.18.

Smagorinsky, P., Augustine, S. M. & Gallas, K. (2006). Rethinking rhizomes in writing about research. *The Teacher Educator*, 42(2), 87–105. http://dx.doi.org/10.1080/08878730609555396.

St. Pierre, E. A. (2015). Practices for the 'new' in the new empiricisms, the new materialisms, post qualitative inquiry. In N. K. Denzin & M. D. Giardina (eds), *Qualitative Inquiry and the Politics of Research*, pp. 75–95. Walnut Creek, CA: Left Coast Press.

Strayhorn, T. L. (2012). *College Students' Sense of Belonging: A key to educational success for all students.* New York: Routledge.

Winberg, C., Adendorff, H., Bozalek, V., Conana, H., Pallitt, N., Wolff, K., Olsson, T. & Roxå, T. (2019). Learning to teach STEM disciplines in higher education: A critical review of the literature. *Teaching in Higher Education*, 24(8), 930–47. http://dx.doi.org/10.1080/13562517.2018.1517735.

Index

In *Belonging and Identity in STEM Higher Education*, leading scholars, teachers, practitioners and students explore belonging and identity in Science, Technology, Engineering and Mathematics (STEM) fields, and how this is impacted by disciplinary changes and the post-pandemic higher education context. In STEM fields, positivist approaches and a focus on numerical data can lead to assumptions that they are unemotional, impersonal disciplines. The need for mathematical competency, logical thinking and disciplinary contexts can be barriers to engagement, belonging and success in STEM.

STEM ways of thinking, such as those underpinning abstract and complex mathematics, can form the basis for new ways of conceptualising belonging for both staff and students, going beyond socio-demographic and cultural differences. In this book, chapters and case study contributions analyse what is unique about STEM educational environments for staff and students in the UK, Ireland, Europe, Scandinavia and Asia. The authors examine the role of STEM pedagogies in facilitating belonging, variable impacts across student characteristics and the experiences STEM students face in their higher education experiences. It provides a valuable resource for those working in equality, diversity and inclusion (EDI), STEM educational researchers and practitioners, as well as offering insights for academics and teachers in STEM higher education.

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