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Students' perspectives on the 'STEM belonging' concept at A-level, undergraduate, and postgraduate levels: an examination of gender and ethnicity in student descriptions

Gulsah Dost[1*]

Abstract

Background Women and ethnic minorities have historically been underrepresented in some STEM fields. It is therefore important to understand the factors influencing students' persistence in STEM fields, and what STEM belonging means from the voices of socio-demographically diverse students, in order to ensure equity among students in STEM fields and to increase their belonging to this field, which has not been clearly defined in the literature, and there is a lack of agreement about the definition of belonging itself. For this purpose, the perspectives of students in England are brought together in this study in an attempt to better understand the concept of STEM belonging within a broader context of integration.

Result The inductive thematic analysis with the voices of socio-demographically diverse 313 A-level, undergraduate and postgraduate Mathematics, Physics, and Chemistry students showed that compared to male students, it was mostly female, non-binary, non-White, and first-generation students who defined STEM belonging as 'Feeling safe and comfortable in the STEM community and settings'. This theme was defined by the participants as the group/community/learning environment in which the individual belongs, the interaction with the people in the field, and the comfort that this participation/interaction creates. Students stressed the importance of creating a supportive and welcoming STEM environment so that individuals can feel at home, as well as a safe and comfortable STEM environment for people of all identities, genders, ethnicities, and backgrounds. Based on the participants' responses, this study also conceptualised the concept of STEM belonging as having four phases: the 'adaptation phase', the 'integration phase', the 'continuum phase', and the 'transition phase'. These four phases which comprise the STEM belonging concept are consecutive and interconnected.

Conclusion The study concluded that all human beings are connected in a relational way (either strong or weak) and that the concept of STEM belonging develops as a result of interactions with 'self' and 'others' who have a shared passion and an interest in STEM fields. Although individuals have intrinsic motivation and individual prompts in STEM fields (i.e. resilience, beliefs in their capacity/ability and curiosity, etc.), social determinants (i.e. receiving adequate support from members of the STEM community, social capital and social cohesion, etc.) also play a significant role in influencing individual's sense of STEM belonging.

Keywords Belonging, STEM, STEM belonging, Gender, Ethnicity, K-12 education, Higher education, Thematic analysis, Covid-19 pandemic

*Correspondence:
Gulsah Dost
gulsah.dost@durham.ac.uk
Full list of author information is available at the end of the article

Introduction

Women continue to be underrepresented in certain STEM fields, where they also experience lower levels of equity and inclusion despite progress made toward increasing women's interest and involvement. Between 2010 and 2019, only 31% of students enrolled for STEM A-level qualifications were female (WISE Campaign, 2020). In England, the highest qualification that students take in school is A-level, usually taken at the age of 18 (Dilnot, 2018). The number of female pupils at A-level who rated a STEM-related subject for enjoyment was 32%, compared to 59% of male pupils (DfE, 2019). In addition, female students (33%) were less likely than male students (60%) to consider themselves to be the best at a STEM subject (DfE, 2019). In the university context, women remain underrepresented in certain areas; for example, in engineering and technology, only 20.5% of engineers were female in 2021/22, while science-related subjects (especially subjects related to medicine) have around the same proportion of male students (20.5%) (WISE Campaign, 2021, 2022). Furthermore, women represent 16% of graduates in engineering and 10% of United Kingdom (UK) engineering professionals (WISE Campaign, 2020, 2021). These statistics provide the current and recent gender gap issue in STEM fields. Even though gender disparities in participation in STEM disciplines have decreased in recent years, they are nevertheless still significant.

There is significant evidence in the literature for the broad range of factors that can influence the participation of women/female students in STEM education and careers in the UK, including personal, psychological, contextual, environmental, and behavioural factors (Dost, 2021b; Du & Wong, 2019; Mujtaba & Reiss, 2013; Tandrayen-Ragoobur & Gokulsing, 2021; Watermeyer, 2012). Examples of challenges include cultural and stereotypes (Powell et al., 2012; Wood et al., 2022); insufficient social support networks (Vekkaila et al., 2018; Wilcox et al., 2005; Wong, 2015); cold, unwelcoming, and hostile academic/work environments (Archer et al., 2015a, 2015b; Simon et al., 2017); being overlooked for their contributions to group projects; lack of formal mentoring for women in STEM careers; a lack of opportunities for networking and collaborating on research projects; a lack of guidance on how to achieve career goals; and feelings of isolation in the workplace (Jebsen et al., 2020; Ro et al., 2021; White & Smith, 2022). A lack of social capital can also negatively impact relationships with co-workers and direct supervisors, leading to a higher rate of social isolation among women and a reduced ability to integrate into STEM-related fields (Archer et al., 2015a, 2015b; Moote et al., 2020). This may lead students to feel belonging uncertainty. Belonging uncertainty is defined as the quality of social relationships within an academic setting (Höhne & Zander, 2019; Mallett et al., 2011) and can manifest as the belief that "people like me do not belong here" (Walton & Cohen, 2007, p. 83). Academic achievement and persistence are both associated with belonging uncertainty. A student experiencing belonging uncertainty is more likely to give up their course or field of study when they face difficulties during their studies (Walton et al., 2015). Evidence indicates that the range of factors discussed above may lead to belonging uncertainty (Deiglmayr et al., 2019) and contribute to women's reluctance to choose to study or work in STEM fields. There is a high probability that female students in STEM fields may suffer from belonging uncertainty in the university context, as they constitute a numerical minority in these stereotypically masculine fields (OECD, 2017).

Sense of belonging relates to the human need to belong to a group/community. It has been shown to positively influence motivation, academic achievement, and well-being among students (Tavares etal., 2021; Van Herpen et al., 2020; Winstone et al., 2022; Pedler et al., 2022). A low sense of belonging in one's STEM field has been shown to adversely impact one's persistence (London et al., 2012; Good et al., 2012) and studies have shown that women and students of colour are most likely to persist in STEM when they feel a sense of belonging (Rainey et al., 2018). There is evidence that persistence is positively correlated with peer group connections, self-efficacy, and academic achievement and that students who interact with peers inside and outside the classroom feel more connected (Reay et al., 2010; Wilcox & Fyvie-Gauld, 2005). Studies have suggested that students who quit university often do so as a consequence of a diminished sense of belonging and a lack of social integration (Suhlmann et al., 2018; Wilcox & Fyvie-Gauld, 2005). The transition from A-level to university and from undergraduate to postgraduate studies can be particularly critical for developing engagement (Evans et al., 2018; Jackson et al., 2007; Tobbell et al., 2010), and it is also a time when an individual may question one's belonging, capabilities, and potential.

Given this link between sense of belonging and persistence in STEM, it is important to understand the term 'STEM belonging' in depth. Despite numerous studies demonstrating that sense of belonging has a direct and positive influence on social integration, academic achievement, mental health, etc., several scholars have noted that the concept itself remains vaguely conceptualised (Antonsich, 2010; Johansson & Puroila, 2021; Mattes & Lang, 2021). Additionally, while no consensus exists in the literature on the definition of sense of belonging, when an analysis of STEM belonging is conducted, it is apparent that the conceptualisation made are quite narrow. Therefore, the purpose of this study is to gain an understanding of the 'STEM belonging' concept. This article provides valuable insights into the indispensable components of 'STEM belonging' based on the definitions and conceptualisations of these terms by a wide range of A-level ('Levelling Up: Aspire Higher'[1] programme students), undergraduates and postgraduate students in consideration of their socio-demographic backgrounds, and to unpick the more complex relationships between these characteristics from three Russell Group universities.[2]

Literature review

An overview of the English education system and STEM participation

Schooling in England is split into three stages: primary (Key Stage 1 and 2), lower secondary (Key Stage 3) and upper-secondary (Key Stage 4). Key Stages 3 (grades 7–9, ages 11–14) and 4 (grades 10–11, ages 14–16) are required to offer all STEM subjects as part of the National Curriculum for England (DfE, 2014). During Key Stage 3, students study a general curriculum and are required to comply with STEM subjects. These subjects include mathematics, science, computing, and design and technology. In Key Stage 4, where the subjects are mathematics and science (taught separately as biology, chemistry, and physics), computing is a compulsory foundation subject, while design and technology is an elective course (DfE, 2014). In Key Stage 4, nearly all students take a national examination called the General Certificate of Secondary Education (GCSE). Typically, students continue to study Key Stage 5 (grades 12–13, ages 16–18) subjects for an additional two years called GCE Advanced Level (also called A levels). The A-level is an examination set used by admissions departments in British universities in England, Wales, and Northern Ireland that constitutes 'the main currency' (UCAS, 2012, 1). The examination is similar to those in other countries that are taken at the end of secondary education. As a result of the A-level system, students who wish to pursue STEM-related careers are generally required to take at least one science or math subject at the A-level as a prerequisite for STEM-related careers (Tomei et al., 2014). There are two parts to Advanced Level study: Advanced Subsidiary Level (AS level) and A2 level. The AS Level is an independently recognised qualification, and the AS Level along with the A2 Level form the complete A-Level (Sammons et al., 2018). When students are above 16 years old, they typically choose four AS-level subjects in Year 12, and then three A2-level subjects in Year 13 (Dilnot, 2018). Further, some schools and Sixth Form Colleges (grades 12–13) in England offer an engineering Business and Technology Education Council (BTEC) award, which is an alternative vocational and work-related route to Higher Education courses and are considered 'equivalents' to GCSEs (General Certificate of Secondary Education) (Gill, 2012; Skilling, 2020). Among English-domiciled university applicants, A-levels are the most commonly obtained qualification. In 2015, 73% of English 18-year-olds applying to UK universities held only A-levels and 9% had both A-levels and BTECs. A further 15% held only BTECs (UCAS, 2016).

The majority of higher education courses in England require advanced-level qualifications as entry requirements (Sammons et al., 2018). In Year 13, most students apply to university with grades predicted by their schools in each of their A-level subjects. Universities offer places based on both the subjects followed and the grade required. Due to the importance of subject content to university courses, many university courses require applicants to have particular A-levels (Dilnot, 2018). A-Levels are the most common path to university, but they differ in terms of which subjects were studied. A number of educational subjects are referred to as 'facilitating subjects', including maths and further maths, English literature, sciences, geography, history, and languages (classical and modern). These subjects are considered favourably by Russell Group universities, regardless of the course for which students are applying. These subjects are also required more often than others when it comes to entering degree courses (Russell Group, 2015).

Some STEM subjects are less likely to be taken by female students. For example, among all STEM A-Level exam entries in 2019, female students accounted for 44%; they represented just 13% of examination entries in computing, 22% in physics, and 39% in mathematics. In terms of STEM subjects at A Level, 22% of girls take two or more STEM subjects, whereas only 10% take three or more STEM subjects (DfE, 2020). As a percentage of the total, 21.3% of girls in A-level pursued computing in 2022, down from 21.4% in 2019. Design and technology fell modestly from 29.8% to 29.5% in 2022, compared to 2019. During the period between 2019 and 2022, the proportion of girls pursuing engineering increased from 10.3% to 16.8% (this may be due to more female students taking the exam in 2022) (WISE Campaign, 2022). The girls are choosing alternative subjects to STEM even

[1] 'Levelling Up: Aspire Higher' is an academic and pastoral support programme, running from March of Year 12 and continuing through to March/April of Year 13. It is targeted at Year 12 students who are aiming to pursue the study of Chemistry, Maths, or Physics at these three Russell Group universities.

[2] The Russell Group comprises 24 leading UK universities that were formed to protect the interests of the universities and ensure that they maintain ambitious standards in teaching and research (Russell Group, 2023).

though they outperform boys in almost all GCSE STEM subjects. After GCSEs, only 35% of females choose to study STEM subjects, with this decreasing to 25% of females choosing to study them at university (WISE Campaign, 2022). STEM subjects are often first chosen at A Levels, which can either open or close the door to higher education or employment in STEM fields. At this point, gender disparities in STEM subjects begin to emerge (DfE, 2020).

According to the UK Higher Education Statistics Agency (HESA), the number of women accepted into full-time STEM undergraduate courses increased by 50.1% between 2011 and 2020. From 33.6% to 41.4% of female students enrolled in full-time undergraduate STEM courses during the same period (HESA, 2020). Female graduates in mathematical sciences decreased by 1% in 2018/2019 compared to 2015/2016. However, between 2016 and 2017, the number of female computer science graduates decreased, but by 2018/19 it had increased to 16% (HESA, 2020). Students studying physical sciences were 39% female between 2017 and 2018, but only 19% were female students studying computer science-related degrees, with an astounding 81% being male. Similarly, the number of female engineering and technology students was 19%, between 2017 and 2018 (HESA, 2018).

In the postgraduate context, there was a higher proportion of females receiving STEM postgraduate qualifications in four out of five subject areas in the 2018/2019 academic year than there were female students receiving STEM undergraduate qualifications. At 35% overall, female postgraduate STEM qualifications are significantly more prevalent than female undergraduate STEM qualifications, which are 26% (WISE Campaign, 2019). There has been a steady growth in the number of female graduates with STEM degrees, but there are still only 26% of female STEM undergraduates. This figure is also shown in the number of female STEM professionals, which is around 24%. Women with minoritised backgrounds make up 13% of STEM professionals, and 10% are white women, while 65% of STEM professionals are white men. Science and maths are more gender-balanced than most other fields (Brett, 2022). There has been no meaningful change in women's representation in the STEM workforce since December 2021. The number of women in the STEM workforce has slightly increased from 26.6 to 26.9%. Women engineers account for 13.0% of the STEM workforce, down from 13.6% last quarter and up from 12.5% last December. From 19.9% in June 2022 to 19.5% in June 2023, and from 25.9 to 24.7%, the proportion of IT technicians and professionals who are female has dropped further (WISE Campaign, 2019). Women are particularly underrepresented in mid-level and small and medium-sized businesses, no matter what their age is. A Women in Technology Survey found that 47% of women left their roles in 2019, compared to 17% of their male peers, because of the 'leaky pipeline' phenomenon (Brett, 2022).

Stereotype threat in STEM

Stereotype threat is the most cited factor that causes female students not to uptake STEM fields and to pursue a career in this field. The stereotype threat occurs when a person is concerned about being judged or treated negatively because of a negative stereotype about his or her group (Spencer et al., 2016). In negatively stereotyped domains, stereotype threat disrupts and undermines performance by creating anxiety or concerns about being viewed through the lens of a stereotype (Kinias & Sim, 2016; Schmader et al., 2008; Shapiro & Williams, 2012). The authors of Gunderson et al. (2011) demonstrate how parents and teachers transmit negative stereotypes about women's math abilities to girls, thereby undermining their performance and interest in STEM fields as a result.

In the UK, girls outperform boys in STEM subjects with higher school grades, but this advantage is not transferred to the workforce. When it comes to STEM, traditionally male-dominated fields, girls are prone to conforming to stereotypes, and backlash hinders them from succeeding (Shapiro & Williams, 2012). It has been discovered through gender stereotype research that science is often associated with men, as well as masculine traits. Archer et al. (2010) found that young children attribute masculine traits to science even though they have no deep understanding of science subjects. Adolescents ages 14 to 15 classified occupations as women or men based on gender stereotypical attributes (Francis et al., 2017; Fuller & Unwin, 2013). A notable difference was found between young men and women who were considering taking on a gender-atypical job. However, women were concerned about how they would be treated in male-dominated fields (Fuller & Unwin, 2013). Joshi (2014) used social role theory to investigate gender and recognition of expertise in teams. She also found that women are often perceived as less competent by their teammates in male-dominated fields like STEM and have less influence on team decision-making processes according to social role theory. Despite their actual knowledge, capabilities, and expertise, this is a result of the fact that women are underrepresented in these settings and atypical (Gabay-Egozi et al., 2022; van der Vleuten et al., 2018). Accordingly, the underrepresentation of women in STEM fields, as well as their atypical roles in engineering and science, may have an impact on how their expertise is assessed (Riegle-Crumb et al., 2016). Women's attitudes and behaviours toward math identification are influenced by internalised beliefs about female identity and stereotypes (Nadal et al., 2021; O'Dea et al., 2018). There are cognitive and physiological aspects to stereotype threat, but these aspects are strengthened by socially ascribed stereotypes, such as the notion that women are less math-competent (Cadaret et al., 2017). Individuals are heavily influenced by how they perceive the actions of others, especially those who are similar to them. Consequently, we tend to emulate their behaviour. It is commonly believed that STEM disciplines are predominantly favoured by males (Kings, 2019; Le et al., 2023). According to Archer et al., (2013), girls tend to not view STEM fields as suitable for themselves. This is due to the lack of representation of individuals who resemble them in the STEM domain (Cassidy et al., 2018). As a result, female students may feel a reduced sense of belonging in STEM fields, which creates uncertainty about their suitability for these fields.

Belonging uncertainty

In psychology, belonging is described as a fundamental human motivation that is essential to individual well-being (Baumeister & Leary, 1995). A sense of belonging comes from both connections and attachments. An individual who is embedded in a stable social network is more likely to feel like they belong than an individual without a stable social network (Chiu et al., 2016). Sense of belonging is defined by Tovar and Simon (2010) as a sense of identification or positioning in the college community. Strayhorn (2012) defined sense of belonging as a student's sense of social support on campus, a feeling of connectedness, or the sense of being cared about, accepted, respected, valued by, and important to the group or others. The context in which a person feels belonging has much to do with one's sense of belonging, since any one life domain might not have sufficient resources to fully satisfy one's need (Chiu et al., 2016). It is necessary to examine the sense of belonging in specific contexts because most people are exposed to multiple contexts. Each individual's sense of belonging is unique. It depends on what makes them feel most comfortable or what is available to them at various stages of their lives. A sense of belonging may be felt by some people in a small group or just a few people who have become close friends or family. Diversity and acceptance of differences can foster unity in some groups. This type of belonging is manifested by appreciating/valuing each individual's unique contributions.

In the higher education context, more recent research by Dost and Mazzoli Smith (2023) defined sense of belonging to university as 'feeling part of somewhere an individual can be themselves and feel confident in their personal and social identities, through secure, meaningful, and harmonious support in cohesion with other diverse group members and creating ethnically heterogeneous communities and learning areas both on and off the faculty/campus setting' (p. 21). Belonging means being accepted for who you are, being included, being supported, and being respected both by your peers and by the institution as a whole. Many studies suggest that students with a powerful sense of social belonging perform better in class (Edwards et al., 2021; Marksteiner & Kruger, 2016; Sandstrom & Rawn, 2015). According to Goodenow (1993), a significant contributor to belonging is the support of teaching faculty as well as peer-to-peer relationships. Thus, students who believe they are academically incapable will find it extremely difficult to feel a sense of belonging within higher education. Academic achievement and persistence are both strongly influenced by belonging uncertainty, which is defined as the general concern about the quality of one's social relationships (Höhne & Zander, 2019). Belonging uncertainty is a perception that 'people like me don't belong here' (Walton & Cohen, 2007, p. 83). Students who feel that they don't belong or fit in, especially those who belong to groups that are underrepresented, women, and students of colour in a field, may experience a lower sense of belonging, express disinterest in their major course or eventually change majors, which is why the concept of belonging uncertainty was developed (Cheryan et al., 2009; Mooney & Becker, 2020; Sax et al., 2018). It can be detrimental to one's academic performance if one feels uncertain about one's belongingness in an academic environment. When individuals experience rejection due to their membership in a devalued group, they can become anxious about future rejection, which can negatively affect their self-esteem, relationships with peers, and academic performance (Mendoza-Denton et al., 2002; Sato et al., 2020). Students who were concerned about rejection based on their gender category also expressed greater self-doubt and expectations of unfairness than their peers (Feinstein, 2020; Gao et al., 2017; London et al., 2012). The possibility of belonging uncertainty is more likely to arise in female students than in male students, which can manifest itself even in the absence of specific performance requirements (Aelenei et al., 2020; Fink et al., 2020). Members of underrepresented social groups are likely to experience belonging uncertainty, such as women in STEM fields where negative stereotypes exist (Broda et al., 2018; OECD, 2017).

Theoretical framework

In this study, constructivist and social constructionist approaches were applied. The constructivist approach refers to individuals constructing knowledge based on their real-life experiences (Barkin, 2003; Bredies et al., 2010; Kalpana, 2014; Mills et al., 2006; Ramalho et al., 2015). Constructivism can be viewed from two perspectives: psychological constructivism (influenced by Piaget's work) and social constructivism (influenced by Vygotsky's work) (Amineh & Asl, 2015). The Psychological/Individual Constructivist approach emphasises that people learn through active exploration and that these inconsistencies between knowledge representations and experience lead to learning (Bozkurt, 2017; Sjøberg, 2010). A critical component of social constructivism is the idea that humans learn in a social context and interacting with their social groups is an integral part of learning (Kalina & Powell, 2009; Palincsar, 1998). Adapting to and learning from the experiential world allows the person to construct knowledge actively (Bada & Olusegun, 2015; Jones & Brader-Araje, 2002). The constructivist theory provides a clear explanation of how humans learn about the world around them and what new knowledge is created (Agius, 2013). During interactions with the world and with each other, human beings construct knowledge rather than discover it (Xu & Shi, 2018). In this way, external reality is likely to be perceived differently by different learners, and the construction of common meaning comes from social negotiation (Jonassen, 1991; Tenenbaum et al., 2001; Yilmaz, 2008). As a result of their real-life experiences, individuals continuously create new thoughts, ideas, and understandings (Bada & Olusegun, 2015). Therefore, there are varying forms of knowledge, and they are all unique to each individual. Learning is described as holistic and relative in social constructivism, emphasising the strengths and understanding each individual brings to the group/society/classroom, while also providing them with a way to make sense of their social and cultural environments (Burr, 2015; McRobbie & Tobin, 1997). These social and cultural environments play a crucial role for students to feel a sense of belonging in their specific field or the members of their community (Rowe et al., 2023). As a result of implementing a social constructivist approach to STEM education, students can work together more effectively and have higher levels of social interaction, which may improve the chilly climate and specifically lead women, women of colour, and underrepresented groups to feel a sense of belonging, become more involved and persist in STEM fields (Ejiwale, 2013; Falk et al., 2015; Jeong et al., 2019; Johnson, 2012).

A social constructionist points out that how we understand and perceive the world depends on how we represent the world in language, as well as on the culture and times in which we live (Burr & Dick, 2017). Social constructionism is a sociological concept of knowledge suggesting that individuals develop their understanding of the world through social order (Andrews, 2012; Turner, 1991). People comprehend the world in collaboration with others through socially imposed limitations and predetermined ideas of acceptable behaviour (Amineh & Asl, 2015). Social constructionism is rooted in a relativist epistemology, which maintains that all knowledge is relative to an individual's position within a set of social norms (Cruickshank, 2012). This relativism leads to a profound doubt towards all claims of knowledge, particularly those made by authoritative figures like professionals, because social norms are believed to be infused with power (Potter, 2003). It is, therefore, true that our understanding and knowledge are not absolute and final, but rather are expressed through discourse, reflecting the ideas of powerful groups in society, often to the detriment of less powerful groups and individuals (Burr & Dick, 2017).

According to Koro-Ljungberg et al. (2006), social constructionism is an interpretive theory that explains the socialisation, conversation, roles, and change of the participants. Following the social constructionist perspective on gender role stereotypes, these stereotypes do not remain fixed but instead emerge through interactions among individuals belonging to various social groups (Ahl, 2006). According to the social constructionist framework, assumptions and conditions underlying gender inequality and gender role stereotypes can be seen as temporary and changeable; they can be changed as circumstances change and change across time and cultures (Burr, 2015). Alterations in societal perspectives on traditional gender roles over a considerable period of time are associated with changes in gender role stereotypes (Bussey, 2011; Eagly & Wood, 2012). The notion of feminine characteristics being attributed to women and masculine characteristics being attributed to men is a product of societal construction, interpretation, and internalisation (Dost, 2021a). These societal expectations of gender roles and stereotypes create pressure for both men and women to conform to prescribed gender norms (Dost, 2021a). Consequently, the existence of masculine gender stereotypes regarding the skills and knowledge necessary for success in STEM careers acts as a barrier for female students to feel a sense of belonging in STEM fields and pursue a career in STEM (Garriott et al., 2017).

Methodology

This exploratory qualitative research was designed to unpack the concept of STEM belonging from the views of socio-demographically diverse students at A-level, undergraduate, and postgraduate levels, in order to increase their belonging to this field, which has not been clearly defined in the literature, and there is a lack of agreement about the definition of belonging itself.

Data collection

Data were collected both via a questionnaire created on the Jisc Online Survey (n: 290) and one-to-one interviews (n:23) via Microsoft Teams (to gain a more in-depth understanding). All students from the Chemistry department, Physics department, and Mathematical Science department were asked to participate in this study on their understanding of the general sense of belonging. 'Levelling Up: Aspire Higher' programme A-level students at Durham University, the University of Birmingham, and the University of Oxford were also invited to participate in this study. Gatekeepers were involved in circulating the survey links and interview invitations via email to the students at each of the universities. Students participated voluntarily and without receiving any reward. A socio-demographic background information questionnaire was also prepared and included in the email invitation for the interview and online questionnaire, and that was used to collect socio-demographic background information for the student participants. Both interviews and an online questionnaire were applied in this study, allowing students to share their experiences in the preference they feel most comfortable with.

One main open-ended question and three prompt questions were designed to promote an open-ended discussion representative of participants' views of their sense of STEM belonging. Braun et al., (2020) explain that online surveys that collect textual responses can reach a wider audience and allow research to reach, which is of great benefit with regard to inclusivity and accessibility. In this way, online survey data collection provided us with an opportunity to reach students whose voices might typically go unheard, and thus provide a more in-depth insight into the lived experiences of students. Due to the purpose of this study, a semi-structured one-to-one interview was also conducted in which the questions were asked verbatim so that we could understand students' perceptions of the general sense of belonging from the students' perspectives. In semi-structured interviews, the researcher/s sought to understand others' lived experiences and their sensemaking of those experiences (Seidman, 2013). Due to their unstructured nature, they allowed for prompting and further probing based on the responses received.

The main question was: "What does a STEM belonging mean to you?" and prompt questions were: "How can you tell if someone in a STEM setting feels that they belong in STEM?", "What does it feel like when you belong in STEM?", and "What would others see if you felt like you belonged in STEM?". To maximise the strengths of in-depth interviewing, researchers approach the interview to prompt respondents to discuss topics relevant to the main research question(s) (Jiménez et al., 2021). Therefore, prompting questions were added to enable students to give a more detailed response to the primary research question. The question aimed to explore participants' understanding and views of their sense of STEM belonging and to conceptualise the term to prevent belonging uncertainty in this field. Students were informed about the voluntary nature of their participation, assured of the anonymity of their responses, and instructed that all data would be kept confidential and be used for research purposes only. Personal codes for all participants were generated that allowed the researcher to match interviews and questionnaires while maintaining the participants' anonymity. In addition, students gave their written consent at each stage of the research and were informed that they could withdraw their participation at any time without giving any reason. It was emphasised that there were no correct answers and ensured that everyone answered for themselves.

Data analysis

In the data analysis phase, an exploratory sequential design was conducted. In this research, the researcher first collected and analysed qualitative interview data and these findings informed subsequent quantitative data collection (Onwuegbuzie, Bustamante, and Nelson 2010). In order to see the biggest picture and understand students' perceptions about the general sense of belonging from a broader perspective the researcher included the same interview questions in a questionnaire in the same order and sent them to the A-level, undergraduate, and postgraduate students. In the process of the integration of data, the qualitative and quantitative data were merged and brought together for analysis (Fetters, Curry, and Creswell, 2013). From these interview transcripts and questionnaire responses, an inductive thematic analysis was conducted. An inductive analysis involves coding data without using preconceptions about analytical preconceptions or coding the data according to a pre-existing coding frame. By taking this inductive approach, perceptions of their understanding of sense of belonging were uncovered to provide a rich, holistic perspective and deep and meaningful insights, which can be drawn on in practice to inform thinking (Braun & Clarke, 2006).

This inductive thematic analysis adopted the six-step approach of Braun and Clarke (2006) to analyse students' responses. In order to gain an understanding of the data and a sense of overarching patterns of meaning, the data were carefully read to allow the researchers to familiarise themselves with them. The second step was to generate codes by hand across the dataset by using the same unit of text in more than one code and collating the data relevant to each code. In the third step, overarching patterns are categorised by systematically reviewing, checking against one another, and categorising them into specific descriptive themes. All interview data were transcribed verbatim. An initial analysis of the raw data from the transcript and questionnaire responses was merged and conducted using the NVivo 12 Plus Qualitative Software at the same time, and the interview transcript and students' questionnaire responses were then coded using lean coding without relying on software (Creswell, 2013). In order to find a deeper meaning in the dataset, NVivo 12 plus was used to code axially and descriptively, where the lean coding process revealed several broad codes (Creswell, 2013). The fourth step involved reviewing themes and checking them against the coded data and the entire dataset to generate a theme map; the fifth step involved defining and naming themes; the sixth step involved deeply analysing themes, selecting data extracts, and relating these extracts to the research question and the literature. Then, the researcher sent the codes (anonymised) and theme map that emerged from the dataset to three faculty lectures in the School of Education to discuss the classifications and data analysis. We discussed and compared the overall findings to describe emerging codes and themes, and we cross-checked recurring codes and themes for validation, thus bringing credibility and dependability to the findings. We then agreed on the codes and themes.

Participants

Permission was obtained from the School of Education Ethics Committee on October 18th, 2022, at Durham University, to distribute questionnaires and interview invitations at Durham University, the University of Birmingham, and the University of Oxford. A total of 290 A-level, undergraduate, and postgraduate mathematics, physics, and chemistry students (48.6% female, 44.8% male, and 3.8% non-binary) filled out the questionnaire. The age range of the majority of participants ($n=115$, 43.1%) was between 18 and 19. The Department of Chemistry had the highest number of participants ($n=112$, 38.6%), followed by the Department of Physics ($n=95$, 32.8%), and the Department of Mathematical Science ($n=83$, 28.6%). Many participants considered themselves as either English ($n=181$, 62.4%) or any other White background ($n=40$, 13.8%). The majority of participants ($n=188$, 64.8%) described themselves as not first-generation student. The questionnaire participants' full demographics are reported in Table 1.

A total of 23 first-year Durham University undergraduate-level mathematics, physics, and chemistry students (% 43.5 female, 47.8% male, 8.7% non-binary) participated in the interviews. The age range of the majority of participants ($n=19$, 82.6%) was between 18 and 19. The Department of Mathematical Science ($n=12$, 52%) had the highest number of participants, and then, the Department of Chemistry ($n=6$, 26%), and the Department of Physics ($n=5$, 22%). More than half of the participants considered themselves as either English ($n=12$, 52.2%) or any other White background ($n=4$, 17.4%). The interview participants' full demographics are reported in Table 2.

Results and discussion

In Dost's (2024) study, the concept of the general sense of belonging was conceptualised into four parts, respectively—'adaptation period sense of belonging', 'integration period sense of belonging', and 'continuum period sense of belonging', and 'transition period sense of belonging'. Essentially, Dost (2024) describes these four phases as consecutive and interrelated phases of a cumulative cycle. The periods of this cycle are defined as follows: 'Adaptation period sense of belonging' is conceptualised as 'the first connection and step of an individual's adaptation to a new environment, a new team/group/community, or a new subject'. 'Integration period sense of belonging' is also conceptualised as 'the positive and effective interaction between the self and values of the individual with the self and values of the community/society/group members, and the tendency for the group members to build social bonds and promote cooperative learning'. 'Continuum period sense of belonging' is also conceptualised in this study as 'the ongoing positive feeling of an individual to somewhere, the subject or team/group/community they are in overtime and stick together in line with achieving a common objective until the next transition phase'. The study conceptualised the 'transition period sense of belonging' as 'the feeling in the period between two stable states when something changes from one state to another and individuals are ready to move on to the next stage, adapt to the process, learn new skills, or cope with new experiences'.

Certain characteristics define the general sense of belonging, a field with a specific focus may also contain unique technical characteristics, such as STEM belonging in this study, which includes technical themes in addition to the main notions about the sense of belonging. Therefore, the researcher prepared a main question and prompt questions to gain a better understanding of the unique technical themes that form the STEM belonging concept. The main question was: "What does a STEM belonging mean to you?", and prompt questions were: "How can you tell if someone in a STEM setting feels that they belong in STEM?", "What does it feel like when you belong in STEM?", and "What would others see if you felt like you belonged in STEM?". Analysis of the survey responses and interview transcripts revealed nine main themes (see Fig. 1) relating to students' perspectives and experiences of STEM belonging. In accordance with the

Table 1 Demographic characteristics of questionnaire respondents ($N = 290$)

Variables	Description	N	%
Gender	Female	141	48.6
	Male	130	44.8
	Non-binary	11	3.8
	Prefer not to say Other	6 2	2.1 0.7
Age			
	Below 18- 19 years old	115	43.1
	20–21 years old	96	33.1
	> 21 years old	69	23.8
Ethnicity			
	White-English/British/ Welsh/ Scottish/ Northern Irish	181	62.4
	White-Irish	8	2.8
	Any other White background	40	13.8
	Mixed/multiple-White and Black Caribbean	3	1.0
	Mixed/multiple-White and Black African	1	0.3
	Mixed/multiple-White and Asian	9	3.1
	Any other Mixed or Multiple ethnic background	8	2.8
	Asian/Asian British-Indian	9	3.1
	Asian/Asian British-Pakistani	4	1.4
	Asian/Asian British-Bangladeshi	1	0.3
	Asian/Asian British-Chinese	12	4.1
	Any other Asian background	5	1.7
	Black and Black British-Black British	1	0.3
	Black and Black British-African	3	1.0
	Any other Black background	1	0.3
	Other	2	0.7
	Prefer not to say	2	0.7
University			
	University of Oxford	71	24.5
	University of Birmingham	95	32.8
	Durham University	124	42.8
Education Level	A-level	28	9.7
	Bachelor's degree	170	58.6
	Masters	46	15.9
	PhD candidate	43	14.8
	Prefer not to say	3	1%
Current year of study			
	First Year	99	34.1
	Second Year	66	22.8
	Third Year	56	19.3
	Fourth Year	41	14.1
	A-level	28	9.7
Academic discipline			
	Department of Mathematical Science	83	28.6
	Department of Chemistry	112	38.6
	Department of Physics	95	32.8
First generation			
	Yes	66	22.8
	No	188	64.8
	Prefer not to say	32	11.1

Table 1 (continued)

Variables	Description	N	%
	Other	4	1.4
Considered leaving university without completing			
	Never	122	42.1
	Just once	43	14.8
	Sometimes	77	26.6
	Frequently	17	5.9
	Prefer not to say	31	10.7

Table 2 Demographic characteristics of interview respondents (*N* = 23)

Variables	Description	*N*	%
Gender	Female	10	43.5
	Male	11	47.8
	Non-binary	2	8.7
Age			
	Below 18- 19 years old	19	82.6
	20–21 years old	3	13
	> 21 years old	1	4.3
Ethnicity			
	White-English/British/ Welsh/ Scottish/ Northern Irish	12	52.2
	Any other White background	4	17.4
	Mixed/multiple-White and Black Caribbean	1	4.3
	Mixed/multiple-White and Asian	1	4.3
	Asian/Asian British-Indian	2	8.7
	Asian/Asian British-Bangladeshi	1	4.3
	Any other Asian background	2	8.7
University			
	Durham University	23	100
Education level			
	Bachelor's degree	23	100
Current year of study			
	First Year	23	100
Academic discipline			
	Department of Mathematical Science	12	52
	Department of Chemistry	6	26
	Department of Physics	5	22
First generation			
	Yes	4	17.4
	No	17	73.9
	Other	2	8.7

participants' answers, this study conceptualised the concept of STEM belonging into four phases, namely the 'adaptation phase, the 'integration phase', the 'continuum phase', and the 'transition phase', based on Dost's (2024) study. The 'adaptation phase' is the period in which individuals become interested in STEM fields for the first time and desire to take an active role and contribute to this field. Students' adaptation phase encompasses their inner drive, intrinsic motivation, and desire to pursue a career in STEM. The 'integration phase' can be defined as the stage of individuals' connection to the STEM fields, sharing their interest and passion in STEM with

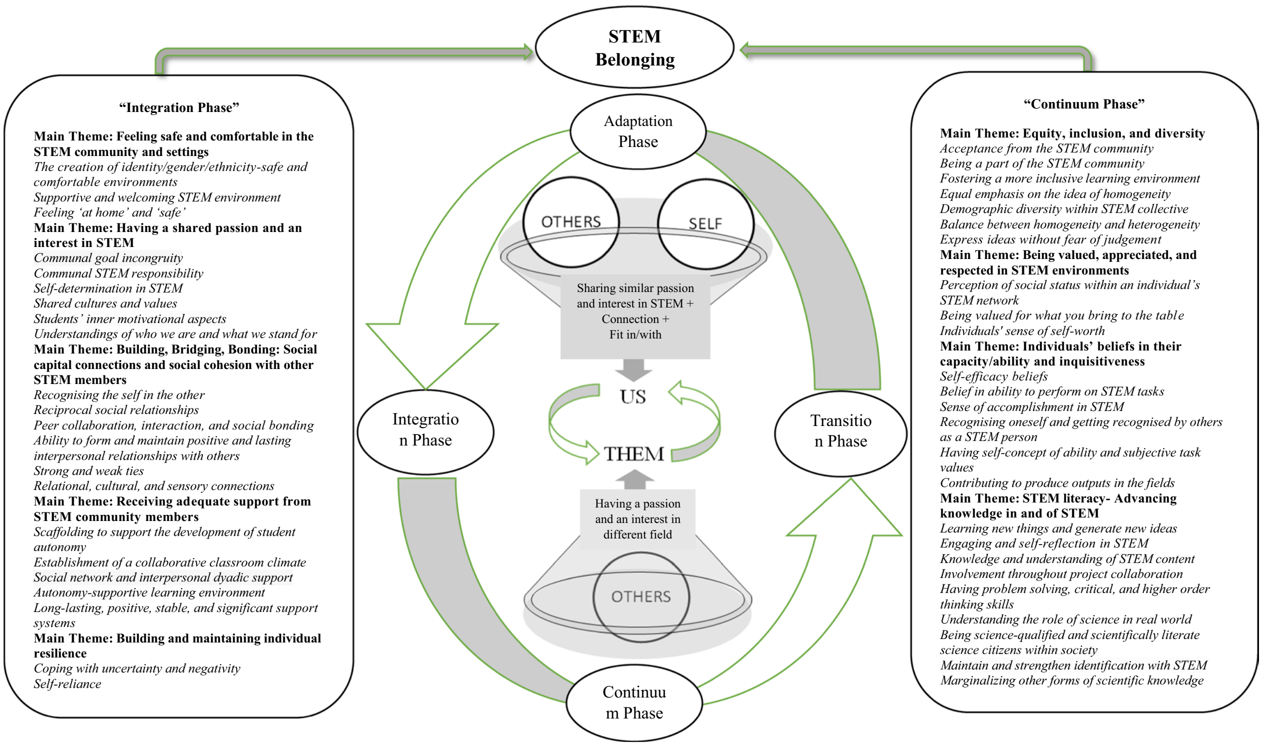

Fig. 1 Representative presentation of thematic analysis

other group members, ensuring mutual respect, value, and appreciation, and accepting each member as who they are as well as being accepted with the other members of the group, as well as feeling in harmony with the group members and acting accordingly, and feeling ready to start to gain knowledge and contribute to the field. Five main themes form the 'integration phase' in STEM. These themes include (1) feeling safe and comfortable in the STEM community and settings, (2) having a shared passion and an interest in STEM, (3) building, bridging, bonding: social capital connections and social cohesion with other STEM members, (4) receiving adequate support from members of the STEM community, (5) building and maintaining individual resilience. The 'continuum phase' encompasses individuals' intrinsic motivation, inner drive, and desire to pursue a STEM career, and their social interactions in STEM environments, as well as their active participation in this field and improving themselves so that they have the knowledge and equipment to contribute. During the 'continuum phase', individuals gain self-confidence and develop the necessary skills and knowledge to contribute to their field. They become STEM literate by learning the main elements of their specific area, supporting one another, and developing the necessary skills to overcome the challenges they face in the field. Four main themes are crucial to consider in the 'continuum phase' in STEM. These themes are (1) equity, inclusion, and diversity in STEM fields, (2) being valued, appreciated, and respected in STEM environments, (3) individuals' beliefs in their capacity/ability and inquisitiveness in STEM areas, (4) STEM literacy—advancing knowledge in and of STEM. The 'transition phase' is defined as the feeling that individuals are ready to adapt to the new process, learn new skills, or cope with new experiences when moving from one STEM environment to another STEM environment or from one educational level to another in STEM. Figure 1 illustrates that as individuals transition from 'the adaptation phase' to 'the integration phase' or from 'the continuum phase' to 'the transition phase', they develop a sense of commonality with their 'self' and 'others' who have a shared passion and an interest in STEM fields. This formulation refers to the implicit and intrinsic relation between 'self' and 'others' in representational content. This means what is internalised or represented are patterns of relationships, rather than isolated elements. This leads to a state of harmony with their STEM environment and with 'others' who have a shared passion and an interest in STEM, and it fosters a sense of connection, and community, and subsequently fits in. This process creates the feeling of 'us' in STEM. Those who do not meet these common denominators are considered "them". For the continuation of the feeling of "us", individuals must be valued, appreciated, and respected in their environment, accepted by the group/community, comfortable and safe in this environment, and have a shared passion and an interest as well as social cohesion with the group members.

Main theme: feeling safe and comfortable in the STEM community and settings

> *"STEM belonging is a sense of comfort in taking up space in STEM, not feeling out of place amongst your colleagues/peers. Just being comfortable as part of the community of STEM students, academics, and industry professionals" (P100, Female, White background, first-year Mathematical Science master's student).*
>
> *"STEM belonging means feeling comfortable in STEM settings, welcomed by peers and superiors, and confident about your place in the field. Feeling a sense of community, like 'this is *my* place'" (P2, Male, any other Mixed or Multiple ethnic backgrounds, second-year Inorganic Chemistry Ph.D. candidate second year).*

The theme of 'Feeling safe and comfortable in the STEM community and settings' is the most cited theme by students in defining the concept of STEM belonging. To advance in the field students are interested in, many of the research into and otherwise obtain information about the field, as well as create an impression about specialisations in that field, and they may question whether they belong in the field or otherwise, or whether they are suited to the job and whether they are qualified it. The creation of identity/gender/ethnicity-safe and comfortable environments can help individuals feel they belong in their chosen area and can contribute to the field. In male-dominated professions, including STEM fields, there is often an unintentional promotion of the "masculine default" (Cheryan & Markus, 2020). Therefore, feeling safe and comfortable in STEM environments, which are seen as male-dominated, can be considered an important concept and a part of their sense of belonging, even if they acknowledge the reality of stereotypes but deny their validity. The experience of fit and belonging produces a sense of psychological safety and comfort, and, as a result, students show an increased ability to adjust to the setting (Held, 2015; Levett-Jones & Lathlean, 2008; May et al., 2004). They are also more likely to engage in their academic experience, show increased persistence in the face of adversity, and ultimately perform up to their potential (Fouad et al., 2011; Osterman, 2000; Soria & Stebleton, 2012).

Main theme: having a shared passion and an interest in STEM

> *"As opposed to other industries, I think we have a responsibility that others do not. So first, I do not think it is just about personal belonging. I think as a group we need to reach out to others who are not necessarily part of our industry and make them feel like they can be a part of it so that we can enact the change that needs to happen. I think there is like a common goal, usually regardless of what your research area is, we are generally trying to reach the same thing, which is to find new things and innovative solutions, whatever it might be" (P65, Female, White background, first generation, first-year Biosciences undergraduate student).*

Individual characteristics, common goals, and experiences may shape the short-term and long-term life goals that affect community members' belonging, persistence, and career choices in STEM. Cooperative action among the members may facilitate the pursuit of intrinsically valuable goals and the realisation of common interests, in addition to being compatible with individual self-concepts. According to the participants, motivations for communal action are rooted in a desire to connect with, care for, and share with others, as opposed to motivations for agentic action based on concerns for the self as it relates to status, achievement, and independence.

Pursuing collective objectives assists in meeting the needs for belonging, connectivity, and association (Kahu et al., 2022; Li & Loverude, 2013; Walton & Brady, 2017). When deciding to pursue or leave a particular context, individuals rely on their beliefs regarding whether a role enables them to pursue objectives (referred to as goal affordances) to determine which of their valued goals can be achieved (or potentially hindered) within that context (Diekman & Steinberg, 2013; Fuesting et al., 2019; Yang & Barth, 2015). When there is alignment between the environment and an individual's goals, s/he experiences goal congruity. The communal goal congruity framework suggests that orientation toward others can involve collaboration and working to benefit others (Diekman & Steinberg, 2013). During adolescence, young people tend to associate themselves with friendship groups or cliques (Brown, 2004, 2020; Turner & Cameron, 2016). Researchers in the field of development have observed that belonging to such a group can shape the thinking and behaviour of its members (Gaither, 2018; Powlishta, 2004). According to social identity theory (Tajfel & Turner, 2004), this happens because individuals typically look to other group members for social comparison and approval; in turn, identifying with a group can lead to the internalisation of norms, goals, and values. Being a member of a close-knit friendship group that supports STEM would also predict students' interest and persistence in STEM (Robnett & Leaper, 2013). Students often rely on their close friends and peers to assess the types of pursuits that they perceive as attainable for themselves (Robnett & Leaper, 2013; Rodrigues et al., 2011). If a student's friendship group values STEM, it may strengthen his or her interest and dedication to a STEM career path.

"STEM belonging is having similar interests and personality traits within a group such that camaraderie prevails between its members" (P34, Female, White background, first generation, first-year Chemistry master's student).

> *"STEM belonging is having a community where you can share interests and findings about STEM with other people who think similarly, and we can constantly push each other to excel. It is at least seeing that you have something in common with the people around you. Thinking that STEM can be a challenging subject and so believing that you can work through this and be successful is also quite important in STEM. And also, I guess knowing that everybody in STEM probably has a similar goal, which is just like understanding science, like the development of humanity. Just set of interest to be honest" (P79, Female, any other White background, A-level Chemistry student).*

An individual may gain commitment and belonging when their goals and tasks match their motivational trigger with those who have the same trigger. There was a clear consensus among participants that identifying and realising common goals, as well as establishing a group consciousness, contributes to the formation of a sense of belonging, which are essential elements to finding solutions to problems and creating new outputs in an area.

> *"You belong in STEM if any of your interests lie in STEM subjects, and if you pursue those interests to develop skills in them. To belong in STEM is to belong to a world-leading advance in technology and health it is amazing, fantastic, and inspiring. No doubt over whether STEM is what I want to do with the rest of my life" (P71, Female, any other White background, first-year Chemistry master's student).*

Having an enthusiasm and positive attitude toward STEM may become an indicator of students' interest in such (Archer & DeWitt, 2021; Sithole et al., 2017). Interest in STEM is linked to individuals' persistence in the field and their continued participation in STEM subjects (Sithole et al., 2017). Maintaining continuity by focusing on interests does not merely serve as a self-selection mechanism for a few binary choices in life, such as obtaining a career; rather, their interests contribute to their readiness for STEM fields by promoting learning in these fields and provide the basis for individuals' education and career development throughout their lives (Corin et al., 2018). Some interviewees stated that they had intrinsic motivation in this field and that they could not think of themselves pursuing any profession outside this field, which can be positively related to the students' genuine interest, belonging, and intrinsic motivation. Curiosity and enjoyment are viewed as leading to an individual's increased focus on a subject like science, followed by an inclination to participate in and seek out scientific activities in the future (Hidi & Renninger, 2006). A person's intrinsic motivation, skill with and access to domain-relevant knowledge, and creative skills are greater when s/he engages in STEM (LaForce et al., 2017; Simon et al., 2015; Young et al., 2018).

Main theme: building, bridging, bonding: social capital connections and social cohesion with other STEM members

> *"The sense of belonging in STEM would be like seeing myself in a certain place, seeing others like me of my similar background in a certain place, but also even if there are not people like of my background, people being nice to me and friendly to me as if I'm just a colleague a friend" (P220, Male, Asian/Asian British-Bangladeshi background, first generation, first-year Physics undergraduate student).*

According to participants, STEM social capital refers to how membership in a formal or informal social network based on similarity enhances individuals' learning and engagement in STEM subjects. Social Capital Theory highlights that individuals acquire information about education norms, values, standards, and expectations through their interactions with parents, peers, and others (Coleman, 1988). Putnam (1995) contends that social capital is a community resource that cannot be measured at an individual level. The access to social capital at both individual and group levels is influenced by three main factors: member position, distribution of individual attributes, and tie distribution within the entire group (Baker-Doyle & Yoon, 2011). Member position impacts both individual and group social capital, ranging from isolation to centrality. The second factor that affects social capital levels is associated with the distribution of individual attributes within the community. Tie distribution describes the quantity and pattern of relationships within a network. Lin (2001) concept of social capital perceives an individual's social network as a pool of resources that aids in achieving personal goals. According to social capital theory, although individuals can achieve goals independently of their social networks

(Lin, 2001), the resources within their social network offer valuable assets that can be effectively utilised (van der Gaag & Snijders, 2005). Social networks are the interconnected relationships that students depend on to seek information, resources, support, and advantageous opportunities (La Due Lake & Huckfeldt, 1998; Lin, 1999; Schafft & Brown, 2003; Williams & Durrance, 2008).

> *"It feels good, really joyful when I belong to a community. Let's say it is a school community, for example, I really look forward to going to school because I know it is the people that are not the place. So, it not only makes my learning experience more enjoyable or whatever task I am doing, but it makes being them more enjoyable too" (P111, Female, any other White background, A-level Chemistry student).*
> *"STEM belonging is having people whom you can rely on to care about you, whom you share important things with" (P9, Female, White background, Fourth Year Chemistry Ph.D. candidate).*

STEM education can demonstrate social capital bonding through connections with peers, superiors, or other members. Students state that belonging is more than just related to a field; it comes from engaging with people in that field.

> *"An example for defining STEM belonging would be to show someone who doesn't feel like they belong would be someone who's sort of actively avoiding other people because they feel when they interact with other people, they aren't sort of having a positive experience." (P28, Male, White background, first-year Mathematics Master's student).*

Bridging social capital refers to both formal and informal horizontal relationships and norms among diverse individuals, for example, between groups with different demographics (Claridge, 2018; Halpern, 2005; Patulny et al., 2007). Meeting with STEM professionals and receiving informational support at in-school or out-of-school activities or programmes demonstrates the linking of social capital in STEM education. Every human being possesses an inherent desire or drive to establish and sustain at least a minimal amount of enduring, affirmative, and significant connections with others (Baumeister & Leary, 1995). This inclination serves as a fundamental principle in theories like Abraham Maslow's. According to Maslow's hierarchy of needs (1970), the need to feel a sense of belonging ranks as one of the most crucial human needs, second only to physiological and safety needs. Given that belongingness is a fundamental necessity, much of human behaviour can be interpreted as an effort to satisfy this basic requirement (Baumeister & Leary, 1995). In the context of higher education, experiences of belongingness arise when students establish strong bonds with their peers (Maunder, 2018; Pedler et al., 2022). Belongingness becomes particularly significant during the transition to university, as students explore their fit within the new social environment (Dost, 2023; Janke et al., 2023; Pittman & Richmond, 2008). Research from various sources suggests that people engage in behaviours that support the need for belonging (Over, 2016; Underwood & Ehrenreich, 2014). Multiple studies demonstrate that social connections can easily be formed (Baumeister & Leary, 1995). Additionally, group affiliations appear to form with relatively little effort and are a significant factor in establishing relationships (Newman et al., 2007). Participants emphasised the importance of students having opportunities for peer interaction and social bonding within or near their academic departments. The availability of such opportunities was considered essential for the university experience by the majority of participants and was identified as a means for students to develop interpersonal skills by facilitating their involvement in groups and the establishment of meaningful personal connections.

Main theme: receiving adequate support from members of the STEM community

> *"STEM belonging means having a good support network and colleagues to offer help when needed. It means you are getting the support you need with your project so you can do your research or study. It is kind of being able to roll back on people and just ask for help, whether it is your supervisor or your colleagues" (P286, Female, White background, first generation, first-year Chemistry Ph.D. candidate).*
> *"When I belong somewhere, it makes me feel good about myself happy and, I probably say excited because I feel I belong. Then I feel I can be myself and engage in things more, whether that is in a classroom environment, I feel like I belong to engage more with the lessons and the topics, and I think I've learned better. If it is outside of lessons with people, I feel like I belong with them, I can just engage with them better and have better friendships. I will get along with people more. In STEM settings, I will be united in a desire to pursue truth and wield it for the good of humanity, and to know that my peers will support me in that pursuit as I support them" (P57, Male, White background, A-level Physics student).*

Relationships among peers and interpersonal interactions have a significant impact on STEM belonging and are often viewed by participants as one of the most important components of STEM belonging.

Participating in peer discussions both inside and outside the classroom, engaging with activities/lectures/practicals/topics or supporting peers by helping each other when necessary is extremely valuable to students' STEM belonging. Some interviewees made the connection between sense of belonging and existence/absence of a support network and peer support system. Social support pertains to the perceived availability and provision of social resources to early-stage researchers by their social surroundings and the wider research community (Vekkaila et al., 2018). This encompasses interactions with peers, supervisors, or colleagues, in other words, both formal and informal relationships within the academic community. However, sources of social support are not confined to the academic community and are often extended by close friends and family (Mishra, 2020; Permatasari et al., 2021; Wilcox etal., 2005). Insufficient social support has been linked to elevated levels of distress and attrition in doctoral studies (Peltonen et al., 2017; Vekkaila et al., 2018). Given that the number of female students or individuals from underrepresented groups opting for STEM fields is already limited, and their participation rates remain low even after choosing these disciplines, social support for students is considered crucial at every stage of their education. It is recognised by interviewees as a significant component that fosters a sense of belonging in STEM.

The presence of peer relationships and social support can be highly influential amongst women of colour, first-generation students, and students who are considering leaving university without completing. Weiss's (1974) theory of social support and connection focuses on the individual's desire to engage with others, and the theory distinguishes between primary and secondary connections. Primary/intimate connections encompass close, affectionate, and regular relationships acquired from family and friends (Daly et al., 2013; Gillies, 2003; Jongbloed et al., 2008), while secondary connections involve relationships of lesser emotional significance compared to primary connections (Benítez-Andrades et al., 2021; Red et al., 2011), although they still exert considerable influence. Weiss (1974) outlines six distinct social connections/provisions that must be acquired through interactions with others, and all provisions are necessary for an individual to experience sufficient support. These six elements are personal connections/bonding, opportunity for nurturing, social inclusion, validation of value, a sense of trustworthy partnership, and obtaining guidance—each typically associated with a specific type of connection.

Main theme: building and maintaining individual resilience

> *"Belonging in STEM is just enjoying what you're doing and knowing you want to do it for yourself rather than other people know letting other people affect this joy have in doing STEM-related activities" (P237, non-binary, any other White background, second-year Biochemistry Ph.D. candidate).*
>
> *"STEM belonging is to be actively enabled to do my research rather than having to constantly overcome accessibility roadblocks" (P99, Female, any other White background, second-year Mathematics undergraduate student).*

Participants believe they will be protected from negativity by focusing on the points they enjoy and being interested in and contributing to the field without being influenced by others. The theme of individual resilience is intricately linked to dealing with negative perspectives, gender stereotypes, and norms in STEM settings. It is also connected to perseverance, as per students' perspectives. It is effective in helping students cope with the difficulties they encounter during the integration period. Resilience is defined as the existence of protective factors such as personal, social, and institutional safety nets that empower individuals (Kaplan et al., 1996) to withstand gender stereotypes, and norms in STEM settings (Di Bella & Crisp, 2016). In a broader sense, individual resilience refers to the capacity to endure adversity, adapt, and recover from it. It involves behaviours, thoughts, and actions that promote mental well-being (Ghanizadeh, 2022; Gilligan, 2000; Holdsworth et al., 2018). Some resilience researchers are utilising the fundamental social work concept of the person-in-environment to develop a more comprehensive understanding of resilience processes (Green & McDermott, 2010; Kondrat, 2013; Van Breda, 2019). For instance, Van Breda (2017) classifies resilience processes into those that are personal or individual, those that occur within the social environment, including social relationships and the surrounding environment, and those that are interactional, referring to processes that link the individual and the environment. The value of this approach to resilience lies in highlighting the interactions between individuals and their social environments (Begun, 1993; Fraser et al., 1999; Park et al., 2020). Therefore, resilience processes are not solely limited to the individual or the environment, but in the way these two interact (Van Breda, 2017). For example, while relationships play a critical role in resilience mechanisms, establishing positive connections necessitates individuals to cultivate a set of social abilities that prompt helpful and supportive reactions from others, as well as for others to develop an understanding of these individuals and the obstacles they encounter, and a willingness to engage with them (Van Breda, 2017, 2019). These social connections may enable individuals, especially students from underrepresented backgrounds, to engage in STEM and to strengthen their positive personal development against stereotypical perspectives they encounter in society, as well as in an individual and social context.

Main theme: equity, inclusion, and diversity in STEM fields

> *"STEM belonging means inclusivity for all people: all ethnicities, all genders, all ages, all sexual orientations, and inclusive and supportive for people with disabilities. And for these people to not feel like an outcast or a burden" (P80, Non-binary, White background, first generation, third-year Maths, and Physics undergraduate student).*

The theme 'Equity, inclusion, and diversity in STEM fields' was emphasised by students to feel comfortable bringing their full selves to their field of study, and not feel like they are a different person. Equity in STEM refers to a fair and inclusive environment that supports students in reaching their potential and eliminates any obstacles to their learning (Buck, Francis, & Wilkins-Yel, 2020; Killpack & Melón, 2016; O'Leary et al., 2020). Equity emphasises the rights of individuals and equal access to opportunities while ensuring freedom from prejudice and favouritism (Riley & White, 2016). Being part of a group that aligns with one's individual needs signifies inclusion (Jansen et al., 2014; Koster et al., 2009). The inclusion of students provides them with the confidence that their ideas and perspectives will be respected, as well as the ability to fully engage (Rangvid, 2018; Slepian & Jacoby-Senghor, 2021). Hence, being included is influenced by the compatibility between oneself and other group members and is more easily achieved when there are similarities between them (Jansen et al., 2014). Simple inclusion does not suffice. It is imperative that all voices are heard, barriers are broken down, and our unique backgrounds are appreciated. Based on interviewees' opinions, the intersectionality of students' own identities (as female, LGBTQ, working-class, etc.), and representativeness of their identities in a STEM field, having demographic diversity in the field is related to students' STEM belonging. The ability to connect and interact with other women might foster a greater social fit to the degree that one experiences greater support and acceptance among others. The problem is not that women or people of colour inherently feel they do not belong in STEM but, rather, they are responding to the unbalanced representation of certain demographic groups in certain STEM fields. The diversity of intersectional identities of students was highlighted by participants as an important pillar when defining STEM belonging.

> *"STEM belonging is not to have had a pre-conceived judgement on my ability based on my gender and not feel excluded from the STEM community. STEM belonging is to be given equal opportunities and feels that you are equal with others in STEM as part of a greater scientific endeavour" (P73, Female, White background, first generation, second-year Maths undergraduate student).*
> *"Acceptance of someone despite gender or race and inclusion of underrepresented communities (especially women) and not limited by being female to do anything that anyone else can do" (P18, Female, White background, first generation, first-year Physics undergraduate student).*

Even though gender stereotypes are less prevalent than they were in the past, these stereotypes still affect individuals in STEM fields. The female participants expressed that they should not be treated unfairly because of their gender and background in the STEM field, that their ideas should be evaluated in the same way as other students, and that every student, regardless of their background, should have access to a STEM-friendly environment.

> *"STEM belonging means being in a room with people who listen to and respect your opinion and feeling like you can openly express your thoughts and opinions about the discussion at hand without fear of judgement. It means sharing a passion for the subject and others believing in my ability without any discrimination for differences in the background" (P240, Female, White background, third-year Engineering undergraduate student).*

The cultural, interpersonal, and individual barriers exist and are highly effective in STEM fields, and a belief that women do not have a natural ability in STEM is often linked to a common view that values natural ability over effort (Khine, 2016; Setzekorn et al., 2020; Tandrayen-Ragoobur & Gokulsing, 2021). Department and peers may attribute this belief to the stereotype that women do not possess natural abilities in STEM. Students who are subject to such stereotypes might feel devalued, excluded from discussions and social interactions, and receive less career guidance. In order to combat these systemic barriers and foster women's interest and better fit in STEM, female students also emphasised the importance of being able to express ideas without fear of judgement.

> *"STEM belonging means you're not an outsider, feel like you can keep up with the people around you, and being accepted for who I am and my strengths and weaknesses within my subject" (P25, Female, any other White background, third-year Astrophysics Ph.D. candidate).*
>
> *"STEM belonging means feeling accepted by others, being accepted for who I am and my strengths and weaknesses within my subject and seeing other people like me in STEM" (P6, Female, any other White background, first-year Mathematics, and Computer Science master's student).*

Participants expressed that a person's sense of belonging to a particular academic field is related to that person expressing feelings of belonging, integration, contribution, and acceptance in that field. Having a warm environment where students feel they have the same intellectual capacity as their peers is important in addition to having a social environment where they feel accepted by their peers (Bartholomeu et al., 2021). Interviewees thought that being a part of the STEM community meant that they had a place in the degree settings, and felt accepted by their peers, staff members, and within/between community members. Students who are familiar with their peers and have peers who understand and accept them as who they are will feel part of a group and/or that they belong to a class/subject/place.

In peer groups, relationships can be examined based on how much an individual feels like he/she fits into the group and feels sense of belonging and how much peers accept him/her. The belonging and acceptance concepts are often used interchangeably, but these two concepts are essentially separate. The concept of belonging refers to an individual's perception of social acceptance in a group (Leary et al., 2013; Slaten et al., 2018), while acceptance refers to the degree of acceptance expressed by peers toward an individual (Ladd, Kochenderfer, & Coleman, 1997; Parker & Asher, 1993; Smith et al., 2010). Although these two concepts are different from each other, the desire to belong and to be accepted is an inborn human characteristic (Baumeister & Leary, 1995; Kovač & Vaala, 2021). Being a part of a meaningful group and spending time with peers similar to themselves, helps individuals feel accepted, understood, and valued, which impacts positively on their self-concept (Raufelder et al., 2015; Tajfel & Turner, 1986). When an individual seeks to feel part of a social group, a preference for the in-group increases, which leads them to perceive that they are more alike with their fellow members (Chan et al., 2012; Goette et al., 2006).

Main theme: being valued, appreciated, and respected in STEM environments

> *"I suppose STEM belonging is just about whether you feel welcome in the community and the environment specifically within STEM. For your ideas and propositions to be valued and questioned, even if they turn out to be incorrect. It is how you feel like in lessons or how you feel with the people who you study with" (P12, Female, White background, first-year Mathematical Sciences undergraduate student).*
>
> *"STEM belonging is to feel like a valued member of the community whose efforts and work are valued and appreciated. Being valued for what you bring to the table and feeling like my peers in STEM appreciate me, my work, and my input" (P3, Male, any other White background, fourth-year Organic Chemistry Ph.D. candidate).*

This theme uncovers students exhibit positive reactions as a result of being validated as having qualities that drive value, appreciation, or desirability, which manifests as a sense of belonging. Students tend to see themselves as valuable when they feel that their personal qualities or something they do contribute to a team/group/community. Individuals' sense of self-worth and sense of belonging can be reinforced when they are recognised and appreciated for their contributions by the members of the community with which they identify. When they are not treated fairly, they may feel worthless. Participants also discussed their need to feel appreciated, valued, and respected, both inside and outside their groups/communities, for their ideas, thoughts, and abilities. The concept of experiencing respect, value, and appreciation is intricately linked to the fulfilment of certain shared social desires and is a significant aspect of STEM belonging. In some research, respect is conceptualised as an observable manifestation of a sender's perception of the value of another individual (Grover, 2014; Markman et al., 1994); in other research, respect is defined from the perspective of the receiver as an individual's assessment of how they are perceived by members of a common group (Ellemers et al., 2004; Langdon, 2007). Respect is the value others attribute to an individual (Spears et al., 2006; Ronzi et al., 2020). Individuals feel valued by others when these others act in ways that meet the needs and motivations, they have toward them (Browne, 1993; Ellemers et al., 2004; Frei & Shaver, 2002). By considering all members in STEM as inherently deserving and demonstrating appreciation and value towards them, general respect nurtures a sense of belonging to the STEM community that embraces individuals as they are, motivating members to contribute to and persevere in STEM.

Main theme: individuals' beliefs in their capacity/ability and inquisitiveness

> *"STEM belonging means feeling confident, intelligent, driven in STEM subjects, wanting to better the world, and being perceived by everyone around you to be a worthy, capable student" (P91, Male, White background, second-year Chemistry master's student).*
>
> *"I feel like I belong in STEM when my work makes sense to me, desire to be on the forefront of innovation as a student and professional, and I start to 'speak the language' of the field, and share this with my peers" (P40, Male, White background, third-year Theoretical Physics undergraduate student).*
>
> *"STEM belonging means feeling like I have some proficiency or understanding of my STEM field that I could positively contribute to a discussion or situation and be well received by my peers" (P29, Male, Black and Black British-Black British background, second-year Chemistry undergraduate student).*

Interviewees believe that they have and use personal judgment about how well they can implement the necessary action plans to deal with possible situations because this is a positive predictor of students' sense of belonging. All kinds of human experiences are affected by cognitive self-assessment, from the goals people seek to achieve, the amount of energy expended achieving goals, to the likelihood of achieving certain behaviours. By overcoming the difficulties in their success in completing tasks they are assigned to or choose; students can develop a belief in self-efficacy and sense of belonging that can support their career development in STEM fields.

> *"To a considerable extent, I think STEM belonging is about feeling clever enough to be there because when you start university, everything is a lot harder and there are times when you think I am maybe not cut out for this. So, I guess it is having a sense of belonging that you as an individual, coming from your own background with all of your experiences, can sort of interact with everyone else there, but is also thinking I am actually intelligent enough to have a meaningful contribution" (P56, Female, White background, third-year Mathematics undergraduate student).*

Some interviewees discussed the meaning of a sense of belonging as the belief that they can succeed, being smart, aware of one's abilities, inquisitive, and having a good relationship with others in STEM. In addition, students mention that one of the most important components when defining sense of belonging in STEM fields is to have sufficient ability/intelligence to produce output in that field. There are four primary factors that contribute to the development of self-efficacy beliefs in the literature: subjective experiences of success or failure, learning from others' actions, receiving feedback and support from others, and experiencing physiological reactions during task execution. These factors include mastery experience, vicarious experience, social persuasion, and emotional states (Bandura, 1977; Zimmerman, 2000). Mastery experience is based on an individual's past achievements or failures in performing a specific task. Vicarious experience involves gaining knowledge and confidence by observing others, such as role models, performing tasks in a particular area or field (Jenson et al., 2011; Rittmayer & Beier, 2008). Social persuasion refers to the feedback, encouragement, and support received from significant others, such as parents and teachers (Anderson & Betz, 2001; Capa-Aydin et al., 2018; Rittmayer & Beier, 2008). Lastly, physiological reactions encompass physical responses and emotions, such as fear of failure, fatigue, stress, anxiety, and nervousness, that occur during task execution (Rittmayer & Beier, 2008; Zimmerman, 2000). The motivational model of achievement developed by Dweck (2013) also mentions both entity beliefs and incremental beliefs; students believing their abilities are an unchangeable entity, and students who believe they can change and develop their abilities through experience and practice. According to Dweck's theory of motivation, these implicit beliefs about ability specify how students respond to cultural and gender stereotypes in STEM, how they deal with negative situations, and how they cope with them (van Aalderen-Smeets et al., 2019).

Main theme: STEM literacy—advancing knowledge in and of STEM

> *"STEM belonging means to be open-minded like you can view big images, big pictures, and ideas even though you physically cannot grasp them. That is called advanced into space. For example, I do not think people on Earth can physically actually picture the advantages of what is going on, but in STEM we understand what is going on. Then I felt like to be a part of STEM and belonged in STEM. I feel it is a great feeling. It makes you feel more valued as a person and more independent because I think STEM is the future. For example, I think science and technology as well as engineering and maths, is the way forward in the future. We use maths every day,*

whether we are shopping or just in nature for example. It occurs a lot with the golden ratios, Fibonacci numbers, and things. But then we also use chemistry and other sciences every day through well like medication people might take or just everyday processes driving like fuels. And it is just to me, I feel like we used to every day so. If I can interact with STEM, be part of it, and work non-artistically to create, innovate, and progress humanity that would be great for me because it is particularly important and it is the way the world is heading towards" (P290, Female, Any other Asian background, second-year Physics undergraduate student).

This theme was seen as important among interviewees as they see today's world is shaped by rapidly changing and increasing information and competition between countries, and as a result, the characteristics sought in the members of societies have also diversified. These characteristics include critical thinking, communication skills, creativity, information literacy, technology skills, digital literacy, problem-solving, etc. Students who are educated with twenty-first century skills, and have project-based, and problem-based educations in which students are active are individuals who will help shape the future and, indeed, give it direction. When students who are STEM literate and have STEM identity feel they belong in a setting, they may tend to be more motivated to engage with others, as in making friends, and want to advance their knowledge and their area of focus.

"I guess when I think about STEM belonging, I think about what your mind drifts to when you are thinking about a certain topic. So, if you are analysing a problem or a real-world problem or something, I would say belonging in STEM for me has felt like when you see that kind of problem, your first thought is of what it means scientifically, what it means mathematically. So, it is kind of an interpretation or a go-to interpretation, and it is not I cannot think about it in other ways it is just that is the first place my mind goes to. And I feel like that really helps me feel a sense of belonging amongst other people in STEM" (P233, Male, White background, second-year Engineering undergraduate student).

To understand the universe, twenty-first century students must possess skills, abilities, and learning dispositions. The cultivation of scientifically literate individuals is a fundamental objective of 21st-century science education worldwide (Tytler, 2007). According to Bybee (2013), the primary aim of STEM education is to foster a society that is knowledgeable in STEM. STEM literacy entails understanding the distinctive aspects of STEM disciplines as various forms of human knowledge, inquiry, and design, being aware of how these disciplines shape our material, intellectual, and cultural surroundings, as well as being willing to engage with STEM-related issues and the concepts of science, technology, engineering, and mathematics as a constructive and concerned citizen. One of the key elements of ensuring development in STEM fields is understanding how long and what type of knowledge students transfer to the tasks they are expected to perform in lessons, practical applications, and professional life, the approaches they use to solve problems, and how they analyse and synthesise information (Baharin et al., 2018; Priemer et al., 2020; Rifandi & Rahmi, 2019). What is important here is that the information obtained from past experiences is used gradually in many stages of the learning process and synthesised with newly acquired information (Corbett, 2007). Participants associated the STEM belonging concept with twenty-first century skills and considered being innovative, self-confident, logical thinkers, scientifically and technologically literate, and finding solutions to problems from a scientific and mathematical, that is, STEM perspective, as a reflection of the individual's STEM belonging.

"STEM belonging means understanding the world (and people) through rational thinking, being interested in explaining the world around you through building up facts, having analytic skills, using science-driven principles in your work, and producing good scientific work to a high standard" (P214, Female, White background, first generation, second-year Chemistry (Organic/Inorganic) PhD candidate).
"STEM belonging means working together to solve science problems. You are in a group of intelligent, like-minded individuals who have a desire to know more about the universe we live in. Appreciating the symmetries and surprising results of maths and physics" (P97, Male, any other White background, fourth-year Mathematics undergraduate student).

Participants stated that problem-solving and critical thinking skills are the key skills in STEM which involve transforming theoretical knowledge into practice, as well as developing the individual's critical thinking and collaborative work, through their active involvement in the learning process.

"Belonging means having access to logistical and financial resources to engage in STEM activities" (P66, Male Asian/Asian British-Indian background, first-year Mathematics Ph.D. candidate).

In the twenty-first century, rapidly and continuously developing technologies, with the increase in knowledge and skills, follow a process of a mutual transformation that affects and is affected by each other, and individuals who take STEM education and are active in this field contribute to changing the world. During this process, some participants discussed how important it is to access, interact with, and use financial and technological resources while defining their STEM belonging. The creation of a creative product is more likely when the environment supports it by providing resources, information, opportunities, etc.

Conclusion

Based on the lack of a well-defined concept of STEM belonging in existing literature, this study aimed to uncover the key themes that help define STEM belonging from three Russell Group universities' A-levels, and undergraduate and postgraduate students' perspectives. The study concluded that the sense of STEM belonging can be divided into four phases: the 'adaptation phase', the 'integration phase', the 'continuum phase', and the 'transition phase'. These four phases as consecutive and interrelated phases of a cumulative cycle as described by Dost (2024). The 'adaptation phase' is the period in which individuals become interested in STEM fields for the first time and desire to take an active role and contribute to this field. Students' adaptation phase encompasses their inner drive, intrinsic motivation, and desire to pursue a career in STEM. The 'integration phase' can be defined as the stage of individuals' connection to the STEM fields, sharing their interest and passion in STEM with other group members, ensuring mutual respect, value, and appreciation, and accepting each member as who they are as well as being accepted with the other members of the group, as well as feeling in harmony with the group members and acting accordingly, and feeling ready to start to gain knowledge and contribute to the field. There are five main themes that form the 'integration phase' in STEM. These themes include (1) feeling safe and comfortable in the STEM community and settings, (2) having a shared passion and an interest in STEM, (3) building, bridging, bonding: social capital connections and social cohesion with other STEM members, (4) receiving adequate support from members of the STEM community, (5) building and maintaining individual resilience. The 'continuum phase' encompasses individuals' intrinsic motivation, inner drive, and desire to pursue a STEM career, and their social interactions in STEM environments, as well as their active participation in this field and improving themselves so that they have the knowledge and equipment to contribute. During the 'continuum phase', individuals gain self-confidence and develop the necessary skills and knowledge to contribute to their field. They become STEM literate by learning the main elements of their specific area, supporting one another, and developing the necessary skills to overcome the challenges they face in the field. There are four main themes that are crucial to consider in the 'continuum phase' in STEM. These themes are (1) equity, inclusion, and diversity in STEM fields, (2) being valued, appreciated, and respected in STEM environments, (3) individuals' beliefs in their capacity/ability and inquisitiveness in STEM areas, (4) STEM literacy—advancing knowledge in and of STEM. The 'transition phase' is defined as the feeling that individuals are ready to adapt to the new process, learn new skills, or cope with new experiences when moving from one STEM environment to another STEM environment or from one educational level to another in STEM.

'Being valued, appreciated, and respected in STEM environments', 'Equity, inclusion, and diversity in STEM fields', and 'Feeling safe and comfortable in the STEM community and settings' was the most frequently repeated and emphasised themes by the participants (see Table 3). Compared to male students, it was mostly female students who defined STEM belonging as feeling safe and comfortable in the STEM community and settings (see Table 3). This theme is defined by the participants as the group/community/learning environment in which the individual belongs, the interaction with the people in the field, and the comfort that this participation/interaction creates. This study also found that participants identifying themselves as transgender and non-binary defined belonging as feeling comfortable and safe, feeling like a member of a community of individuals similar to themselves, as well as being accepted as equals to others and listening to their perspectives (see Table 3). The majority of female, first-generation, and non-binary student participants stated that they occasionally or frequently consider leaving university without completing their degrees. The students who frequently think of leaving university without completing and first-generation students' responses to the 'What does STEM belonging mean to you?' are categorised under the theme of 'Equity, inclusion, and diversity in STEM fields' and 'being valued, appreciated, and respected in STEM environments'. In essence, first-generation students defined STEM belonging as having a community where they can share interests and findings about STEM with other people who think similarly, fostering an inclusive learning environment, a strong emphasis on equal access to opportunities, achieving a balance between homogeneity and heterogeneity, as well as being valued for what you bring to the table (see Table 4). Students who frequently consider leaving university defined STEM belonging as either sacrificing the soul, being competitive, being a part

Table 3 Frequency of student responses to the interview and questionnaire questions by gender

Frequency of response coded													
Main themes	**University of Birmingham ($n = 95$)**					**University of Durham ($n = 147$)**				**University of Oxford ($n = 71$)**			**Total**
	Female students ($n = 48$)	**Male students ($n = 38$**	**Non-binary students ($n = 4$)**	**Other ($n = 2$)**	**Prefer not to say ($n = 3$)**	**Female students ($n = 67$)**	**Male students ($n = 70$)**	**Non-binary students ($n = 7$)**	**Prefer not to say ($n = 3$)**	**Female students ($n = 36$)**	**Male students ($n = 33$)**	**Non-binary students ($n = 2$)**	
Feeling safe and comfortable in the STEM community and settings	11	3	2	1	1	9	8	1	-	6	7	–	49
Having a shared passion and an interest in STEM	9	6	–	–	–	6	11	2	1	5	4	–	44
Building, bridging, bonding: social capital connections and social cohesion with other STEM members	2	3	–	–	–	5	8	1	–	3	4	–	26
Receiving adequate support from members of the STEM community	3	4	–	–	–	6	6	–	–	3	2	–	24
Building and maintaining individual resilience	1	1	–	–	–	3	4	–	–	-	1	–	10
Equity, inclusion, and diversity in STEM fields	8	4	2	1	1	14	9	–	1	9	1	1	51

Table 3 (continued)

Frequency of response coded

Main themes	**University of Birmingham ($n=95$)**					**University of Durham ($n=147$)**				**University of Oxford ($n=71$)**			**Total**
	Female students ($n=48$)	**Male students ($n=38$**	**Non-binary students ($n=4$)**	**Other ($n=2$)**	**Prefer not to say ($n=3$)**	**Female students ($n=67$)**	**Male students ($n=70$)**	**Non-binary students ($n=7$)**	**Prefer not to say ($n=3$)**	**Female students ($n=36$)**	**Male students ($n=33$)**	**Non-binary students ($n=2$)**	
Being valued, appreciated, and respected in STEM environments	10	8	–	–	1	13	11	3	-	4	5	–	55
Individuals' beliefs in their capacity/ability and inquisitiveness in STEM areas	2	3	–	–	–	6	5	–	1	2	3	1	23
STEM literacy—Advancing knowledge in and of STEM	2	6	–	–	–	5	8	–	–	4	6	–	31

Table 4 Frequency of student responses to the interview and questionnaire questions by other socio-demographic factors

Main themes	Frequency of response coded									
	White students (*n*=245)	**Non-White students (*n*=68)**	**First-generation students (*n*=70)**	**Non-first-generation Students (*n*=243)**	**A-level students (n=28)**	**Undergraduate students (n=193)**	**Master's students (*n*=46)**	**Ph. D students (*n*=43)**	**Prefer not to say (*n*=3)**	**Total**
Feeling safe and comfortable in the STEM community and settings	35	14	6	44	1	39	5	4	–	49
Having a shared passion and an interest in STEM	34	10	9	35	12	20	6	5	1	44
Building, bridging, bonding: social capital connections and social cohesion with other STEM members	22	4	3	23	–	22	4	–	–	26
Receiving adequate support from members of the STEM community	21	3	3	21	2	19	3	–	–	24
Building and maintaining individual resilience	7	3	1	9	1	5	3	1		10
Equity, inclusion, and diversity in STEM fields	35	16	18	33	5	34	7	4	1	51
Being valued, appreciated, and respected in STEM environments	48	7	22	33	4	23	8	9	1	55
Individuals' beliefs in their capacity/ability and inquisitiveness in STEM areas	19	4	–	23	–	16	2	5	–	23
STEM literacy—advancing knowledge in and of STEM	24	7	8	23	3	8	7	15	–	31

of a snobby hierarchy that feels superior to everyone else and their subjects, or being smart and heard. Students who identified themselves as non-White also defined the concept as 'feeling safe and comfortable within STEM communities and settings' and 'equity, inclusion, and diversity in STEM fields'. They stressed the importance of creating a supportive and welcoming STEM environment so that individuals can feel at home, as well as a safe and comfortable STEM environment for people of all identities, genders, ethnicities, and backgrounds. Similarly, students from White backgrounds defined STEM belonging as 'Feeling safe and comfortable in the STEM community and settings' and 'Equity, inclusion, and diversity in STEM fields' which were the second highly identified themes. This theme has shown that the sense of belonging becomes increasingly important for students of colour, first-generation students, women, trans, and non-binary students who feel that they are not welcome, outsiders, lonely, discriminated against, or who feel a masculine culture be extant in the educational and learning environment. When Dost and Mazzoli Smith (2023) defined belonging to higher education, they emphasised the importance of creating heterogeneous communities and learning areas both on and off faculty/campus settings. A number of studies have also demonstrated that students' perceptions of the academic environment are related to their intention to persist in STEM (Eddy & Brownell, 2016; Sithole et al., 2017). The term overlaps with the themes of feeling safe and comfortable in the STEM community and settings. Specifically, female students or members of underrepresented groups may have a reduced interest in STEM fields and a reduced interest in majors if the environmental cues they encounter in STEM contexts undermine their sense of belonging. In order for students to develop a sense of belonging, it is necessary to adjust the cues in their environment so that they feel secure, and comfortable, and can be who they are.

From A-level to PhD level, students' definitions of STEM belonging are interconnected. While A-level and undergraduate-level students defined the concept from a social perspective and in a more general sense regarding the STEM community, master's and Ph.D. level students defined the concept as being more engaged and involved in their field and desiring and working to make a difference in their field, as well as being respected by others for their efforts. STEM belonging was defined by the majority of A-level students as sharing a common interest and passion with people in the STEM field, as well as being accepted, included, and valued by them (see Table 3). For most undergraduate students, STEM belonging means establishing social connections, feeling safe and comfortable in the STEM community and settings, receiving adequate support from members of the STEM community, and believing in their own abilities and inquisitiveness. After having A-level and undergraduate-level experiences, master's students begin to understand the STEM belonging concept as learning new things and generating new ideas, engaging in STEM and self-reflecting, and becoming STEM-literate. In addition to being valued and accepted by their STEM colleagues, Ph.D. students also began associating themselves with contributing to the field by participating in project collaborations, having problem-solving and critical thinking abilities, and being science-qualified and scientifically literate.

Feeling valued can be a vital stimulus/indicator for students to connect with a group/community or persist in a specific field. Being asked to look for solutions to problems encountered or being assigned the role of trusted leader and to receive respect in return for the respect shown to others, working together to develop new skills, helping others and other people helping in return can help establish meaningful relationships and create a sense of belonging in a particular field or group/community. This shows that being valued, respected, needed, and needing others also contributes to students' perception of sense of STEM belonging. Individual resilience is also another aspect of sense of STEM belonging that was defined by the participants. According to Masten et al. (2003), resilience represents "[a] pattern of positive adaptation in the context of significant risk or adversity" (p.4). Edwards, Lunt, & Stamou (2010) also mention that sense of belonging focuses on the development of an individual's strengths, leading to reduced vulnerability to adversity. Students' resilience in STEM is a key dimension of their persistence in the area, as with resilience students are better able to overcome the inherent (e.g., interest, curiosity, confidence, etc.) and external (e.g., dealing with masculine culture, cold environment, gender stereotypes, etc.) challenges in the STEM fields. Individuals' ability to cope with difficulties, and to overcome adversity by becoming stronger every time they encounter obstacles, may strengthen their resilience to difficulties and allow them to enjoy their field and pursue STEM careers.

Interviewees defined the theme of receiving adequate support from members of the STEM community as needing to be bridged between members in STEM communities, establish strong networks of internal and external support, and further that this network/connection should be protected (e.g., reduce cultural and gender norms). To protect and improve a community, it is crucial for students to feel they are a part of it. It is also possible for each student to create a connection/harmony/match with a group/community that they perceive as being closer to their self-identity. As a member of the group/community, social relations can be formed in environments where there are people with similar identities, which can also help to consolidate self-identity and social identity as a member of the group. Coping with the difficulties they face in the group together and adapting to the coping skills can make individuals and groups stronger. An individual's sense of belonging can be increased as a result of overcoming difficulties within their group. It is important that group members embrace changes, and if they do, they can promote innovation among individuals, if they contribute useful outputs to the community, they gain the appreciation of their fellow group members, which in turn develops a sense of belonging among the group members. An individual's perception of support derives from his/her physical and social integration into a social network, from his/her membership and involvement with other community members, and from his/her opportunities to access necessary resources in the field. According to interviewees, a key aspect of education in the information age is user-friendly access to information and tools that facilitate rapid, active, and effective problem-solving, as well as the development/enhancement of STEM education. By providing access to innovative curricula, simulations, and hands-on resources, digital resources have the potential to transform STEM education. Students in STEM fields need to benefit from having access to financial and technological resources and facilities (e.g., labs) to practise the new knowledge and skills they have acquired while studying and to transfer that knowledge and experience to their professional careers. Students with numerous opportunities gain 21st-century skills including critical thinking skills, analytical reasoning, curiosity, learning from failures, and being open-minded and applying innovative methods, which are all necessary for them to put the skills they have acquired into practice. Individuals will play an active role in solving complex problems that will contribute to the field with these basic skills, and changes can occur in the sense of belonging of individuals who are encouraged and supported and who see that they are successful in this field.

When female students feel their social environment to be cold and incompatible with their social needs, the theory of belonging indicates that they will seek out new masculinity-free environments in which they believe meaningful, lasting relationships can be more easily achieved. Social capital is one such helpful theory which is based on the idea that social relations influence an individual's sense of belonging (Ahn & Davis, 2020). The concept of social capital was defined by Bourdieu (1986; 2018) as a resource available to individuals as a result of membership in groups, relationships, networks of influence, and support. In the context of education, Harper explained that social capital facilitates meaningful and value-added relationships among underrepresented students and STEM faculty with other well-connected professionals. The relationships between individuals are the basis of social capital, and these relations may further have implications for them. Interpersonal relationships/peer networks provide an important source of social support and connection that can alleviate alienation and anxiety and have positive influences on student attitudes toward STEM (Bhatia & Amati, 2010; McLure et al., 2022; Mulvey et al., 2022), and increase educational opportunities. Women who engage in peer discussions outside the classroom have been shown to be more likely to persist in STEM fields due to peer interactions and thick interpersonal relationships (Espinosa, 2011; Wester et al., 2021). According to the participants, a powerful sense of belonging to the STEM community increases when people have thick relationships with other members of the community. This is also a result of the fact that individuals have a common purpose/interest in STEM fields. In other words, if the students have a common purpose and motivation with the members of the community with whom they have thick relations, their interest, connections, and probability of continuing and pursuing a career in this field will increase. These community-conscious and purposeful individuals can pave the way to taking the next step toward making STEM settings more inclusive and suitable for everyone.

There are many reasons why young people are not interested in, belong to, or pursue a career in STEM fields, but one of the most crucial factors is stereotypes. Dialogues and interactions of individuals around them cause them to create implicit and explicit social categories (stereotypes) about cultural and gender roles, and inequality associated with the roles produced by society as well as biological characteristics with birth can open them up. Social constructionism may offer a vital framework for understanding the factors that undermine or increase a sense of belonging in the STEM fields. According to social constructionist researchers, the majority of human life is formed through social and interpersonal interactions (see Gergen, 1985, 1994, 2001). Social constructionist ideas emerge from a process of ongoing dialogue and consider that the realities we live in are outcomes of the conversations we engage in (Gergen, 1994, 2001). Social constructionism does not suggest that nothing exists outside of dialogue, but instead that we make sense of the world through engaging in dialogue with those around us. As social categorisation influences daily life, understanding how representations of the social category (gender, ethnicity, identity, etc.) are acquired across developmental stages is critical. Since stereotypes emerge during childhood, there may be changes in individuals' perceptions according to their environment.

Recent evidence shows that children as young as two-and-a-half years old understand gender labels/stability (Mulvey & Irvin, 2018). Master et al. (2017) also found that six-year-old children held stereotypes that boys were better than girls at robotics and programming. Individuals' interest in intellectual abilities, belonging to a field, and progressing in STEM fields is related to the stereotypical perceptions that they are exposed to during their earlier childhood, and this coincides with a critical threshold during the adolescent years. Stereotypes may affect the identities and selves of young people who undergo a period of intense identity development during their adolescence years (Erikson, 1968; O'Brien & Hummert, 2006), and high school is a time when STEM beliefs change and students make more consequential STEM-related choices (Archer et al., 2020; Nathan et al., 2010; van Aalderen-Smeets et al., 2019). Although stereotypes may discourage individuals from choosing STEM fields and advancing in these fields, belonging to STEM fields can enable them to pursue a career in these fields. The study concluded that all human self is connected to others in a relational way (either strong or weak). Social beings are constantly communicating and interfacing with their communities/groups, and their experiences, dialogues, and interactions have both positive and negative impacts on their sense of belonging, their interests, their contributions, and their motivations in their fields of study. Although individuals have intrinsic motivation and individual prompts in STEM fields (i.e. resilience, beliefs in their capacity/ability and inquisitiveness, etc.), social determinants (i.e. receiving adequate support from the STEM community members, social capital and social cohesion, etc.) also play a significant role in influencing individual's sense of STEM belonging.

Implications and limitations

The purpose of this study was to conceptualise the concept of STEM belonging from the students' own perspectives and experiences, which have not been clearly defined in the literature, and there is a lack of agreement about the definition of belonging itself. Therefore, students' perspectives were brought together in this study in an attempt to better understand the main themes of STEM belonging within a broader context of integration. The current study extended the limited research on students' sense of STEM belonging with a rich qualitative exploration of students' own experiences and perceptions. This has provided a series of results that give rise to various implications of both a theoretical and practical nature. From a theoretical point of view, the study contributes to increasing the scientific literature on STEM belonging in the educational field. In addition, the results provide insight into one of the most important factors influencing students to pursue STEM-related careers. This study unpacked the concept of STEM belonging, which is a critical concept that can influence individuals, particularly female and underrepresented students, to overcome the perception that certain groups of people do not fit in these fields. This perception can lead to discontinuation of their involvement in STEM. To overcome the issue of historical male dominance in STEM fields, it is essential to increase students' sense of STEM belonging and create a safe and inclusive environment that encourages everyone to participate and continue in these fields. This can be achieved by understanding the concept of STEM belonging from the perspective of students and taking the necessary steps to ensure that they feel a sense of belonging in these fields. By doing so, the number of women and underrepresented individuals may be increased in STEM fields and inspire them to continue contributing to their respective fields.

This research has a few limitations. One of them is the participants of this research from the Physics, Chemistry, and Mathematical Science disciplines among the STEM disciplines. The perspectives of students who belong to Technology (T) and Engineering (E)-related academic disciplines are not reflected, and the research findings can be expanded by including perspectives of students in the Technology and Engineering-related fields. Second, this study was conducted with students at three Russell Group universities in the UK, and findings could be compared by conducting a similar study with students at non-Russell Group universities. Third, a notable limitation of this study was its homogenous sample (i.e. predominantly White students in their undergraduate studies). Therefore, this study is unable to examine how patterns of perspectives may vary across races or ethnicities, so considering the ideas and opinions of a diverse student group will enrich the study's findings. In addition, it would be beneficial to conduct studies with larger samples, as well as with participants from other geographic regions. It would also be valuable to conduct future longitudinal research by tracking the same group of students from A-level to undergraduate and postgraduate levels throughout the academic year or multiple academic years. This would enable us to understand how their experiences change over time and identify the determinants (e.g., demographic characteristics, institutions, motivations, coping strategies, etc.,) that are most closely linked to their increasing sense of belonging in STEM. Future research might also compare the experiences of students who remained in a STEM field with those who switched to other fields of study. By doing so, we can identify additional areas that need interventions in order to improve their sense of belonging in the field of STEM. In conclusion, this study lays a strong foundation for future research. The findings of the study can be useful for educators, lecturers, mentors, and others involved in teaching students in STEM fields. By gaining a better understanding of the feelings and perspectives of A-level, undergraduate, and postgraduate students, educators can offer the necessary support to make students feel included, heard, and belonged.

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Author contributions
The corresponding author conducted the data collection and data analyses. The author was responsible for the design of the study and the writing of the manuscript. This study is part of the researcher's PhD project by publication.

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Availability of data and materials
The datasets used and analysed during the current study are available from the corresponding author upon request.

Declarations

Ethics approval and consent to participate
Permission was obtained from the University of Durham School of Education Ethics Committee on October 18th, 2022. Written and verbal informed and voluntary consent was received prior to starting the recording of each interview and conducting an online questionnaire. Any participant uncomfortable with completing the informed consent waiver or recording the interview was provided the opportunity to withdraw from the study.

Consent for publication
Participants were informed primarily through the Participant Information pack of additional documents that included separate consent forms for the research project, interviews, and an online survey. A number of additional documents accompanied these documents, which explain the purpose and aims of the project as well as how participants can withdraw their consent. These included a Debriefing sheet, Participant information sheet, and Privacy notice sheet. This project used written consent forms that specifically asked participants for their consent to allow their anonymous data to be used in various publications, including the PhD thesis as well as possible future journals, articles, and conferences. As part of the participant information packs, participants are informed that their comments made during interviews or responses to open-ended survey questionnaires will be published along with the Ph.D. thesis, as well as future articles, journals, and publications.

Competing interests
The author states that there are no competing interests in this manuscript.

Author details
[1]School of Education, Durham University, Durham, UK.

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