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# 'STEM belonging': the association between stereotype vulnerability, COVID-19 stress, general self-efficacy, multidimensional perceived social support, and STEM interest among Physics, Chemistry, and Mathematical Science students

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**ABSTRACT**

This study aimed to develop and validate a theoretical framework elucidating the connections between general self-efficacy (GSE), multidimensional perceived social support (MPSS), STEM interest (SI), stereotype vulnerability (SVS-4), COVID-19 Student Stress (CSSQ), and STEM Belonging (SB) among a diverse group of students in England. An online survey was administered to 290 Mathematics ($n = 83$, 28.6%), Physics ($n =$ 95, 32.8%), and Chemistry ($n = 112$, 38.6%) students in three Russell Group universities in England. The majority of participants ($n = 115$, 43.1%) were between 18 and 19 years old. Data were collected and analysed using a structural equation model and multigroup analysis. The study findings revealed that MPSS, GSE, and SI had a positive impact on students' SB, while CSSQ and SVS-4 had a negative impact on students' SB. The findings revealed that the influence of MPSS on SB and the effect of GSE on SI were found to be statistically significant among female, male, and non-binary students, as well as across A-level, undergraduate, master's, and Ph.D. levels.

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Belonging; STEM education; gender stereotype; COVID-19 pandemic; self-efficacy; higher education

## Introduction

Belonging is crucial for success and motivation in STEM fields (Ezadi et al., 2020; Hoffman et al., 2021). Students' sense of connection and acceptance within their campus community influences their persistence in STEM majors or careers (Sithole et al., 2017). However, female, and underrepresented students may have a lower sense of belonging in comparison to their male or white peers due to the historical dominance of men and white individuals in these fields (Lewis et al., 2019; Rainey et al., 2018). This impacts retention and contributes to the gender gap in STEM fields. Gender disparities in STEM fields are a significant issue in the UK, beginning early in the educational pipeline (Archer et al., 2020). While girls perform as well as or better than boys in STEM subjects at GCSE level, their participation drops significantly at A-levels[1] and further declines at the university level (Siani & Dacin, 2018). The gender gap widens at the postgraduate level and in academic research positions (HESA, 2021). The transition from secondary school to higher education and from a bachelor's degree to a postgraduate degree is a critical phase for academic and social development (Briggs et al., 2012; Meehan & Howells, 2019). During this transition, students' dedication, sense of belonging, and feeling of inclusion in STEM may fluctuate as they encounter new challenges and stressors, as well

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as external factors such as stereotype beliefs, social support, and the impact of the COVID-19 pandemic, along with internal factors like general self-efficacy and interest in STEM. Specifically, persistent stereotypes and implicit biases about gender roles can impact the confidence of female students and contribute to their underrepresentation in STEM (Piatek-Jimenez et al., 2018). Gender imbalances begin with educational choices in post-16 education, as female students received only 43% of awarded STEM A-levels in 2018 (IFS, 2018). The JCQ (2021) data showed that girls accounted for around 40% of entries for A level Mathematics and proportions that have remained consistent in recent years. The Higher Education Statistics Agency (HESA, 2022) in the UK shows that female students are underrepresented in university STEM programmes, particularly in fields like engineering, computer science, and physics. In the 2020/2021 academic year, only 19% of engineering and technology undergraduates were women. In 2019/2020, only 42% of female undergraduates in England enrolled in a science subject area, compared with 51% of male undergraduates (HESA, 2021). In the postgraduate context, a higher proportion of females received STEM postgraduate qualifications in the 2018/2019 academic year compared to female students receiving STEM undergraduate qualifications. With 35% of female postgraduate STEM qualifications, this percentage is significantly higher than the 26% of female undergraduate STEM qualifications (WISE Campaign, 2019). The data indicates a potential decline in the involvement of female students, particularly in STEM disciplines, during the transitional phase. The development of a sense of inclusivity and belonging is critical for promoting students' engagement in these fields. However, various internal factors, such as interest in STEM and self-efficacy, as well as external factors, such as the COVID-19 pandemic, influence students' involvement in STEM. Therefore, this research endeavours to investigate the STEM engagement of students across various educational stages, taking into account internal and external determinants.

### *The term sense of STEM belonging*

Sense of belonging includes feeling a connection and being part of a group, like a school, workplace, or social circle (Lambert et al., 2013). A strong sense of belonging can improve mental health, academic performance, and overall well-being (Gopalan & Brady, 2020). It reduces feelings of loneliness and boosts motivation and participation (Allen et al., 2021). Dost and Mazzoli Smith (2023) defined belonging in higher education 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. 842). Dost (2024) also outlined the concept of belonging in STEM by describing four phases: the 'adaptation phase,' the 'integration phase,' the 'continuum phase,' and the 'transition phase.' In the "adaptation phase," individuals first become interested in STEM fields, and this phase includes the individual's internal drive, innate motivation, and desire to pursue careers in STEM fields. In the "integration phase," individuals connect with STEM fields through their interactions with STEM environments and people in STEM; by sharing their interest in STEM with other group members, ensuring mutual respect and acceptance, as well as feeling harmonious with them. During the "continuum phase," individuals gain self-confidence and develop the skills and knowledge needed to contribute to their fields. By learning core elements of their specific field, supporting each other, and developing skills to overcome challenges in the field, they become STEM literate. When moving from one STEM environment to another or from one educational level to another in STEM, individuals experience the "transition phase," which is characterized by adjusting to a new process, learning new skills, or coping with new experiences. While STEM belonging is important for students pursuing a career in STEM, various factors can negatively impact students' STEM belonging during the transition phase, including stereotypical beliefs and the COVID-19 pandemic. Moreover, factors such as self-efficacy, interest in STEM, and multidimensional perceived social support also positively influence students' STEM belonging.

### Antecedent factors to STEM belonging

The sense of belonging in STEM fields is influenced by various factors. These factors encompass individual attributes such as curiosity, drive, identity, and self-perception, social elements like peer support and connections, as well as structural aspects including stereotype threat and bias. Genuine interest in STEM subjects, driven by curiosity and enthusiasm, results in increased engagement in STEM activities and communities (Hayden et al., 2011; Kearney, 2011). This heightened involvement fosters a stronger sense of belonging as individuals naturally feel connected to the field. The self-perception and identity of individuals in STEM are intertwined with how they perceive themselves in relation to the field, including their sense of fitting in and contributing (Berry et al., 2018). STEM fields have been consistently depicted as challenging environments for women, possibly due to the historical male dominance in the field (Cheryan et al., 2017; Powell et al., 2012). Research attributes observed gender differences in STEM to social, cultural, and psychological barriers that hinder girls' and women's participation in STEM (Soylu Yalcinkaya & Adams, 2020; Wang & Degol, 2017). Societal and cultural expectations contribute to gender-specific environments and experiences, impacting interest, confidence, and the sense of belonging in STEM (Kim et al., 2018; Xu & Lastrapes, 2022). Studies in developmental psychology have shown that group affiliations can significantly influence individuals' thoughts and actions (Telzer et al., 2018). According to the social identity theory, individuals tend to look towards group members for social comparison and approval, leading to the internalization of group norms and values (Brown, 2000). Researchers have highlighted the impact of peer groups on students' academic motivation and achievement (Leaper, 2015). Students' perceptions of their friendship group's STEM climate, although subjective, are crucial as they shape their STEM-related attitudes and achievement (Robnett & Leaper, 2013). The underrepresentation of specific genders and ethnicities in STEM fields in higher education has been linked to higher attrition rates among female and minority students (Whitcomb & Singh, 2021). Archer et al. (2023) discovered that at the degree level, Black students, female students, and those from the lowest Index of Multiple Deprivation (IMD) quintile are still not adequately represented in STEM disciplines, especially in subjects such as physics. Furthermore, the experience of gender-based microaggressions in professional environments decreases the likelihood of women, in particular, to persist in these fields (Kim & Meister, 2023). Often subtle and unintended, these microaggressions communicate exclusion and a lack of inclusivity, significantly impacting women's pursuit of careers in STEM fields and potentially dissuading their continued involvement.

### The factors positively influence sense of STEM belonging

#### Self-efficacy

Understanding the concepts of belonging and self-efficacy is crucial for comprehending student achievement and well-being, particularly in academic contexts. Despite being distinct concepts, they are closely intertwined and can significantly influence each other. Self-efficacy, one factor that positively affects STEM belonging, refers to individuals' belief and confidence in their ability to accomplish tasks (Bandura, 2006; Bandura, 1994). From a social cognitive standpoint, self-efficacy reflects a person's perception of their capacity to successfully complete everyday tasks, which in turn influences their decision-making process (Bandura, 2006; Bandura et al., 1999). The social cognitive career theory (SCCT) model of interest and choice suggests that self-efficacy promotes positive expectations about the outcomes of one's actions (Lent & Brown, 2013). Students tend to develop an interest in academic subjects where they have strong self-efficacy, leading to positive outcome expectations (Chiang et al., 2022; Czocher et al., 2020; Schunk & Pajares, 2002). An individual's beliefs about their abilities can greatly impact their career interests, choices, and performance (Lent et al., 1994). Research has shown that students who have higher self-efficacy in STEM also have greater intrinsic motivation, which is true across STEM disciplines (Banfield & Wilkerson, 2014; Shin & Bolkan, 2021). Moreover, those possessing high self-efficacy are more likely to actively participate in STEM academic environments and community, thereby enhancing their sense of belonging through interaction and connection with others. This leads to increased enrolment in STEM courses, higher performance in those courses, and a greater likelihood of declaring a STEM major and pursuing a career in STEM (Kotera et al., 2023; Mujtaba & Reiss, 2013).

### *STEM interest*

Belongingness has been demonstrated to be a significant factor in sustaining interest and commitment in STEM fields. Having a strong passion for STEM can also result in enhanced knowledge and skills, preparing individuals for successful careers in STEM (Baharin et al., 2018; Hoffman et al., 2021). According to the SCCT theory, self-efficacy influences interests, with most studies concentrating on self-efficacy as a determinant of interest (Lent et al., 1994). However, some researchers have suggested that interest may lead to increased task engagement and more opportunities to develop task-related self-efficacy, indicating a more reciprocal relationship (Nuutila et al., 2021). Stereotypes about STEM professions represent a significant influencing factor in STEM career interest (Van Tuijl & van der Molen, 2016). Garriott et al. (2016) observed that high school students' STEM stereotypes significantly predicted their mathematics/science self-efficacy and interest, which in turn influenced their career goals. Similarly, in engineering, a lack of belongingness significantly contributed to students' decision to leave the field, regardless of their gender (Wilson & VanAntwerp, 2021). For computer science students, Cheryan et al. (2009) discovered that an ambient sense of belonging based on the physical structure and environment of a particular context was associated with women's interest in computer science, regardless of whether women were placed in an environment consisting of mostly women or mostly men.

### *Perceived social support*

Perceived social support refers to the subjective perception of how well a family member, close friend, or special person provides assistance and emphasizes a person's actions as opposed to specific supportive behaviour (Bukhari & Afzal, 2017; Kwon et al., 2022; Zimet et al., 1988). The term 'social support' in the education context refers to the social resources that students perceive to be available and provided by their social environment and research community (Singh et al., 2020; Wilks, 2008). Peers, colleagues, supervisors, and other staff members are included in both formal and informal relationships within the research community (Menzies & Baron, 2014; Wilcox et al., 2005). However, potential sources of social support are not restricted to the academic community and are extended by family, friends, and/or a special person (Mishra, 2020; Zimet et al., 1988). Social support has been proposed as a mechanism for promoting health (Berkman & Glass, 2000; Holliman et al., 2021), positive feelings (Alsubaie et al., 2019), and satisfaction through social relationships (Heaney & Israel, 2008). Support that students receive from their families, friends, and academic community can make a major impact on their ability to cope with challenges and failure in STEM (Corwin et al., 2022). Having support from the immediate environment (family, close friends, and/or a special person), social environment, and research community is associated with a successful transition and integration into university, a sense of belonging, and a positive university experience (Nevill & Rhodes, 2004; Scanlon et al., 2020). Specifically, STEM students who receive these supports can be equipped with the skills necessary to cope with the challenges they face within the STEM environment or the broader community, such as stereotypes (Mishra, 2020; Powell et al., 2012; Villanueva Baselga et al., 2022).

## *The factors negatively impact sense of STEM belonging*

### *The Covid-19 pandemic effect*

The COVID-19 pandemic presented additional stress to students with pre-existing mental health conditions due to the uncertainties and fears caused by the pandemic, as well as the difficulties associated with adjusting to online learning (Chatterjee et al., 2020; Horesh et al., 2020). Individuals who have low levels of self-confidence tended to experience distress and anxiety because they feel powerless and susceptible when confronted with unpleasant circumstances (Long et al., 2022; Lopez & Gormley, 2002). Moreover, female, and underrepresented students in STEM fields were particularly burdened by the challenges posed by the pandemic (Barber et al., 2021). The pandemic has resulted in increased uncertainty and disparate access to opportunities for marginalized students (Tsolou et al., 2021). In such stressful situations, students may heavily depend on the supportive resources and information embedded within their social connections with important individuals to alleviate stress and anxiety, overcome obstacles in online learning, and maintain their psychological and social well-being (Holliman et al., 2021; Saltzman et al., 2020). However, limited social interactions during the pandemic adversely affected the mental health and overall well-being of many students (Defeyter et al., 2021). In the post-pandemic period, some students have encountered challenges in readjusting to normal social interactions and establishing connections within their academic departments or universities (Zhao & Xue, 2023). During unexpected, stressful, or challenging circumstances such as the COVID-19 pandemic, perceived self-efficacy and social support play a crucial role in coping strategies and behaviour, and feel sense of belonging in their area of interest.

### *Stereotype vulnerability*

Gender stereotypes are closely linked to interest, motivation, and performance in STEM fields from childhood to adulthood (Bian et al., 2017; Blažev et al., 2017; Master, 2021; Wang & Degol, 2017). One's social and cultural environment may influence these linkages, including social roles, cultural stereotypes related to subject matter and occupation, gender, beliefs, and behaviours of those who socialize with other individuals, and the individual's abilities and past experiences related to achievement (Eccles, 2007). Personal factors that may contribute to these stereotypes include beliefs about ability, beliefs of those who socialize with the individual, expectations, social roles and stereotypes, perceived difficulty of related tasks, goals, self-schemata, emotional memories, and interpretations of past achievement-related experiences and social influences (Eccles et al., 2004; Wigfield & Eccles, 2000, 2002). Steele (1997) showed that students performing challenging tasks feel anxious about confirming or being judged by stereotypes, which interferes with their performance when they are aware that their abilities are being measured in a domain where members of their group are generally considered to perform poorly. The researchers defined this as 'stereotype vulnerability'.

## Methodology

### *Purpose of the study and research hypotheses*

As previously stated, numerous empirical studies have examined the importance of general self-efficacy, multidimensional perceived social support, STEM interest, stereotype vulnerability, the COVID-19 stress, and sense of belonging among STEM students. However, none of these studies have explored the potential moderating role of gender and educational level in a model that simultaneously examines the relations among these relevant factors simultaneously among Physics, Chemistry, and Mathematical Science students in England. Additionally, no prior studies have investigated the relationship between stereotype vulnerability and STEM belonging through mediating factors such as general self-efficacy, multidimensional perceived social support, STEM interest, and COVID-19 stress. The principal aim of this study was to propose and validate a conceptual model using structural equation modelling (SEM) to elucidate the interconnections among these variables. The secondary objective was to examine the mediating roles of general self-efficacy, multidimensional perceived social support, STEM interest, and COVID-19 stress in the relationship between stereotype vulnerability and STEM belonging. Additionally, the study aimed to investigate the potential moderating influence of gender and educational level within a comprehensive model that concurrently examines the associations among these variables. Based on the previous literature, a conceptual model was created to explain the interrelationships among these factors (Figure 1). To validate the model, this study addressed 14 research hypotheses.

**Hypothesis 1:** Stereotype vulnerability will negatively impact STEM belonging among Physics, Chemistry, and Mathematical Science students.

**Hypothesis 2:** Stereotype vulnerability will negatively influence general self-efficacy among Physics, Chemistry, and Mathematical Science students.

**Hypothesis 3:** Stereotype vulnerability will negatively influence STEM interest among Physics, Chemistry, and Mathematical Science students.

**Hypothesis 4:** Stereotype vulnerability will have a positive effect on COVID-19 stress among Physics, Chemistry, and Mathematical Science students.

**Hypothesis 5:** COVID-19 stress will be negatively associated with STEM belonging among Physics, Chemistry, and Mathematical Science students.

**Hypothesis 6:** COVID-19 stress will negatively influence general self-efficacy among Physics, Chemistry, and Mathematical Science students.

**Hypothesis 7:** Multidimensional perceived social support will have a positive effect on STEM belonging among Physics, Chemistry, and Mathematical Science students.

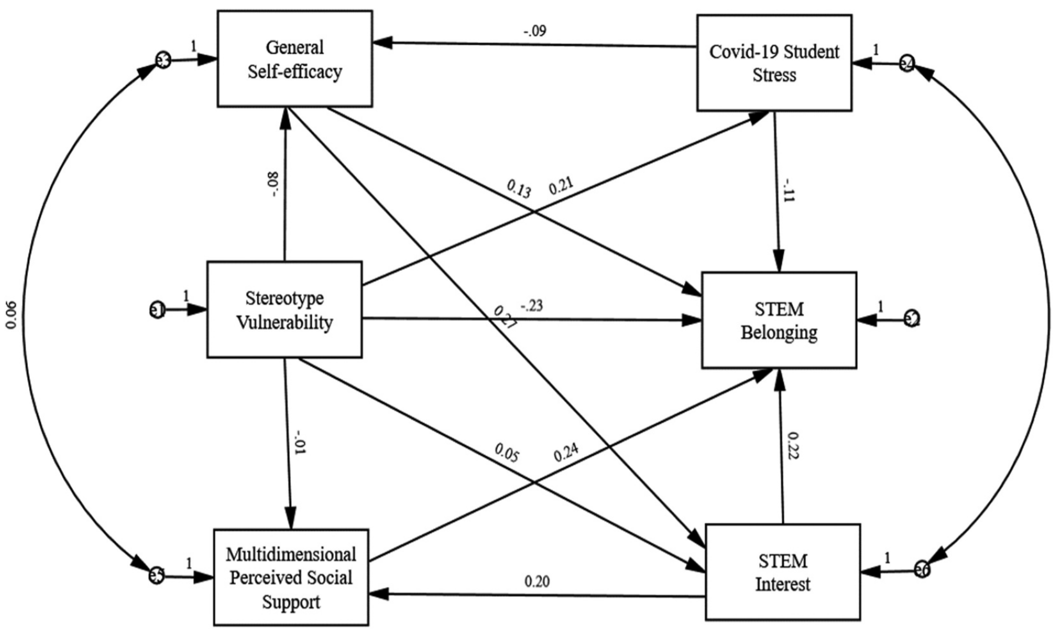


Figure 1. Hypothesised model with determinants of STEM belonging and their interrelationships.

**Hypothesis 8:** STEM interest will have a positive impact on multidimensional perceived social among Physics, Chemistry, and Mathematical Science students.

**Hypothesis 9:** General self-efficacy will have a positive effect on STEM belonging among Physics, Chemistry, and Mathematical Science students.

**Hypothesis 10:** General self-efficacy will have a positive impact on STEM interest among Physics, Chemistry, and Mathematical Science students.

**Hypothesis 11:** STEM interest will have a positive effect on STEM belonging among Physics, Chemistry, and Mathematical Science students.

**Hypothesis 12:** General self-efficacy, multidimensional perceived social support, STEM interest, and COVID-19 stress will serve as mediators in the relationship between stereotype vulnerability and STEM belonging.

**Hypothesis 13.** The associations among general self-efficacy, multidimensional perceived social support, STEM interest, stereotype vulnerability, student stress related to COVID-19, and STEM belonging will differ among female, male, and non-binary students.

**Hypothesis 14.** The associations among general self-efficacy, multidimensional perceived social support, STEM interest, stereotype vulnerability, COVID-19 Student Stress, and STEM Belonging will vary across A-level, undergraduate, master's, and PhD levels.

## *Recruitment and participants*

A purposive sampling strategy was employed to select participants who were A-level, undergraduate, and postgraduate students pursuing studies in STEM fields. Participants were recruited via email and gatekeepers were involved for sending emails to the students. For A-level students, Aspire Higher: Levelling Up Programme[2] coordinator was contacted, and the research invitation emails was sent to programme students at one of the Russell Group[3] Universities and volunteer students were recruited for this study. Physics, Chemistry, and Mathematical Science Department Student Offices were contacted, and research invitation emails were sent to first-year undergraduate students at the same Russell Group University through them. A total of 290 A-level, undergraduate, and postgraduate Mathematical Science, Physics, and Chemistry students completed the questionnaire. The majority of participants ($n = 115$, 43.1%) were between 18 and 19 years old. The Department of Chemistry had the most 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%). All students from the Chemistry department, Physics department, and Mathematical Science department of three Russell Group universities were invited to participate in this study. Additionally, the 'Levelling Up: Aspire Higher' programme A-level students at these three Russell Group universities were also invited to participate. Data were collected from October to December 2022 (a 2-month period) through questionnaires. During this period, three reminders were sent to the students. Students participated voluntarily and did not receive any reward. A total of 320 questionnaires were distributed. The final analysis included 290 questionnaires, excluding 20 questionnaires that had insincere responses (i.e. those that skipped questions in a pattern, or those that were otherwise incomplete or contained unclear responses in some way).

### Ethical considerations

All study procedures were approved by the School of Education Ethics Committee on 18 October 2022, before data collection began. Ethical guidelines were rigorously followed throughout the research process to ensure the protection of participants' rights and confidentiality. Informed consent was obtained from all participants before starting the survey, and measures were implemented to safeguard their anonymity and privacy. Any potential risks or discomforts associated with participation were carefully addressed, and participants were assured of their right to withdraw from the study at any time without consequences. As some A-level participants were under the age of 18, consent posed some challenges. The researcher created pupil-friendly consent, debrief, privacy, and participant information documents to gain transparent and fully informed consent. The aim was to make these less formal, using simple vocabulary, so that students could find them easy to understand and supportive. To ensure that participants were informed properly, the participant information was explained how data would be shared and processed in transparent, robust, and pupil-friendly language.

### Instruments

All data for this study were collected using a questionnaire administered through the JISC Online Survey. To achieve the study objectives, structured questionnaires were used, consisting of demographic characteristics and six factors: general self-efficacy, multidimensional perceived social support, STEM interest, stereotype vulnerability, COVID-19 stress, and STEM belonging. For construct validity, each factor was analysed for reliability, including general self-efficacy, multidimensional perceived social support, STEM interest, stereotype vulnerability, COVID-19 stress, and STEM belonging. To establish content validity, the survey instruments were reviewed by three experts in the areas of Chemistry, Mathematical Science, and well-being/education – all holding doctorate degrees. The feedback from the experts was used to revise the survey instruments, which were then given to the participants. The following sections give details of each of the questionnaires used in this study.

#### STEM belonging

The Psychological Sense of School Membership Scale was initially developed by Goodenow (1993) to measure middle school students' views of school memberships. The scale was modified to cover A-level, undergraduate, and graduate students, and only eight of these modified items were included in this study (e.g. 'It is hard for people like me to be accepted here' was changed to 'It is hard for people like me to be accepted in my STEM settings'). The adapted scale examined students' general sense of STEM belonging (8 items, $\alpha = .78$, see Appendix 1). The items in this combination exhibited loadings that ranged from .57 to .86 (PCA extraction, varimax rotation). Participants rated items on a 5-point Likert-type scale ranging from ''Strongly disagree'' to '"Strongly agree,"' and scores were created by taking the mean of all items.

#### STEM interest

Students' STEM identity (Dou et al., 2019) was measured using a 6-point anchored Likert scale consisting of seven items. The items represented theoretical constructs that makeup identity, including interest and recognition. The STEM Interest subscale included three items: 'I am interested in learning more about STEM,' 'Topics in STEM excite my curiosity,' and 'I enjoy learning about STEM.' The internal reliability measure for the STEM identity items as a whole was 0.97 Cronbach's α.

#### The Multidimensional Scale of Perceived Social Support Scale (MPSS)

The MPSS scale (Zimet et al., 1988) was used to measure the perceived adequacy of social support from family, friends, and a significant other. The scale consisted of 12 items, and participants responded using a 5-point Likert scale (0 = strongly disagree, 5 = strongly agree). The internal reliability measure, Cronbach's coefficient alpha, was obtained for the scale as a whole and for each subscale. The values for the Significant Other, Family, and Friends subscales were .91, .87, and .85, respectively. The reliability of the total scale was 88. The test-retest reliability for the Significant Other, Family, and Friends subscales were .72, .85, and .75, respectively. The whole scale had a value of .85, indicating that the MSPSS demonstrated good internal reliability and adequate stability over the time period indicated.

### *Stereotype Vulnerability Scale (SVS-4)*

SVS-4 was used to measure stereotype threat. The SVS-4 was created by Woodcock et al. (2013) and is a modified and shortened version of the SVS developed by Spencer (1993). It consists of 4 items and is designed to determine the extent to which individuals feel that their group is viewed negatively by society due to stereotypes. The response format for this scale is based on a 5-point Likert scale ranging from 1 (never) to 5 (almost always). For example, one item reads, 'Some people believe you have less ability because of your ethnicity.' In this study, Woodcock et al. (2012) adapted the scale for a large sample of college students who were underrepresented ethnically/racially by replacing ethnicity with gender. The reliability of the SVS-4 was reported as ($\alpha = .85$) by Woodcock et al. (2013) and ($\alpha = .83$) in the current study using Cronbach's alpha reliability coefficient.

### *General self-efficacy (GSE)*

The GSE (Jerusalem & Schwarzer, 1995) was used to measure an individual's overall sense of self-efficacy. Its purpose is to predict how well they will cope with daily stressors and adjust to various stressful life events. Originally developed by Jerusalem and Schwarzer (1981), the German version of the scale was later reduced to a 10-item version. The scale is intended for use with adults and adolescents, and each item refers to successful coping and implies an internal-stable attribution of success. Perceived self-efficacy helps individuals set goals, invest effort, persist in the face of obstacles, and recover from setbacks. It is considered relevant for clinical practice and behaviour change, as it is related to subsequent behaviour. The scale is unidimensional and has high Cronbach's alphas, ranging from .75 to .90.

### *COVID-19 Student Stress Questionnaire (CSSQ)*

The COVID-19 Student Stress Questionnaire (CSSQ) is a tool used to evaluate stress related to the COVID-19 pandemic among university students. It comprises 7 items that assess sources of stress. Exploratory Factor Analysis (EFA) was conducted on the questionnaire using one sub-sample, which revealed a three-component solution. The Confirmatory Factor Analysis (CFA) was then carried out on a separate sub-sample to confirm the dimensional structure. The results indicated that the CSSQ has three subscales that measure stressors related to Relationships and Academic Life, Isolation, and Fear of Contagion. The questionnaire demonstrated good internal consistency with a Cronbach's alpha value of 0.71 and McDonald's omega of 0.71. Only the Relationships and Academic Life subscale, which consists of 4 items, was used in this study. The scale used for undergraduate and postgraduate students with the current format, but the scale was modified for A-level students (e.g. 'How do you perceive the relationships with your university professors during this period of COVID-19 pandemic?' was changed to 'How do you perceive the relationships with your teachers during this period of COVID-19 pandemic?').

## *Data analysis*

In this study, statistical analysis was conducted with the use of IBM SPSS version 27 and IBM AMOS 28 software. Descriptive statistics were analysed using SPSS version 27, while AMOS 28 software was used for other research-related analyses. Frequency analysis, reliability analysis, and correlational analysis were carried out through SPSS. Confirmatory factor analysis (CFA) and Structural Equation Modelling (SEM) were performed through the use of AMOS. Prior to analysis, missing responses and outliers were screened for. Convergent and discriminant validity were assessed through the use of CFA. Convergent validity was evaluated through the intercorrelation and underlying dimension of measurement items. The item reliability of each measure was evaluated through factor loading, with a value of .70 or higher recommended by Hair et al. (2010). The composite reliability of each construct was assessed using an alpha coefficient of .70 or higher, as suggested by Nunnally and Bernstein (1994) to reflect adequate reliability. Average Variance Extracted (AVE) was evaluated with a suggested minimum value of .5 for each factor (Fornell & Larcker, 1981; Nunnally & Bernstein, 1994). Discriminant validity, which measures the uniqueness in the dimension of a scale, was assessed using two analytic procedures suggested by Barclay et al. (1995). The first criterion was that the square root of AVE for each construct should be larger than the inter-construct correlation. The second criterion was achieved when the loading of an item for a construct was greater than its loading for any other construct in the model. SEM was used to assess the research model. Fit indices were utilized to measure model fit. Three categories of fit indices were used: absolute fit indices, parsimony indices, and comparative indices. Absolute fit indices measure how well the proposed model reproduces the observed data, while parsimonious indices take into account the model's complexity (Brown, 2006; Teo et al., 2012). The most common fit index is the model chi-square ($\chi 2$). The next categories of fit indices are the parsimonious indices, which are similar to the absolute fit indices except that they take the model's complexity into account. An example is the root mean square error of approximation (RMSEA). Comparative fit indices evaluate model fit relative to an alternative baseline model (Harrington, 2009). Examples of comparative fit indices cover the Tucker-Lewis index (TLI) and comparative fit index (CFI). The hypothesis outlined in the research model was tested, and path coefficients were calculated to determine significantly related constructs.

## Results

### *Demographic information*

A total of 290 A-level, undergraduate, and postgraduate Mathematics, Physics, And Chemistry students filled out the questionnaire. 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%) (see Table 1).

### *CFA measurement model*

In this study, the CFA was utilized to determine the psychometric properties of the constructs under investigation. The purpose of the CFA was to assess the construct validity of the latent variables and determine if the data fit a preconceived measurement model. To reflect adequate reliability at the construct level, an alpha reliability of .70 and higher is recommended (Nunnally & Bernstein, 1994). In this study, all factors had Cronbach's α coefficient greater than 0.70, indicating that all of the scaled measurements reached satisfactory reliability levels. The reliability of the research questionnaires was calculated using Cronbach's alpha method (see Table 2). The results showed that the STEM belonging scale had a Cronbach's alpha of .858, the STEM interest scale was equal to .869, the COVID-19 scale was equal to .800, the stereotype vulnerability scale was equal to .932, the multidimensional perceived social support was equal to .830, and self-efficacy scale was equal to .814, all at favourable levels.

To use structural equations, factor validity is required, and the results are presented in Appendix 1. The KMO value for the combination of the questionnaire was .825, indicating that the amount of data is suitable for factor analysis. Additionally, the Bartlett index for all variables and their dimensions was less than 0.01, showing that the data has a good correlation. Normality analysis was also conducted, and the data in this study were regarded as normally distributed as the skewness and kurtosis indices were below an absolute value of 3.0 and 8.0, respectively, following Kline's (2010)

**Table 1.** Demographic characteristics of the main characteristics of the sample (*N* = 290).

| Variables | Description | N | % |
|---|---|---|---|
| *Gender* | Female | 141 | 48.6% |
| | Male | 130 | 44.8% |
| | Non-binary | 11 | 3.8% |
| | Prefer not to say | 6 | 2.1% |
| | Other | 2 | 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 (The first generation indicates that both of an individual's parents have not attended university and obtained a degree (Pascarella et al., 2004))* | | | |
| | Yes | 66 | 22.8% |
| | No | 188 | 64.8% |
| | Prefer not to say | 32 | 11.1% |
| | 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.** Descriptive statistics.

| Variables | Number of items included | Cronbach's α | SKEWNESS | KURTOSIS |
|---|---|---|---|---|
| *General self-efficacy (GSE)* | 6 | .814 | −.302 | −.217 |
| *STEM belonging (SB)* | 8 | .786 | −.205 | −.358 |
| *Multidimensional Perceived social support (MSPSS)* | 12 | .830 | −.299 | −.265 |
| *Stereotype vulnerability (SVS-4)* | 4 | .932 | .667 | −.746 |
| *Covid-19 student stress (CSSQ)* | 3 | .800 | .449 | .335 |
| *STEM interest (SI)* | 3 | .869 | −1.00 | .453 |

recommendations. An evaluation of standardized factor loadings and residuals was conducted. Those items with factor loadings below .40 and large standardized residuals were removed from the model (T. A. Brown, 2006). An analysis of the measurement model demonstrated a good fit for a revised model consisting of 36 items, six subscales of general self-efficacy, multidimensional perceived social support, STEM interest, stereotype vulnerability, and COVID-19 stress. To evaluate the model fit, various measures were used, such as the comparative fit index (CFI), Tucker Lewis Index (TLI), and root mean square of error approximation (RMSEA). CFI and TLI values range from 0 to 1, with values above 0.90 and 0.95 indicating acceptable to excellent fit (Bentler, 1990). Lower values of RMSEA suggest better fit, with values less than 0.05 indicating good fit, values up to 0.08 indicating acceptable fit, and values over 0.10 indicating poor fit (Rigdon, 1996). The fit indices for the confirmatory factor analysis of the full measurement model were acceptable with relatively good fit ($\Delta\chi 2/df = 1.5$ (<3 good), RMSEA = 0.04 (<0.08 good), PCLOSE = 0.96 (>0.05 good), CFI = 0.95 (>0.95 great), TLI = 0.94, IFI = 0.95). Table 4 presents the results of the reliability analysis of each construct and the indicator loadings (>.50).

### *Correlation analysis for the CFA measurement model*

To determine the unidimensionality of each measure, correlation analysis was conducted and validated through confirmatory analysis. The direct relationships among stereotype vulnerability, STEM belonging, STEM interest, general self-efficacy, multidimensional perceived social support, and COVID-19 student stress were analysed. The results in Table 3 show that STEM belonging had a positive correlation with STEM interest ($r = 0.28$, $p < 0.01$), general self-efficacy ($r = 0.34$, $p < 0.01$), and multidimensional perceived social support ($r = 0.30$, $p < 0.01$). However, it was negatively correlated with gender ($r = -.256$, $p < 0.01$), stereotype vulnerability (Gender Stereotype) ($r = -0.46$, $p < 0.01$) and COVID-19 Student Stress ($r = -0.31$, $p < 0.01$). COVID-19 Student Stress had a negative relationship with education level ($r = .116$, $p < 0.05$). STEM interest and multidimensional perceived social support also had a positive correlation with general self-efficacy ($r = 0.30$ and $r = 0.20$, respectively, both $p < 0.01$). However, stereotype vulnerability (Gender Stereotype) ($r = -0.18$, $p < 0.01$) and COVID-19 student stress ($r = -0.17$, $p < 0.01$) had a negative correlation with general self-efficacy.

**Table 3.** Correlation between variables included in the study.

| Variables | Mean | Standart Deviation | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|
| *Gender* | 1.65 | .717 | 1 | | | | | | | |
| *Educational Level* | 1.3993 | .93905 | −.050 | 1 | | | | | | |
| *STEM interest (SI)* | 4.5081 | .58297 | −.006 | −.079 | 1 | | | | | |
| *Covid-19 student stress (CSSQ)* | 2.4248 | .95410 | .059 | .116* | −.101 | 1 | | | | |
| *Stereotype vulnerability (SVS-4)* | 2.1675 | 1.19465 | .475** | −.051 | .051 | .258** | 1 | | | |
| *Multidimensional Perceived social support (MSPSS)* | 3.9358 | .64239 | .051 | .100 | .227** | −.046 | −.002 | 1 | | |
| *STEM belonging (SB)* | 3.4776 | .66513 | −.256** | −.042 | .282** | −.312** | −.468** | .308** | 1 | |
| *General self-efficacy (GSE)* | 3.6678 | .66942 | −.193** | .014 | .305** | −.177** | −.186** | .204** | .344** | 1 |

*$p < .05$; **$p < .01$.

Additionally, stereotype vulnerability (Gender Stereotype) had a positive correlation with gender ($r = .475$, $p < 0.01$) and gender had also negative relationship with general self-efficacy ($r = -.193$).

## Convergent validity

To evaluate the measurement properties, SEM and Confirmatory Factor Analysis were employed on a questionnaire containing 32 items. The convergent validity of the questionnaire was tested using factor loading, average variance extracted (AVE), and composite reliability (CR) measures. Adequacy was determined if AVE and CR were equal to or greater than 0.50. The results, presented in Table 4, showed that all AVE and CR scores exceeded the minimum threshold values and factor loadings were above the recommended cut-off point, indicating satisfactory convergent validity at the item level.

**Table 4.** Discriminant validity results for all latent variables.

| Latent variable | Manifest variable | Standardized Factor Loading | Average Variance Extracted (AVE) | Composite Reliability (CR) |
|---|---|---|---|---|
| *General self-efficacy (GSE)* | | | | |
| | GSE1 | .774 | 0.539574 | 0.954248 |
| | GSE2 | .890 | | |
| | GSE3 | .622 | | |
| | GSE4 | .611 | | |
| | GSE5 | .675 | | |
| | GSE6 | .794 | | |
| *STEM belonging (SB)* | | | | |
| | SB1 | .806 | 0.550469 | 0.905988 |
| | SB2 | .865 | | |
| | SB3 | .668 | | |
| | SB4 | .733 | | |
| | SB5 | .573 | | |
| | SB6 | .640 | | |
| | SB7 | .826 | | |
| | SB8 | .776 | | |
| *Multidimensional Perceived Social Support (MPSS)* | | | | |
| | MPSS1 | .594 | 0.723255 | 0.968435 |
| | MPSS2 | .685 | | |
| | MPSS3 | .922 | | |
| | MPSS4 | .850 | | |
| | MPSS1 | .667 | | |
| | MPSS2 | .758 | | |
| | MPSS3 | .914 | | |
| | MPSS4 | .904 | | |
| | MPSS1 | .952 | | |
| | MPSS2 | .987 | | |
| | MPSS3 | .941 | | |
| | MPSS4 | .920 | | |
| *Stereotype vulnerability (SVS-4)* | | | | |
| | SVS1 | .922 | 0.781838 | 0.934552 |
| | SVS2 | .951 | | |
| | SVS3 | .833 | | |
| | SVS4 | .824 | | |
| *Covid-19 Student Stress* (CSSQ) | | | | |
| | CSSQ1 | .783 | 0.604806 | 0.81808 |
| | CSSQ2 | .899 | | |
| | CSSQ3 | .627 | | |
| *STEM Interest (SI)* | | | | |
| | SI1 | .786 | 0.693856 | 0.87161 |
| | SI2 | .853 | | |
| | SI3 | .858 | | |

Average variance extracted (AVE) is computed by ∑λ 2/∑λ2 + ∑ (1 − λ2); Composite reliability (CR) is computed by (∑λ)2/(∑λ)2 + ∑ (1 − λ2), where λ = factor loadings.

### Discriminant validity

The correlations between the latent variables are presented in Table 4. Discriminant validity was assessed by calculating the square roots of the AVEs and comparing the diagonal elements of the correlation matrix with the off-diagonal elements in the corresponding rows and columns. Results, shown in Table 4, demonstrate discriminant validity for all latent variables based on the guidelines suggested by Fornell et al. (1982).

### Test of the structural model and hypotheses

In this study, AMOS 28.0 was used to analyse the hypothesized theoretical model through structural equation modelling (SEM), as the measurement model was acceptable from the CFA analysis. The purpose of SEM in this study was to confirm the goodness-of-fit of the structural model. The global fit indices were computed to measure how well the hypothesized model fits the data, and the fit indices suggested that the structural model was an acceptable fit to the data. The fit indices for the structural model indicated relatively great fit, including $\Delta\chi 2/df = .121$, $p = 0.8$, RMSEA = 0.00, IFI = 0.99, CFI = 0.99, NFI = 0.98, TLI = 0.95, and PCLOSE: 0.98.

This study examined the hypothesized relationships between several variables through SEM, including general self-efficacy, multidimensional perceived social support, STEM interest, stereotype vulnerability, COVID-19 stress, and STEM belonging. Findings of this study showed that SVS-4 had a negative direct influence on SB (H1, β =-.230, $p < 0.001$); second, SVS-4 had a negative direct influence on GSE (H2, β = –.084, $p < 0.01$); third, SVS-4 had no impact on SI (H3, β = .053, $p > 0.05$); fourth, SVS-4 had a significant positive impact on CSSQ (H4, β = .206, $p < 0.001$); fifth, CSSQ had a negative direct influence on SB (H5, β = –.106, $p < 0.01$); sixth, CSSQ had a negative direct influence on GSE (H6, β = –.094, $p < 0.05$); seventh, MPSS had a significant positive impact on SB (H7, β = .237, $p < 0.001$); eighth, the proposed link between SI and MPSS was positive and significant (H8, β = .200, $p < 0.01$); nineth, GSE had a significant positive impact on SB (H9, β = .134, $p < 0.01$); tenth, GSE had a significant positive impact on SI (H10, b = .274, $p < 0.001$); and eleventh, SI had a significant positive impact on SB (H11, β =. 223, $p < 0.001$) (see Table 5). The path diagram of the SEM is presented in Figure 1.

The finding showed that the indirect effect of GSE on SB through SI and MPSS was positive and statistically significant (β = 0.013**) (see Table 6). There was a positive and statistically significant indirect effect of GSE on SB through SI (β = 0.062***). The indirect effect of SI on SB through MPSS was positive and statistically significant (β = 0.042**). The indirect effect of SVS-4 on SB through CSSQ, GSE, SI, and MPSS was statistically significant and positive (β = 0.00*). Through CSSQ, GSE, and SI, SVS-4 had a statistically significant and negative indirect effect on SB (β = –0.002*). The indirect

**Table 5.** Direct effects of structural models.

| | | Overall | | | |
|---|---|---|---|---|---|
| Hypotheses | Direct Effect | β | S. E | t-value | Results |
| H1 | SB<— SVS-4 | –.230*** | .033 | –3.192 | Supported |
| H2 | GSE<— SVS-4 | –.084** | .033 | –2.538 | Supported |
| H3 | SI<— SVS-4 | .053 | .028 | 1.929 | Not Supported |
| H4 | CSSQ<— SVS-4 | .206*** | .046 | 4.530 | Supported |
| H5 | SB <— CSSQ | –.106** | .056 | 4.006 | Supported |
| H6 | GSE <— CSSQ | –.094* | .041 | –2.280 | Supported |
| H7 | SB <— MPSS | .237*** | .049 | 4.868 | Supported |
| H8 | MPSS <— SI | .200** | .066 | 3.038 | Supported |
| H9 | SB <— GSE | .134** | .049 | 2.732 | Supported |
| H10 | SI <— GSE | .274*** | .050 | 5.504 | Supported |
| H11 | SB <— SI | .223*** | .027 | –8.645 | Supported |

*$p < .05$; **$p < .01$; ***$p < .001$.

**Table 6.** The result of hypothesis 12-indirect effects between determinants of students' STEM belonging.

| Indirect Path | Unstandardized Estimate | Lower | Upper | P-Value | Standardized Estimate |
|---|---|---|---|---|---|
| GSE –> SI –> MPSS –> SB | 0.013 | 0.005 | 0.027 | 0.003 | 0.013** |
| GSE –> SI –> SB | 0.061 | 0.033 | 0.100 | 0.001 | 0.062*** |
| SI –> MPSS –> SB | 0.047 | 0.017 | 0.089 | 0.005 | 0.042** |
| SVS-4 –> CSSQ –> GSE –> SI –> MPSS –> SB | 0.000 | −0.001 | 0.000 | 0.012 | 0.000* |
| SVS-4 –> CSSQ –> GSE –> SI –> SB | −0.001 | −0.003 | 0.000 | 0.011 | −0.002* |
| SVS-4 –> CSSQ –> GSE –> SB | −0.003 | −0.007 | −0.001 | 0.016 | −0.005* |
| SVS-4–> CSSQ –> SB | −0.022 | −0.041 | −0.010 | 0.002 | −0.039** |
| SVS-4 –> GSE –> SI –> MPSS –> SB | −0.001 | −0.003 | 0.000 | 0.004 | −0.002** |
| SVS-4 –> GSE –> SI –> SB | −0.005 | −0.012 | −0.002 | 0.002 | −0.009** |
| SVS-4–> GSE –> SB | −0.011 | −0.025 | −0.003 | 0.010 | −0.020* |
| SVS-4–> SI –> MPSS –> SB | 0.003 | 0.001 | 0.007 | 0.023 | 0.005* |
| SVS-4 –> SI –> SB | 0.012 | 0.003 | 0.027 | 0.024 | 0.021* |
| CSSQ –> GSE –> SI –> MPSS –> SB | −0.001 | −0.004 | 0.000 | 0.012 | −0.002* |
| CSSQ –> GSE –> SI –> SB | −0.006 | −0.013 | −0.002 | 0.014 | −0.008* |
| CSSQ –> GSE –> SB | −0.013 | −0.030 | −0.003 | 0.022 | −0.018* |

*$p < 0.050$, **$p < 0.010$, ***$p < 0.001$.

effect of SVS-4 on SB through CSSQ and GSE was negative and statistically significant (β = −0.005*). The indirect effect of SVS-4 on SB through CSSQ was negative and statistically significant (β = −0.039**). SB was negatively and statistically significantly impacted by SVS-4 through GSE, SI, and MPSS. (β = −0.002**). The indirect effect of SVS-4 on SB through GSE and SI was negative and statistically significant (β = −0.009**). The indirect effect of SVS-4 on SB through GSE was negative and statistically significant (β = −0.020*). The indirect effect of SVS-4 on SB through SI and MPSS was positive and statistically significant (β = 0.005*). Through SI, SVS-4 had a positive and statistically significant indirect effect on SB (β = 0.021*). The indirect effect of SVS-4 on SB through GSE, SI, and MPSS was negative and statistically significant (β = −0.002*). There was a negative and statistically significant indirect effect of CSSQ on SB through GSE and SI (β = −0.008*). The indirect effect of CSSQ on SB through GSE was negative and statistically significant (β = −0.018*).

## *Predictive models*

A multigroup path analysis was performed using AMOS 29. Multigroup path analysis permits complex interrelationships to be modelled across and within groups in order to examine similarities and dissimilarities in overall model fit by the grouping variable of interest (i.e. gender and education level). Multigroup path analysis was conducted to explore the potential moderating role of gender and educational level in a model that simultaneously examines the relations among general self-efficacy, multidimensional perceived social support, STEM interest, stereotype vulnerability, COVID-19 stress, and STEM belonging. Analysis of cross-group invariance necessitated comparing two nested models: (1) a baseline model without specified constraints, and (2) a second model where all paths were constrained to be invariant across groups, with only covariates allowed to vary. Additionally, this research systematically imposed constraints on covariates one by one to assess the similarities and differences in their effects across groups and identify the model that best represented the data. Fit indices were good for female (Δχ2/df = .412; NNFI = 99; CFI = 1.00; RMSEA < .05), male (Δχ2/df = .678; NNFI = 99; CFI = 1.00; RMSEA < .05), and non-binary (Δχ2/df = .139; NNFI = 99; CFI = 1.00; RMSEA < .05), providing a good fit to the data. Fit indices were good for A-level (Δχ2/df = .609; NNFI = 98; CFI = 1.00; RMSEA < .05), undergraduate (Δχ2/df =.025; NNFI = 1.00; CFI = 1.00; RMSEA < .05), master's (Δχ2/df = 547; NNFI = 99; CFI = 1.00; RMSEA < .05), and PhD's (Δχ2/df = .749; NNFI = 99; CFI = 1.00; RMSEA < .05), providing a good fit to the data. Table 7 reveals the impact of gender on the hypothetical hypotheses examined.

The finding showed that the direct effect of SVS-4 on SB was negative and statistically significant among female students (β = –.319***) and the direct effect of SVS-4 on CSSQ was positive and

Table 7. The result of hypotheses 13.

| Hypotheses 13 | | Female | | | Male | | | Non-binary | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Hypotheses | Direct Effect | β | S. E | t-value | β | S. E | t-value | β | S. E | t-value |
| H1 | SB<— SVS-4 | −.319*** | .044 | −7.221 | −.030 | .074 | −.401 | −.168 | .214 | −.785 |
| H2 | GSE<— SVS-4 | .024 | .056 | .426 | −133 | .096 | −1.388 | −.280 | .255 | −1.101 |
| H3 | SI<— SVS-4 | .083 | .045 | 1.848 | .005 | .084 | .061 | .243 | .211 | 1.152 |
| H4 | CSSQ<— SVS-4 | .312*** | .074 | 4.218 | .117 | .143 | .822 | .096 | .385 | .249 |
| H5 | SB <— CSSQ | −.064 | .047 | −1.348 | −.141** | .046 | −3.086 | −.176 | .152 | −1.159 |
| H6 | GSE <— CSSQ | −.100 | .059 | −1.701 | −.110 | .059 | −1.884 | .059 | .131 | .447 |
| H7 | SB <— MPSS | .195** | .075 | 2.600 | .208** | .064 | 3.259 | .976* | .470 | 2.077 |
| H8 | MPSS <— SI | .170* | .086 | 1.973 | .292** | .106 | 2.749 | −.097 | .186 | −.524 |
| H9 | SB <— GSE | .119 | .070 | 1.684 | .178** | .069 | 2.579 | .364 | .410 | .887 |
| H10 | SI <— GSE | .276*** | .072 | 3.851 | .190* | .077 | 2.481 | .769** | .238 | 3.238 |
| H11 | SB <— SI | .156* | .078 | 1.996 | .324*** | .080 | 4.066 | .084 | .292 | .288 |

*$p < 0.050$, **$p < 0.010$, ***$p < 0.001$.

statistically significant among female students (β = .312***) (see Table 8). The direct effect of MPSS on SB was positive and statistically significant among female students (β = .195**), male students (β = .208** and non-binary students (β = .976*). The direct effect of SI on MPSS was positive and statistically significant among female students (β = .170*), and male students (β = .292**). The direct effect of SI on SB was positive and statistically significant among female students (β = .156*) and male students (β = .324***). The direct effect of GSE on SI was positive and statistically significant among female students (β = .276***), male students (β = .190*), and non-binary students (β = .769**). The direct effect of CSSQ on SB was negative and statistically significant among male students (β =–.141**).

The finding showed that the direct effect of SVS-4 on SB was negative and statistically significant among A-level (β = –.203***), undergraduate (β = –.242***) and masters (β = –.297***) students. The direct effect of SVS-4 on SI was positive and statistically significant among undergraduate students (β = .065*), and the direct effect of SVS-4 on CSSQ was negative and statistically significant among undergraduate students (β = –.234***). The direct effect of MPSS on SB was positive and statistically significant among all education level; A-level (β = .231*), undergraduate students (β = .170**), and master's students (β = .409**), and PhD students (β = .976*). The direct effect of SI on MPSS was positive and statistically significant among only undergraduate students (β = .226*). The direct effect of GSE on SI was positive and statistically significant among students at four education levels: A-level students (β = .237*), undergraduate students (β = .288***), master's students (β = .317*), and PhD students (β = .769**). The direct effect of SI on SB was positive and statistically significant among only both A-level (β = .151*) and undergraduate students (β = .210**).

## Discussion

### *Theoretical implications*

This study aimed to explore the relationships between various factors such as general self-efficacy, multidimensional perceived social support, STEM interest, stereotype vulnerability, COVID-19 stress, and STEM belonging among Physics, Chemistry, and Mathematical Science students from three Russell Group universities. SEM and multigroup modelling were utilized to analyse the interrelationships between these variables and the impact of students' gender and educational level on these variables. This study's SEM and multigroup modelling result supported the proposed model and extended the existing literature on STEM belonging among Physics, Chemistry, and Mathematical Science students. While many studies have been conducted to investigate factors affecting students' persistence in STEM, STEM interest, multidimensional perceived social support, and general self-efficacy, a limited number of studies have concurrently explored the correlations between these factors and the influence of students' gender and educational level on these relationships. This study found that general

**Table 8.** The result of hypotheses 14.

| Hypotheses 14 | | A-level | | | Undergraduate level | | | Master's level | | | PhD level | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hypotheses | Direct Effect | β | S. E | t-value | β | S. E | t-value | β | S. E | t-value | β | S. E | t-value |
| H1 | SB<— SVS-4 | −.203*** | .055 | −3.683 | −.242*** | .034 | −7.141 | −.297*** | .065 | −4.555 | −.168 | .214 | −.785 |
| H2 | GSE<— SVS-4 | −.274 | .147 | −.019 | −.053 | .045 | −1.176 | −.136 | .084 | −1.624 | −.280 | .255 | −1.101 |
| H3 | SI<— SVS-4 | −.046 | .102 | −.457 | .065* | .032 | 2.010 | .063 | .083 | .760 | .243 | .211 | 1.152 |
| H4 | CSSQ<— SVS-4 | .164 | .118 | 1.392 | −.234*** | 057 | 4.121 | .223 | 128 | 1.748 | .096 | .385 | .249 |
| H5 | SB <— CSSQ | −.017 | .078 | −.218 | −.132 | .043 | −3.057 | −.089 | .073 | −1.211 | −.176 | .152 | −1.159 |
| H6 | GSE <— CSSQ | −.003 | .147 | −.019 | −.054 | .058 | −.943 | −.149 | .089 | −1.677 | .059 | .131 | .447 |
| H7 | SB <— MPSS | .231* | .104 | 2.068 | .170** | .063 | 2.705 | .409** | .127 | 3.220 | .976* | .470 | 2.077 |
| H8 | MPSS <— SI | −.048 | .199 | −.242 | .226* | .093 | 2.429 | .207 | .133 | 1.557 | −.097 | .186 | −.524 |
| H9 | SB <— GSE | .216* | .104 | 2.068 | .103 | .062 | 1.666 | .179 | .124 | 1.441 | .364 | .410 | .887 |
| H10 | SI <— GSE | .237* | .102 | −.457 | .288*** | .058 | 4.949 | .317* | .144 | 2.205 | .769** | .238 | 3.238 |
| H11 | SB <— SI | .151* | .101 | 1.495 | .210** | 077 | 2.712 | .212 | .117 | 1.805 | .084 | .292 | .288 |

self-efficacy, multidimensional perceived social support, STEM interest, and COVID-19 stress mediate the relationship between stereotype vulnerability and STEM belonging. This study also found that STEM interest plays a critical role in the relationship between general self-efficacy and STEM belonging. Highly efficacious individuals are more likely to be interested in STEM, which leads them to feel a sense of belonging and experience fewer negative emotions in achieving their goals. This study provides a major addition to the literature by demonstrating the mediating role of STEM interest between general self-efficacy and STEM belonging. While the positive influence of general self-efficacy on STEM belonging has been well established, our findings provide a more in-depth understanding of the processes involved.

### *Interpreting significant results*

The findings of Hypothesis 1 confirm previous research that shows a negative correlation between stereotype vulnerability and a sense of belonging to STEM fields among Physics, Chemistry, and Mathematical Science students in three Russell Group universities in England (see McGuire et al., 2020; Wood et al., 2022). The effect of SVS-4 on SB was negative and significant only among female students and at the A-level, undergraduate, and master's levels. Studies have established that negative societal stereotypes can have psychological effects on students, particularly female and underrepresented students, in STEM which has historically been male-dominated (Carli et al., 2016). Women who endorse gender stereotypes may perform worse in STEM, and even merely highlighting a woman's gender can have negative consequences (Saucerman & Vasquez, 2014; Shapiro & Williams, 2012). These stereotypes about who can excel in STEM are formed in childhood and reinforced by classroom imbalances in adolescence (Blažev et al., 2017; Kessels, 2015). They continue to impact higher education, the workplace, and broader society, affecting women's representation in STEM (Fogg-Rogers & Hobbs, 2019; Olsson & Martiny, 2018). This can lead to individuals feeling like they don't belong in STEM fields, which can have long-lasting effects on their engagement and motivation (Padwick et al., 2023). Hypothesis 2 found that stereotype vulnerability had a negative effect on general self-efficacy among Physics, Chemistry, and Mathematical Science students, and this effect was consistent across female, male, and non-binary students, as well as across different education levels. Girls as young as six years old may be affected by stereotypes about intellectual ability, which can lead to avoiding difficult tasks and feeling less confident in their abilities (Master et al., 2017). These damaging stereotypes can impact women's self-efficacy, belonging, and career motivation in STEM fields. Research has shown that STEM stereotypes predict future educational and career aspirations (Luo et al., 2021). Hypothesis 3 highlights that there is no impact of stereotype vulnerability on STEM students' interest in STEM. STEM interest is largely established by the end of elementary school (Babarović, 2022), and since stereotypes can emerge in childhood, it is important to intervene at earlier ages to foster these interests. Stereotype threat can negatively affect students' interest and academic performance in STEM settings, particularly underrepresented students like students of colour and female students (Beasley & Fischer, 2012; Shapiro & Williams, 2012). The COVID-19 pandemic has also affected many students negatively, further supporting Hypothesis 4, which shows a relationship between stereotype vulnerability and pandemic stress. This effect was significantly important among female students and undergraduate level. Studies in the UK have shown increased anxiety among students during the pandemic, with effects still ongoing (Chen et al., 2022). Online learning during the pandemic has disrupted students' routines and exposed them to unfamiliar instructional methods and technological obstacles (Coman et al., 2020; Ferri et al., 2020). Chen and Lucock (2022) found elevated levels of anxiety and depression, with over 50% experiencing levels surpassing the clinical thresholds, and female students at one university in the North of England achieving significantly higher scores than males. Appleby et al. (2022) also found that nearly all students at Oxford University acknowledged that COVID-19 is a serious concern. However, they found that female students were more inclined than males to adhere to government recommendations and adjust their lifestyle. The researchers suggested that this gender disparity could be attributed to higher levels of anxiety among female students. These findings also support Hypothesis 4. In addition to the stereotypes in STEM fields, female students have also been affected by the COVID-19 pandemic.

The stress caused by COVID-19 has had a negative impact on the sense of belonging of Physics, Chemistry, and Mathematical Science students, as per Hypothesis 5. The shift to online learning has impacted students' sense of belonging, with some students affected more than others based on factors like gender, ethnicity, and socio-economic background (Mooney & Becker, 2021; Potts, 2021). The pandemic-induced uncertainties and stressful online learning experiences have led to psycho-social maladjustment, which can further harm their well-being (Huang & Zhang, 2022). Studies have shown that the COVID-19 pandemic caused decreased motivation, belonging, and accountability among A-level, undergraduate, and postgraduate students, which can ultimately affect their sense of belonging (Golding, 2021; Marler et al., 2021; Mooney & Becker, 2021; Mulrooney & Kelly, 2020). Feeling disconnected from their department community can also make it difficult for students to concentrate, leading to adverse effects on their studies (Gillard et al., 2021; Jackman et al., 2022). This study also indicated that the stress caused by the COVID-19 pandemic has a particularly strong impact on male students' STEM belonging, with no observable differences across different education levels. Hypothesis 6 has also shown that COVID-19 has negatively influenced general self-efficacy among Physics, Chemistry, and Mathematical Science students. This study indicated that the stress caused by the COVID-19 pandemic shows no significant differences across various education levels and gender. Individuals evaluate their progress and use self-regulation when working towards their goals, with one major appraisal being coping capability or self-efficacy (Schunk & Usher, 2011). Doubts about their capability for success can lead to decreased goal pursuit (Schunk, 2013). Self-efficacy beliefs of students have significantly decreased due to the unexpected disruptions caused by the COVID-19 pandemic, with a large effect on whether they thought they could still achieve their goals (Ritchie et al., 2021).

The findings of Hypothesis 7 confirm that there is a positive correlation between Physics, Chemistry, and Mathematical Science students' sense of belonging and their perceived social support. The study's findings indicated that students' sense of belonging in STEM and their perceived social support were significant across all education levels and genders. This result builds on previous research conducted on STEM students in United Kingdom universities (Dost, 2024; Hoffman et al., 2021). Hypothesis 7 suggests that STEM students who receive higher levels of social support from their parents, friends, or special person are more likely to feel a sense of belonging in STEM fields. Social support can provide students with emotional and informational support, which in turn helps them navigate challenging situations and cope with stress related to their STEM education (Henry et al., 2022). Previous studies have shown that perceiving social support as available can help students manage stress and reduce the negative effects of perceived bias and threats in their field of study (Casad et al., 2021). The results of Hypothesis 8 reveal a positive impact of STEM interest on perceived social support among Physics, Chemistry, and Mathematical Science students. This study also demonstrates that this positive impact is significant for both male and female students, and it has a notable effect at the undergraduate level. Scholars have reported that receiving support from friends, family, and academic environments can help students develop positive outcome expectations and serve as a protective factor in academically challenging environments (Shoffner et al., 2015; Szelényi et al., 2013). Additionally, social support can serve as an important socializing agent in determining a student's choice of field of study and how to balance academic demands with other aspects of their life (Fisher & Stafford, 1999; Lent, Brown, & Hackett, 1994). Support resources can also come from within the academic environment, such as exposure to exemplars of STEM identity and support groups that boost feelings of comfort and belonging (Rosenthal et al., 2011; Taylor & Lobel, 1989). Emotional and informational support, such as encouragement and constructive feedback, have been shown to increase student satisfaction and resilience in their studies (Peltonen et al., 2017; Vekkaila et al., 2018). However, while the availability of social support is crucial, it is not sufficient on its own to determine a postgraduate researcher's sense of belonging in STEM fields (Mantai, 2019).

Close relationships with institution members and high-quality supervision have also been shown to contribute to a positive postgraduate experience and increase self-efficacy and productivity in postgraduate research life (Pyhältö, 2018; Thiry et al., 2011).

Hypothesis 9 found that there is a direct positive relationship between general self-efficacy and a sense of belonging in STEM fields among Physics, Chemistry, and Mathematical Science students in three Russell Group universities. The effect was found to be significant among male students and at the A-level. Bandura's theory (1994) highlights that self-efficacy plays a major role in goal setting and action, where an individual's belief in their ability to master events in their life affects their outcome expectations. If students believe that their success in STEM fields will please their immediate environment, they may work harder and be encouraged to pursue STEM-related fields (Jahn & Myers, 2014; Kier et al., 2014). The study found a strong positive relationship between general self-efficacy and STEM interest, which supports Hypothesis 10. This study also shows that this positive impact is significant for male, female, and non-binary students, and it has a notable effect at all education levels. Many studies have shown that attitudes of students towards STEM and their self-efficacy play a crucial role in selecting a STEM-related career (see Chen et al., 2022; DeCoito & Myszkal, 2018; Halim et al., 2018). Previous research in STEM education has focused on students' confidence in their abilities in STEM classes and their positive attitudes towards STEM, which ultimately lead to their interest and persistence in STEM-related courses and careers (see LaForce et al., 2017; Sithole et al., 2017). This research has shown that there is a positive connection between STEM interest and STEM belonging among Physics, Chemistry, and Mathematical Science students in three Russell Group universities in England, as demonstrated by Hypothesis 11. The effect was found to be significant among male and female students and at the A-level and undergraduate level. Encouraging students' interest and motivation in STEM fields has been proven to increase their sense of belonging in STEM and promote STEM career choices (Dasgupta & Stout, 2014; Master et al., 2016; Wang & Degol, 2013). Studies have found a strong correlation between students' early interest, their sense of belonging in STEM, and the career they ultimately choose (Tai et al., 2006; Yoel & Dori, 2021). Tai et al. (2006) discovered that the career choices of eighth graders are strong predictors of their careers at age thirty.

This research has shown that general self-efficacy, multidimensional perceived social support, STEM interest, and COVID-19 stress served as mediators in the relationship between stereotype vulnerability and STEM belonging, as demonstrated by Hypothesis 12. These variables exert both positive and negative influences on the students' sense of STEM belonging. Furthermore, interdependencies among these variables have been noted. The level of involvement of an individual in STEM disciplines can be influenced by an interplay of internal and external factors. Internal factors, such as social support, interest, and self-efficacy, exert substantial influence. Positive social support serves as a protective element against the detrimental impacts of stereotypes within the STEM fields (Rosenthal et al., 2011). A strong interest in STEM has a positive bearing on students' drive, engagement, and capacity to interact with their environment. Furthermore, self-efficacy, denoting an individual's perception of competence when confronted with challenges, plays a pivotal role. These internal factors have been demonstrated to produce favourable outcomes within STEM disciplines. Conversely, external factors, such as susceptibility to stereotypes and the repercussions of the COVID-19 pandemic, also hold sway over students' sense of inclusion in STEM, as well as their involvement and accomplishments in these areas. A comprehensive understanding of the relationships between these variables and their impacts on STEM belonging will aid in mitigating the gender and ethnic disparities prevalent in STEM fields, thereby positively impacting the sense of belonging for many students either contemplating a STEM career or already engaged in one. This understanding holds significant importance.

The findings from Hypothesis 13 suggest that SVS-4 exerts a statistically noteworthy influence on SB and CSSQ, particularly among female students. Specifically, the findings from Hypothesis 14 suggest that SVS-4 demonstrated a negative and significant effect on SB across A-level, undergraduate, and master's levels, while its influence on CSSQ was statistically positive and significant only at the undergraduate level. The aforementioned finding is consistent with existing literature, suggesting that stereotypical perceptions have been shown to negatively impact female students across various educational levels, impeding their sense of inclusion and belonging within these disciplines (Ertl et al., 2017; Makarova et al., 2019). This research demonstrated a substantial correlation between stereotype vulnerability and stress induced by the COVID-19 pandemic, particularly among female students and at undergraduate level. This connection suggests that an increase in stereotype vulnerability corresponds to heightened pandemic-induced stress experienced by female students. At the undergraduate level, students establish social connections and foster close friendships, which significantly influence their sense of belonging to academic fields, degree programmes, and the university as a whole (Strayhorn, 2018). The measures implemented during the pandemic, resulting in restricted social interactions with peers and academic faculty, have disproportionately impacted female undergraduate students, leading to a particularly pronounced effect (Hunt et al., 2021; Misca & Thornton, 2021). Consequently, female students, who often exhibit low self-efficacy in these areas, may experience heightened stress within STEM fields, consequently reducing their attraction to STEM careers when compared to their male counterparts (McKinney et al., 2021). The influence of MPSS on SB and the effect of GSE on SI were found to be statistically significant among female, male, and non-binary students, as well as across A-level, undergraduate, master's, and Ph.D. levels. Additionally, the effect of SI on MPSS and SB proved to be statistically significant for both female and male students. Pursuing a deep interest in STEM often serves as a significant motivation for students, shaping their academic and career trajectories and fostering a strong sense of purpose and direction (Wang, 2013). A genuine passion for STEM subjects aligns students with the values and goals of the broader STEM community, reinforcing their sense of belonging and fostering a positive perception of the community's support (Xu & Lastrapes, 2022). This literature finding also corroborates the research's conclusion, demonstrating that students' inclination towards STEM fields and their sense of belonging are shaped by both social support and self-efficacy. The presence of these variables serves as a positive influence on students, fostering an increased belonging and interest in STEM fields. Conversely, the absence of these variables has a negative impact, leading to a decline in students' belonging and interest in STEM. The study also unveiled that CSSQ and GSE significantly affected SB exclusively among male students. Moreover, there was no significant variance in the impact of CSSQ on SB across different educational levels. The research findings indicated a decline in the sense of belonging among male students in STEM disciplines, attributed to the stress induced by the COVID-19 pandemic. The literature showed that heightened levels of depression and loneliness were noted among adolescents and young adults, with researchers linking these trends to increased stress during the pandemic (Casagrande et al., 2020). Additionally, recent data suggested a higher likelihood of females experiencing loneliness, depression, and anxiety during the COVID-19 pandemic (González-Sanguino et al., 2020). The findings of this research underlined statistically significant and adverse effects of the stress caused by the COVID-19 pandemic among male students and at A-level. The transition from A-level to undergraduate study, coupled with the challenges of the pandemic, potentially exacerbated stress among male students, impacting their sense of belonging and self-efficacy.

## *Practical implications*

There are several practical implications in this study. Understanding the interaction between STEM belonging, social support, self-efficacy, STEM interest, gender stereotypes, and COVID-19 related stress has practical implications for educators, institutions, and policymakers. Despite the UK government's efforts to promote STEM education, there is a lack of knowledge regarding factors that affect STEM students' sense of belonging. The concept of belonging itself is vague and needs to be defined and conceptualized through further research. This study provides important background information that can help increase STEM students' sense of belonging at different levels of education and develop effective frameworks for their participation and socialization in STEM fields. The study also highlights the significance of multidimensional perceived social support, general self-efficacy, and STEM interest in increasing students' sense of STEM belonging. On the other hand, factors such as stereotype threats and unprecedented circumstances like the COVID-19 pandemic can negatively impact students' sense of belonging. Thus, developing prevention and intervention programmes that address stress related to the pandemic and common stereotypical views can significantly enhance STEM students' sense of belonging. Furthermore, identifying factors that affect STEM students' sense of belonging can offer insights on how to develop more effective intervention programmes for underrepresented groups such as female students, students from underrepresented backgrounds, and students of colour. The background of students including socio-economic status, ethnicity, gender, and previous educational experiences) has a notable impact on how they feel they fit in within STEM fields (Cheryan et al., 2017; Tripney et al., 2010). Students from more privileged socio-economic backgrounds usually have better access to high-quality education, extracurricular STEM activities, and resources like private tutoring (Gorard & See, 2009). This early exposure and preparation can boost their confidence and sense of belonging in STEM. On the other hand, students from less privileged socio-economic backgrounds may encounter financial obstacles that restrict their involvement in STEM activities, leading to feelings of exclusion and reduced belonging (Banerjee & Lamb, 2016. Students from ethnic minority groups might face implicit biases and stereotypes that challenge their abilities in STEM (McGee, 2018). These negative experiences can erode their confidence and sense of belonging. Institutions that actively encourage diversity and inclusion can help alleviate these challenges, creating a more welcoming environment for all students. Female students in male-dominated STEM programmes might feel marginalised or less supported by their peers, which can affect their sense of belonging. The existence of successful female role models in STEM can motivate and empower female students, strengthening their sense of belonging. Targeted mentorship programmes for female students can offer vital support and reinforcement of their position in STEM fields.

### *Limitations and future studies*

There are several limitations that need to be considered when evaluating the current study. Firstly, the study only included three Russell Group universities in England, so it is important to exercise caution when applying the findings to other Russell and non-Russell Group universities in the country. Secondly, conducting the research with a larger group can further validate the study and enhance its generalizability. Thirdly, the study's results, which suggest that all hypothesized direct links were significant, and that multidimensional perceived social support, general self-efficacy, STEM interest, and COVID-19 stress acted as mediators in different links, were based on cross-sectional data. Fourthly, the views of students studying Technology (T) and Engineering (E) disciplines are not represented in the research findings. To expand the scope of the research, future studies could consider incorporating the viewpoints of students in the Technology and Engineering fields. To obtain clearer information about causal inference, longitudinal studies may be more helpful. It is also crucial for forthcoming research endeavours to encompass a varied student demographic, with a specific emphasis on discerning the factors influencing the sense of belonging of students from diverse ethnic backgrounds, varying socio-economic strata, and different genders towards STEM disciplines. Additionally, instead of relying solely on quantitative research methods, future studies could benefit from incorporating qualitative research methods.

## Conclusion

The purpose of this study was to propose and test a conceptual model that explains the interrelationships among general self-efficacy, multidimensional perceived social support, STEM interest, stereotype vulnerability, COVID-19 Stress, and sense of STEM Belonging among Physics, Chemistry, and Mathematical Science students in the three Russell Group universities in England. The findings revealed that the influence of MPSS on SB and the effect of GSE on SI were found to be statistically significant among female, male, and non-binary students, as well as across A-level, undergraduate, master's, and Ph.D. levels. The study found that multidimensional perceived social support, general self-efficacy, STEM interest, and COVID-19 stress all had significant impacts on STEM belonging. Specifically, multidimensional perceived social support, STEM interest, and general self-efficacy had positive impacts on students' STEM belonging, while COVID-19 student stress and stereotype vulnerability had negative impacts on students' STEM belonging. Additionally, stereotype vulnerability had a positive impact on COVID-19 stress and a negative impact on both general self-efficacy and STEM belonging. However, stereotype vulnerability did not have a significant impact on STEM interests. Finally, the study found that general self-efficacy, multidimensional perceived social support, STEM interest, and COVID-19 stress all played a role in mediating the relationship between stereotype vulnerability and a sense of STEM belonging.

## Notes

1. A-Levels are Advanced Level qualifications designed for students aged 16–18-year-olds in the UK. These qualifications typically require two years to complete and are recognized by higher education institutions in the UK and around the world. To gain entry to most UK universities, students need to have a minimum of three A-level qualifications (UCAS, 2012).
2. The academic and pastoral support program 'Levelling Up: Aspire Higher' runs from March of Year 12 and continues until March/April of Year 13. It is designed for Year 12 students who are looking to pursue studies in Chemistry, Maths, or Physics at Russell Group universities.
3. Russell Group universities were formed with the purpose of protecting the interests of 24 universities and ensuring that they maintain high standards in teaching and research (Russell Group, 2023).

## Disclosure statement

No potential conflict of interest was reported by the author(s).

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## Author's contribution

The author has read and approved the manuscript.

## Availability of data and material

The datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request.

## Ethics approval and consent to participate

This study has been approved by the University of Durham School of Education Ethics Committee with the application reference: EDU-2022-12-01T19:20:06-vfjp66. The consent from study participants was obtained via the consent form.

## Consent for publication

The limited personal details of participants presented in this study were obtained permission by the study participants via the participant information form and consent form.

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## Appendix 1. List of items used in this study

| Latent variable | Manifest variable | Standardized Factor Loading |
|---|---|---|
| ***General self-efficacy (GSE)*** | | |
| Thanks to my resourcefulness, I know how to handle unforeseen situations | GSE1 | .774 |
| I am confident that I could deal efficiently with unexpected events. | GSE2 | .890 |
| I can usually handle whatever comes my way. | GSE3 | .622 |
| I can remain calm when facing difficulties because I can rely on my coping abilities. | GSE4 | .611 |
| I can always manage to solve difficult problems if I try hard enough | GSE5 | .675 |
| I can solve most problems if I invest the necessary effort. | GSE6 | .794 |
| ***STEM belonging (SB)*** | | |
| Feeling valued. | SB1 | .806 |
| Feeling disregarded. | SB2 | .865 |
| Feeling included when completing group work | SB3 | .668 |
| It is hard for people like me to be accepted in my STEM settings. | SB4 | .733 |
| I feel very different from most other students in my STEM settings. | SB5 | .573 |
| Other students in my STEM settings like me the way I am. | SB6 | .640 |
| In my STEM settings, I enjoy being an active participant. | SB7 | .826 |
| In my STEM settings, I try to say as little as possible. | SB8 | .776 |
| ***Multidimensional Perceived Social Support (MPSS)*** | | |
| My family really tries to help me. | MPSS1 | .594 |
| I get the emotional help and support I need from my family. | MPSS2 | .685 |
| I can talk about my problems with my family. | MPSS3 | .922 |
| My family is willing to help me make decisions. | MPSS4 | .850 |
| My friends really try to help me. | MPSS5 | .667 |
| I can count on my friends when things go wrong. | MPSS6 | .758 |
| I have friends with whom I can share my joys and sorrows. | MPSS7 | .914 |
| I can talk about my problems with my friends. | MPSS8 | .904 |
| There is a special person who is around when I am in need. | MPSS9 | .952 |
| There is a special person with whom I can share my joys and sorrows. | MPSS10 | .987 |
| I have a special person who is a real source of comfort to me. | MPSS11 | .941 |
| There is a special person in my life who cares about my feelings | MPSS12 | .920 |
| ***Stereotype vulnerability (SVS-4)*** | | |
| Some people believe that you have less STEM ability because of your gender. | SVS1 | .922 |
| If you are not better than average in STEM, people assume you are limited because of your gender. | SVS2 | .951 |
| If you do poorly on a STEM test/assignment, people will assume that it is because of your gender. | SVS3 | .833 |
| People of your gender face unfair evaluations in STEM settings because of their gender. | SVS4 | .824 |
| ***Covid-19 Student Stress* (CSSQ)** | | |
| How do you perceive the relationships with your university colleagues ('peers' were used for A-level students) during this period of COVID-19 pandemic? | CSSQ1 | .783 |
| How do you perceive the relationships with your university professors (teachers were used for A-level students) during this period of COVID-19 pandemic? | CSSQ2 | .899 |
| How do you perceive your academic studying experience during this period of COVID-19 pandemic? | CSSQ3 | .627 |
| ***STEM Interest (SI)*** | | |
| I am interested in learning more about STEM | SI1 | .786 |
| Topics in STEM excite my curiosity | SI2 | .853 |
| I enjoy learning about STEM | SI3 | .858 |