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Pathways to STEM identity: high school students' perceptions in Qatar

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Introduction: This study delves into the intricate relationship between various constructs of student identity formation, which helps comprehend their subsequent impact on students' interest and persistence in Science, Technology, Engineering, and Mathematics (STEM) fields. Understanding how disciplinary identities contribute to the development of a holistic STEM identity is critical for shaping effective educational strategies.

Methods: Utilizing a survey-based quantitative approach, this research encompasses data from 1,428 high school students. The study examined the influence of disciplinary identities in Mathematics, Science, and IT on the overall STEM identity.

Results: The principal findings underscore that students' identities in specific disciplines-Mathematics identity ($\beta = 0.55$, $p < 0.001$), Science identity ($\beta = 0.12$, $p < 0.001$), and IT identity ($\beta = 0.36$, $p < 0.001$)-positively influence their overall STEM identity. Among these, the Mathematics identity exhibited the most substantial positive relationship. Additionally, the constructs associated with each disciplinary identity, particularly "recognition" and "sense of belonging," demonstrated the strongest correlations within STEM subjects.

Discussion: These insights are pivotal for policymakers and educators aiming to cultivate a robust STEM identity among the younger generation. By fostering recognition and a sense of belonging within STEM subjects, these findings pave the way for more inclusive and effective strategies in STEM education.

KEYWORDS

STEM identity, interest, recognition, sense of belonging, performance

1 Introduction

Economic growth and diversification are intimately tied to education, specifically in fields that drive innovation and serve to establish new industries (Yami et al., 2021). Central to this interconnectedness is the cultivation of industries sustained by a well-educated and highly skilled workforce (Smith, 2024). As such, Science, Technology, Engineering, and Mathematics (STEM) education plays a crucial role in equipping students with the requisite ideas, analytical prowess, and innovative skills to spearhead the development of novel and creative ideas, consequently contributing to the economy and creating new job opportunities (Trapani and Hale, 2022).

This venture is particularly salient for Qatar, where the realization of a knowledge-based economy hinges on the ability of the populace to generate novel knowledge, develop innovative products, and establish emergent industries (Ashraah and Yousef, 2020). By equipping the next generation with essential skills, STEM education nurtures a cohort of future innovators poised to drive sustained economic growth and diversification (Klatt and Milana, 2020). Therefore, prioritizing STEM education is imperative for Qatar's trajectory toward a robust, knowledge-driven economy (Hazaimeh et al., 2022).

Aligned with the strategic goals articulated in the Qatar National Vision 2030 (QNV 2030), particularly those aimed at economic diversification and sustained progress, STEM education is critical to Qatar's development (Ben Hassen, 2021; Sever and Tok, 2022). QNV 2030 serves as a blueprint for transforming Qatar into a developed nation capable of self-sufficiency and prosperity. Central to this vision is Qatar's aim to transition from its current reliance on oil and gas exports to a knowledge-based economy (Al-Qahtani and Shirazi, 2023). This strategic shift highlights the need to invest in STEM education as a means of cultivating a skilled workforce capable of driving innovation and technological advancement (Sellami et al., 2024). By nurturing a knowledge-driven economy, Qatar seeks to mitigate the potential challenges associated with the depletion of hydrocarbon resources, thus ensuring long-term sustainability and prosperity.

The purpose of this research was to delve into the interaction between four key constructs—interest, performance/competence, sense of belonging, and recognition—and their influence on students' STEM identity in Qatar. Specifically, we aimed to unravel how these factors shape students' STEM identity. By examining how these factors interact and determine the ways in which individuals perceive themselves as STEM learners, the study aspires to offer valuable insights into the factors that contribute to the development of STEM identity among students in Qatar and elsewhere. In so doing, it contributes to a better understanding of students' educational pathways and future aspirations in the context under study and beyond.

Understanding the formation of STEM identity is important for educators, researchers, educational policymakers, and institutions locally and internationally. By investigating the specific factors that influence students' STEM identity, this study can inform the development of targeted interventions and initiatives aimed at enhancing STEM education outcomes and promoting a greater sense of engagement and belonging among students. Furthermore, as Qatar continues to invest in initiatives to promote STEM education and workforce development, insights from this study can contribute to evidence-based strategies that support the nation's broader goals of innovation, economic diversification, and sustainable development.

Structured in four main sections, this paper first introduces students' STEM identity and reviews its theoretical underpinnings. It then discusses the constructs influencing students' STEM identity in educational settings. The second section of the paper details the methodology used in this research, including data collection procedures, the research instrument, and the mode of analysis, offering a comprehensive view that bridges theory with empirical analysis. The subsequent section offers a detailed description of the results obtained from the study's analysis. Following this, we dig into a discussion of these findings. The paper concludes by presenting practical recommendations and suggestions for future research.

2 Literature review

STEM, an acronym for Science, Technology, Engineering, and Mathematics, represents an interdisciplinary approach to learning and problem-solving that integrates knowledge and skills from these four core disciplines (Lin et al., 2023). Stemming from an educational and professional framework, STEM fields encompass a wide array of subjects and industries, ranging from pure sciences such as biology and physics to applied fields like computer science and engineering. The emphasis within STEM education is often on fostering critical thinking, creativity, collaboration, and innovation to address complex challenges in the modern world, driving advancements in technology, infrastructure, healthcare, and beyond (Bybee, 2013; Norris et al., 2023).

STEM education is recognized globally for its critical role in shaping a nation's future through the cultivation of human capital, fostering innovation, and addressing pressing societal challenges (Idris and Bacotang, 2023). This recognition is highlighted in abundant research emphasizing the intertwined link between STEM fields and global competitiveness. A crucial aspect of STEM education lies in its contribution to human capacity building beyond mere workforce preparation. STEM education cultivates critical thinking, problem-solving skills, and the ability to devise real-world solutions, particularly in areas such as health, energy, and the environment. This empowerment enables nations to thrive in an increasingly complex and dynamic global landscape. Existing research confirms the multiple benefits of STEM education (Kayan-Fadlelmula et al., 2022), including its significance in driving societal progress and resilience (Jamali et al., 2023).

By nurturing a proficient STEM workforce and fostering a culture of innovation, nations can position themselves competitively and adapt effectively to emerging challenges and opportunities. In Qatar and the broader Gulf Cooperation Council (GCC) region, leaders acknowledge the necessity of transitioning to knowledge-based economies. To achieve this goal, they have increasingly prioritized equipping their local populations with STEM credentials to meet the demands of the labor market. Despite substantial investments in educational reforms and resources, the GCC countries continue to face persistent challenges in enhancing student achievement in STEM subjects.

2.1 STEM identity

The concept of STEM identity has gained prominence in educational research, particularly in terms of understanding STEM-related interests, engagement, and career aspirations of students, especially those at the high school level (Wade-Jaimes et al., 2023). Recognizing the pivotal role of identity formation in shaping students' educational pathways and career choices, the study of STEM identity has garnered increasing attention (Chiu, 2024). As educators and policymakers grapple with the promotion of STEM participation, understanding how students perceive themselves within the STEM domain is essential. Indeed, in recent years, there has been a surge of interest in the concept of "STEM identity (Looi et al., 2023)." The literature stresses the complex nature of this concept, which significantly influences individuals' educational experiences and future career decisions.

STEM identity, defined as an individual's sense of belonging, competence, and identification with STEM disciplines, encompasses an assortment of personal, social, and contextual factors. As highlighted by Hazari and other researchers, STEM identity comprises cognitive, affective, and behavioral components, reflecting not only proficiency in STEM subjects but also emotional

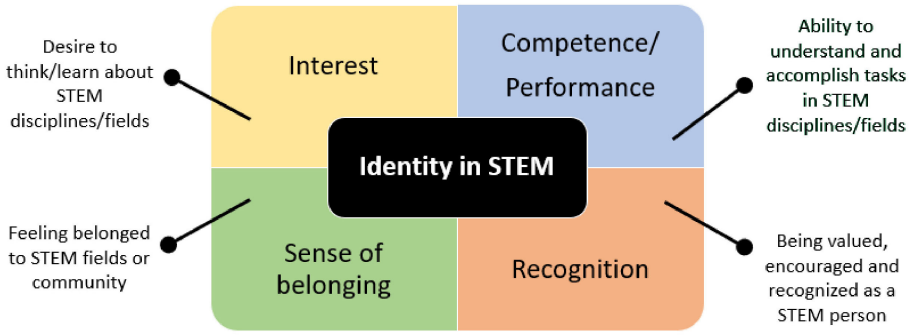

FIGURE 1
Four constructs influencing students' STEM identity.

connections and behavioral inclinations toward STEM-related activities and careers (Hazari et al., 2020; Mahadeo et al., 2020). Several influential factors contribute to the formation and shaping of STEM identity among high school students (Hazari et al., 2020; Mahadeo et al., 2020).

Firstly, family attributes and socio-economic background play important roles in determining students' perceptions of STEM fields and their sense of belonging within these domains (Archer et al., 2015). Secondly, school experiences, including the quality of STEM instruction, availability of resources, and exposure to role models and mentors, significantly impact students' STEM identity development (Wang and Degol, 2017). Thirdly, societal influences, such as media representations of STEM professionals and prevailing stereotypes, contribute to the construction of STEM-related identities (Corsbie-Massay and Wheatly, 2022; Chen et al., 2023).

Furthermore, individual characteristics, including self-efficacy, interests, and prior experiences, interact with contextual factors to shape students' STEM identities (Maltese and Tai, 2010). For instance, students with high self-efficacy beliefs in STEM fields are more likely to develop a strong STEM identity and pursue STEM careers (Hazari et al., 2020; Halim et al., 2023). Similarly, intrinsic interests and early exposure to STEM activities can foster a positive STEM identity and sustained engagement in STEM fields (Maltese and Tai, 2010).

2.2 Constructs influencing students' STEM identity

In STEM education, students' identity formation—as can be gleaned from the preceding discussion—is closely woven with and influenced by four key constructs: interest, performance/competence, recognition, and sense of belonging (Figure 1). Understanding the interrelatedness and interaction among these constructs, factors, and dimensions is key to the comprehension and promotion of STEM identity among students; this will ultimately help in enhancing diversity, inclusion, and achievement within STEM fields (Godwin et al., 2013). These four constructs intertwine, shaping students' academic pursuits and their identities as future engineers, scientists, and innovators (Luo et al., 2021).

STEM identity formation is determined by individual attributes and the interaction of internal and external factors (Santhosh et al., 2024). Internal factors comprise personal attributes such as confidence, curiosity, and self-efficacy, which shape students' attitudes and motivations toward STEM subjects. These internal drivers interact with external factors, including institutional norms, educational practices, and societal perceptions, which collectively contribute to students' perceptions of themselves within STEM fields. These factors can either positively or negatively shape an individual's identity within STEM fields, as highlighted by Abidin (2022) and Razali (2021). Positive experiences and supportive environments can bolster students' confidence and sense of belonging, whereas negative experiences or stereotypes can undermine their confidence and deter them from pursuing STEM pathways.

Prior research has examined STEM identity along three important dimensions (Howard, 2023). Firstly, the "Subjective/Social" dimension explores how individuals perceive themselves in relation to STEM, including their attitudes, beliefs, and sense of identity within the field. Secondly, the "Representational/Enacted" dimension focuses on how individuals enact their STEM identity in various contexts, including academic settings, social interactions, and career aspirations. Finally, the "Change/Stability" dimension acknowledges the dynamic nature of identity development within STEM, recognizing that individuals' identities may evolve over time in response to experiences, opportunities, and personal growth (Howard, 2023; Jergins, 2023; Verdugo-Castro et al., 2023; Wrigley-Asante et al., 2023).

In Qatar, rapid modernization has shifted the traditional mindset to a more modern forward-looking one. Although attitudes toward female employment have improved, it is still not widely acceptable for women to work in environments involving interaction with male colleagues. This presents a significant challenge for Qatari females seeking employment in STEM-related fields, which are often male-dominated (Naguib and Madeeha, 2023). The low percentage of women in the workforce indicates that Qatari women face considerable obstacles in pursuing employment

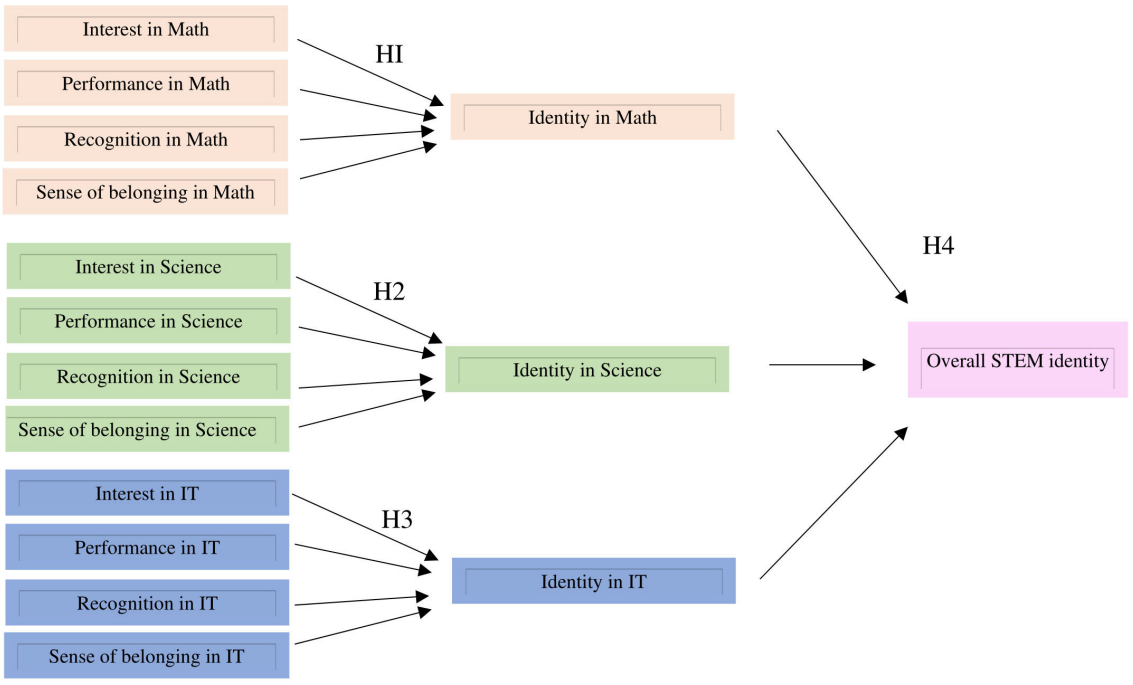

FIGURE 2
Hypothesized model of factors influencing students' STEM identity formation.

in any field. Therefore, efforts are required to encourage women to enter STEM fields of study from a young age and consider future STEM-related careers. This may be achieved through career guidance, informing them of the increasing accessibility of work environments to women and the numerous advantages of working in STEM fields.

3 Theoretical framework

In this current research, we drew on the established structural models for STEM identity, which offers a comprehensive theoretical framework that is particularly well-suited for exploring the multi-faceted nature of identity formation in STEM fields (Hazari et al., 2020; Santhosh et al., 2024). By integrating the four critical constructs of interest, performance/competence, recognition, and sense of belonging, their model provides an informed understanding of the dynamics influencing students' self-perception and engagement with STEM disciplines.

This framework acknowledges that each of these elements does not operate in isolation but rather in a complex interaction with the others, suggesting that STEM identity is both multi-dimensional and context-dependent. The utility of this model lies in its ability to facilitate a detailed examination of how various educational experiences and classroom environments influence students' identity in STEM domains, potentially guiding targeted strategies to enhance student engagement and retention in these fields. Therefore, adopting this comprehensive model can enhance research methodologies by offering a robust framework to analyze the psychological and social factors influencing the formation of a STEM identity (Hazari et al., 2020; Santhosh et al., 2024).

4 Problem statement

The development of disciplinary identities among students is increasingly recognized as crucial for enhancing their engagement, persistence, and success (Kang et al., 2019; Wade-Jaimes et al., 2021). Despite the growing emphasis on the need for skilled professionals in STEM fields, empirical evidence illuminating the direct relationships between these constructs and student identities within specific STEM disciplines remains sparse and fragmented. In particular, it is not clear how these identity constructs interact to shape students' identification with STEM and related other disciplines, and subsequently how these identities integrate into a holistic STEM identity. Addressing this gap is crucial for the design of targeted interventions that promote improved engagement with STEM disciplines and support the cultivation of a diverse and skilled STEM workforce.

The objective of this study was 2-fold. First, it sought to investigate the constructs that intersect to influence students' self-perception and engagement within STEM fields of study. This includes examining how educational experiences, social supports, and classroom environments impact students' identity formation in these domains. Second, the study aimed to inform targeted strategies for enhancing student engagement and retention in STEM fields, and thus contribute to the improvement of STEM education and national workforce skills development. Our study acknowledges that STEM identity is a context-dependent and multi-faceted phenomenon that involves multiple interconnected factors. Collectively, these factors may influence students' educational paths and career decisions in STEM fields. Thus, this research study sought to investigate the following research questions and hypotheses as in Figure 2:

1. How do constructs of math identity (i.e., interest, performance/competence, recognition, sense of belonging) influence students' overall identity in math?
2. How do constructs of science identity (i.e., interest, performance/competence, recognition, sense of belonging) influence students' overall identity in science?
3. How do constructs of IT identity (i.e., interest, performance/competence, recognition, sense of belonging) influence students' overall identity in IT?
4. How do disciplinary identities in math, science, and IT relate to students' overall STEM identity?

5 Methods

A survey-based quantitative research approach was employed to examine the STEM identity of high school students. Data collection utilized a survey questionnaire designed to assess the students' level of STEM identity. The survey, conducted in person during the 2023 Fall Semester (September to November), employed physical questionnaires (paper-and-pencil interviewing or PAPI). The survey implementation comprised three phases: (1) survey development, (2) pilot study testing, and (3) survey administration. The Social and Economic Survey Research Institute (SESRI) at Qatar University initially coded, curated, and cleaned the data in STATA format.

Subsequent analysis utilized the Statistical Package for the Social Sciences (SPSS) software and SPSS AMOS (Analysis of Moment Structures), version 29.0.0.0. Various statistical tests, such as Exploratory Factor Analysis (EFA), construct validity assessments (convergent/discriminant validity), internal consistency reliability measurements (Cronbach's Alpha and MacDonald's Omega), and structural equation modeling (SEM), were employed to gain insights into the hypothesized model and address research questions. Detailed information about study participants, survey instruments, measures, and data analysis has been provided in the subsequent sections.

5.1 Study participants

The research included data from both public and private schools in Qatar, selected through a random sampling approach. After obtaining approval from Qatar University's research ethics board (IRB), the research team sought consent from school board superintendents and teachers to collect data within their schools. A total of 1,428 students' (high school) data were obtained. Since high school students are at a more advanced stage of their academic/cognitive development and are closer to transition to higher education and the workforce compared to middle school students, data from high school students ($n = 632$) was utilized for analysis in this study. This targeted approach allows for a more nuanced exploration of factors influencing STEM identity within the specific demographic that is closer to making consequential decisions about future educational and career paths. The demographic details of the participants have been given in Table 1 with gender distribution consisting of 59% males and 41% females, with 52% in grade 11 and 48% in grade 12. Most of the students were expatriates, accounting for 71.5% of the participants.

TABLE 1 Demographics ($n = 632$).

Variable	Groups	Numbers	Percentage
Gender	Male	375	59%
	Female	257	41%
Nationality	Qatari	180	28.5%
	Non-Qatari	452	71.5%
Grade	Grade 11	329	52%
	Grade 12	303	48%

5.2 Survey phases

The survey implementation process involved three phases: (1) the development of the survey, (2) the testing of the survey through a pilot study, and (3) the administration of the survey.

Step 1: To formulate the survey, we conducted a thorough review of existing research that explored factors and constructs influencing students' STEM identity, drawing from the previous studies (Hazari et al., 2020; Mahadeo et al., 2020; Taheri, 2019; Taheri et al., 2018). This literature review provided valuable insights, guiding our focus on specific aspects pertinent to the study. It enhanced our understanding of how various constructs, including interest in, performance/competence in, recognition by self/others as a STEM person, and a sense of belonging within STEM disciplines, contribute to and shape the STEM identity of high school students.

The survey utilized a five-point Likert scale to evaluate closed-ended items across four distinct constructs: (a) interest in STEM, (b) performance/competence in STEM, (c) recognition by self/others as a STEM person, and (d) sense of belonging within STEM fields/disciplines. Most questions were presented in a disagree-agree format, with responses ranging from strongly disagree (-2) to strongly agree (2). Additionally, the survey included frequency questions (ranging from never = 0 to always = 5), percentage questions, rating questions (ranging from very poor = 1 to very good = 5), emphasis questions (ranging from none = 1 to heavy = 5), and significance questions (ranging from not important at all = 1 to very important = 5). This diverse set of question types facilitated a comprehensive assessment of students' perceptions and experiences related to their STEM identity.

Step 2: In this stage, the developed survey underwent testing through two focus groups—one conducted in Arabic and the other in English. This step played a pivotal role in refining the survey instrument. The discussions within these focus groups proved invaluable for addressing any concerns related to the wording of the survey questions. This process allowed us to rephrase and clarify questions that were inadequately worded or potentially confusing. The primary objectives of the survey were centered on gathering fundamental background information and systematically documenting students' perceptions of their STEM identity. The overarching goal was to understand the level of STEM identity and

its formation, including the identification of potential barriers. The insights gained from the focus group discussions ensured that the survey was clear, concise, and effectively collected the necessary data to fulfill these goals.

Step 3: During the third phase of survey execution, questionnaires were distributed after receiving signed consent forms from students, parents, and school authorities. Students were provided the option to respond to the survey in either English or Arabic. On average, participants took between 15 and 20 min to complete the study.

5.3 Measures (constructs)

The survey constructs were carefully designed as quantitative measures to capture key factors essential for addressing the research questions of this study. These measures encompassed various aforementioned constructs [i.e., (a) interest in STEM, (b) performance/competence in STEM, (c) recognition by self/others as a STEM person, and (d) sense of belonging within STEM fields/disciplines] that influence students' STEM identity. The rationale for selecting these measures was grounded in prior analyses that underscored the presence of numerous factors influencing the formation of high school students' STEM identity. These factors, in turn, play a crucial role in shaping their trajectories in STEM, including decisions related to choosing STEM majors or careers in the future.

5.3.1 Interest in STEM

The first crucial construct under examination was students' interest in STEM, where students were inquired about the degree to which they expressed interest/passion in STEM disciplines and STEM careers. The survey questions followed an agree-disagree format, with coding assigning "−2" and "−1" to responses indicating "often" and "always," respectively. A value of "0" denoted "undecided," while "1" and "2" were assigned to represent "rarely" and "never," respectively. The same coding methodology has been employed for the following constructs.

5.3.2 Performance/competence in STEM

The second construct under investigation was focused on examining students' performance/competence in STEM disciplines. Students were queried regarding the level of difficulty they encountered in studying STEM subjects and their motivation to excel/perform better in those subjects. This line of inquiry sought to gain insights into the students' academic challenges and their intrinsic drive to achieve higher levels of competence in the STEM disciplines.

5.3.3 Recognition in STEM

The third construct, termed "Recognition in STEM," focuses on students' perceptions of the support, value, respect, and encouragement they receive in relation to studying STEM subjects or pursuing careers in STEM fields. This aspect aimed to capture the extent to which students feel acknowledged and endorsed in their STEM pursuits, shedding light on the social and supportive aspects influencing their engagement with STEM disciplines and professions.

5.3.4 Sense of belonging within STEM

The fourth construct, identified as the "sense of belonging within STEM," aimed to provide an understanding of students' sense of connection to the STEM community and the perceived relevance of STEM disciplines in their own life narratives. The objective was to investigate students' perceptions of belongingness, appreciation for professionals in STEM, and the significance they ascribe to STEM in shaping their personal lives. This inquiry sought to uncover the students' sense of connection to the broader STEM community and the perceived relevance of STEM disciplines in their own life narratives.

5.3.5 STEM identity score

The students' STEM identity was condensed by the overall STEM identity score, derived from the summation of the previously mentioned constructs. This score was a scale variable, where higher values indicated a heightened level of students' STEM identity. In essence, the overall STEM identity score served as a quantitative measure reflecting the composite impact of various factors influencing identity formation.

5.4 Data analysis

The analysis of the data utilized the SPSS statistics software and SPSS AMOS version 29.0.0.0. Initially, an Exploratory Factor Analysis (EFA) was employed to assess data reliability, item quality, and construct validity. The process involved evaluating data suitability, extracting factors, selecting relevant factors, applying rotation techniques for interpretability, and analyzing results. Statistical indicators, such as Kaiser Meyer Olkin's value and Bartlett's test of sphericity, were computed to determine the appropriateness of the data for factor analysis, guiding the construction of a structural model with significant constructs.

Subsequently, the research proceeded to assess the construct validity of each item (question), with a specific emphasis on both convergent validity and discriminant validity. This evaluation aimed to enhance the understanding of how distinct components, or questions, either overlap or diverge in explaining the variance within their respective indicators. Convergent validity was gauged through the average variance extracted (AVE), representing the average of the squared loadings of the indicators linked to each component. In contrast, discriminant validity was examined using the Heterotrait–Monotrait ratio (HTMT) of correlations, comparing average correlations between indicators measuring different components to those among indicators measuring the same component.

Following this, the internal consistency reliability of the survey model was assessed using two tests: Cronbach's Alpha and MacDonald's Omega. These tests were employed to gain insights into the reliability and consistency of the measurement scales used in the survey. Descriptive statistics were calculated for an overall

TABLE 2 Measures of goodness-of-fit.

Measurement	Indicator	*p*-value	Recommended criteria
Absolute fit	CMIN/df	1.75	1 < x < 5
	GFI	0.932	>0.8
	RMSEA	0.022	<0.08
	RMSR	0.05	<0.1
	NFI	0.945	>0.8
Incremental fit	CFI	0.956	>0.8
	AGFI	0.961	>0.8
Parsimonious fit	PNFI	0.735	>0.05
	PGFI	0.612	>0.05

χ2/DF, Chi-squared divided by degrees of freedom; GFI, Goodness-Of-Fit Index; AGFI, Adjusted Goodness-Of-Fit Index; CFI, Comparative Fit Index; RMSR, Root Mean Square Residuals; RMSEA, Root Mean Square Error of Approximation; NFI, Normed Fit Index; and PNFI, Parsimony Normed Fit Index.

analysis of the data, aligning with the paper's specified scope. Subsequently, SEM was utilized to address the stated hypotheses. Within the SEM approach, the diverse constructs of STEM identity (interest, performance/competence, recognition, and, sense of belonging) and disciplinary identity (identity in science, identity in math, and identity in IT) were designated as dependent observed variables, while overall STEM identity was treated as independent observed variable.

The study evaluated multiple goodness-of-fit measures, as indicated in Table 2, to assess the adequacy of the model in SEM. These measures comprised the chi-square divided by degrees of freedom (χ^2/df), Tucker-Lewis Index (TLI), Comparative Fit Index (CFI), Root Mean Residual (RMR), Root Mean Square Error of Approximation (RMSEA), Root Mean Square Residuals (RMSR), and Normed Fit Index (NFI; Hair et al., 2012).

6 Results

6.1 Validation of the instruments

To formulate constructs that effectively addressed the research questions in this study, factor analysis was employed. This analysis involved principal component analysis and varimax rotation, with a minimum factor loading requirement of 0.50. The data's suitability for factor analysis was confirmed by its significance, evident in the chi-squared test ($\chi 2$) = 5661.088, $p < 0.001$. To further affirm the adequacy of the sample, the Kaiser–Mayer–Olkin value and Bartlett's test of sphericity were utilized. With a Kaiser–Mayer–Olkin value of 0.915, it was determined that the data was suitable for factor analysis.

For construct validity, convergent validity was established by computing the AVE for all indicators within each construct, yielding AVE values above 0.5, considered acceptable (Farrell, 2010). Discriminant validity was assessed using the Heterotrait–Monotrait Ratio (HTMT) of correlations, resulting in a value of 0.8, also considered acceptable. Subsequently, to validate internal consistency, Cronbach's Alpha and MacDonald's Omega were computed, with all values falling within the acceptable range (> 0.7; Cohen et al., 2022). Similarly, Composite Reliability (CR) was calculated, and all these values were within the acceptable threshold (> 0.7). The results of factor loadings and internal reliability are presented in Supplementary Table S1. Consequently, the proposed model exhibits strong convergent validity.

6.2 Findings

The findings of this study offer valuable insights into the factors that shape the STEM identity of high school students. Before delving into structural equation modeling, the study first verified correlations among the identity constructs. Table 3 (a, b, and c) illustrates the correlations among the disciplinary identity constructs. All constructs demonstrated significant correlations, indicating that students' "interest in math" influences their "performance, recognition, and sense of belonging in math," and vice versa. This pattern holds true for other disciplinary identity constructs, such as those related to science and IT.

A noteworthy finding reveals that the most robust correlation is observed between "recognition" and "sense of belonging" within the subject. In essence, if a student experiences higher levels of "recognition" in math, they are likely to exhibit a greater "sense of belonging" to math, and vice versa. This observed relationship holds true for science and IT disciplines as well.

6.3 Structural model and hypothesis testing

We employed the maximum-likelihood method to estimate the parameters of the model, and all analyses were conducted based on the variance-covariance matrices. The fit of the model was assessed through various indices, including CMIN/Df, RMSEA, GFI, and AGFI. Additionally, the model was tested by evaluating TLI, NFI, and CFI, as well as parsimonious fit with PNFI and PGFI reference indicators. This study utilized these three methods to test the fit of the model, as Table 2 has demonstrated (Hair et al., 2012).

Table 4 and Figure 3 present the outcomes of the SEM analysis. The key findings indicate that all the students' disciplinary identities—math identity ($\beta = 0.55$, $p < 0.001$), science identity ($\beta = 0.12$, $p < 0.001$), and IT identity ($\beta = 0.36$, $p < 0.001$)—demonstrate positive associations with their overall STEM identity. The positive path coefficient values affirm the direct positive effect (relationship) between these variables/constructs. In other words, disciplinary identities (identity in math, science, and IT) influence the formation of overall STEM identity. Notably, among these three relationships, the most robust connection is observed between math identity and overall STEM identity. In essence, students' identity in math contributes the most to their overall STEM identity compared to their identity in science and IT.

Furthermore, the disciplinary identities are influenced by the constructs associated with each disciplinary identity. In simpler terms, high school students' identity in math is affected by their interest in, performance/competence in, recognition in, and sense of belonging in math. Similarly, the same principle applies to

TABLE 3 The correlation between the constructs of STEM identity within each discipline.

Correlation coefficients (Spearman's rho)				
	Interest in math	Performance/ competence in math	Recognition in math	Sense of belonging in math
(a) Spearman's correlation between the constructs of math identity				
Interest in Math	1.000			
Performance/competence in Math	0.599**	1.000		
Recognition in Math	0.588**	0.350**	1.000	
Sense of Belonging in Math	0.600**	0.417**	0.707**	1.000
	Interest in science	Performance/ competence in science	Recognition in science	Sense of belonging in science
(b) Spearman's correlation between the constructs of science identity				
Interest in Science	1.000			
Performance/Competence in Science	0.484**	1.000		
Recognition in Science	0.610**	0.340**	1.000	
Sense of Belonging in Science	0.598**	0.340**	0.702**	1.000
	Interest in IT	Performance/ competence in IT	Recognition in IT	Sense of belonging in IT
(c) Spearman's correlation between the constructs of IT identity				
Interest in IT	1.000			
Performance/competence in IT	0.725**	1.000		
Recognition in IT	0.857**	0.678**	1.000	
Sense of belonging in IT	0.828**	0.667**	0.865**	1.000

**Indicate significance level at 0.01.

science and IT identities and their respective causal constructs. This is evident from the positive path coefficient and associated significant p-value. Within each discipline, different constructs exert varying levels of influence on the formation of disciplinary identity. For instance, in the case of Math, recognition in math has the most significant contribution to the formation of identity in Math ($\beta = 0.32$, $p < 0.01$). Conversely, for science/IT, the sense of belonging in science/IT plays the most influential role in forming identity in science/IT (Science: $\beta = 0.29$, $p < 0.001$ and IT: $\beta = 0.40$, $p < 0.001$).). One peculiar finding is that recognition in IT does not positively influence students' identity in IT and therefore the hypothesis is partially supported ($\beta = -0.02$, $p < 0.05$).

Finally, there are correlations between all the constructs of disciplinary identities. The most robust positive correlation is observed between the sense of belonging in STEM disciplines and recognition within those disciplines. These findings were initially confirmed by Spearman's correlations (Table 4).

7 Discussion

The present research focused on analyzing the construct of STEM identity, investigating the interactions among its various components, and examining their overall influence on specific disciplinary identities. Additionally, it explored how the disciplinary identities (identities of individual STEM subjects) impact the existence and development of an overall STEM identity. This study relates to the existing literature that highlights the connection and influence of several subcomponent concepts, namely interest, sense of recognition, and performance-competence (Hazari et al., 2020; Santhosh et al., 2024) on disciplinary identity. To these three dimensions, a fourth dimension called "sense of belonging" has also been added to provide a more comprehensive approach to understanding subject identity within the collective societies of the GCC (Taheri, 2019; Taheri et al., 2018; Baatwah et al., 2023).

This study brings valuable and interesting findings in validating the reliability of the four subconstructs for measuring disciplinary identity in mathematics. The findings exhibit significant mutual relationships, i.e., students' "interest in a particular STEM subject" influences their "performance, recognition, and sense of belonging in that particular STEM subject," and vice versa. These corroborate Hazari et al.'s (2020) findings, that all subconstructs inform disciplinary identity in science. Therefore, our research not only confirms Hazari's findings for science but more importantly, validates their relevance for other STEM subjects, i.e., IT and mathematics (Hazari et al., 2020). Furthermore, according to Hazari, the subconstructs of disciplinary identity can not only be perceived as potential predictors for disciplinary identity but also study choices and career orientation. Hence, these results can inform educational authorities and decision-makers in the promotion of STEM subjects, endorsing the importance

TABLE 4 Table of hypothesis testing (findings of SEM analysis).

	Path	Path coefficient	S.E.	Effect type	*p*-value	Results
H1	Math-Interest → Math-identity	0.21	0.037	Positive	<0.001	Hypothesis supported
	Math-Perfor → Math-identity	0.23	0.042	Positive	<0.001	Hypothesis supported
	Math-Recog → Math-identity	0.32	0.044	Positive	<0.01	Hypothesis supported
	Math-Belong → Math-identity	0.29	0.048	Positive	<0.001	Hypothesis supported
H2	Science-Interest → Science-identity	0.13	0.057	Positive	<0.001	Hypothesis supported
	Science-Perfor → Science-identity	0.24	0.062	Positive	<0.001	Hypothesis supported
	Science-Recog → Science-identity	0.22	0.074	Positive	<0.01	Hypothesis supported
	Science-Belong → Science-identity	0.29	0.008	Positive	<0.001	Hypothesis supported
H3	IT-Interest → IT-identity	0.12	0.057	Positive	<0.001	Hypothesis supported
	IT-Perfor → IT-identity	0.22	0.062	Positive	<0.001	Hypothesis supported
	IT-Recog → IT-identity	−0.02	0.034	Negative	<0.05	Hypothesis partially supported
	IT-Belong → IT-identity	0.40	0.048	Positive	<0.001	Hypothesis supported
H4	Math-identity → STEM-identity	0.55	0.037	Positive	<0.001	Hypothesis supported
	Science-identity → STEM-identity	0.12	0.052	Positive	<0.001	Hypothesis supported
	IT-identity → STEM-identity	0.36	0.004	Positive	<0.001	Hypothesis supported

H, Hypothesis; S.E, Standard Error; Perfor, performance/competence in a particular discipline; recog, recognition in a particular discipline; belong, Sense of belonging in a particular discipline; significance level at 0.05, 0.01, and 0.001 as indicated.

of fostering disciplinary identity in promoting STEM subjects among students. It is linked to developing the STEM workforce by increasing disciplinary identity and its components as relevant for the development of a knowledge society. Hence, reinforcing disciplinary identity and its specific subconstructs would contribute to Qatar's transition to a knowledge society.

Another informative result of this research is the particularly compelling correlation between "recognition" and "sense of belonging" within the STEM subjects. In other words, social support (from peers, parents, and teachers) and the school experiences/environments must be mutually reinforced for STEM identity formation (Verhoeven et al., 2019). It is known that disciplinary identities are also often influenced by ethnic and cultural context within the classroom environment (Edele et al., 2020). Our research contributes to this debate by highlighting the particularly strong connection between these two dimensions, in developing STEM disciplinary identities, placing forward the relevance and importance of taking into consideration the specific cultural setting of Qatar, and by extension of the GCC countries when promoting STEM subjects among students. This result also confirms that STEM identity not only involves students' self-perception in STEM fields but also its intimate link to how others see them within the STEM fields (Kim et al., 2018). This research thereby confirms the intricate connection between the four dimensions and disciplinary identities in the emergence of an overall situated STEM identity.

Another notable finding is the pronounced influence of mathematical disciplinary identity on overall STEM identity, compared to the impact of other disciplinary identities. This finding is particularly compelling when considering previous research. Prior studies have established that a robust mathematical disciplinary identity is pivotal in shaping students' aspirations and decisions regarding STEM careers (Sellami et al., 2023; Bohrnstedt et al., 2020). Our research reinforces these conclusions, revealing that mathematical identity exerts the most significant effect on overall STEM identity among the subjects examined, indicating that a strong mathematical disciplinary identity profoundly shapes the broader STEM identity.

The findings of this study provide critical insights that can guide informed decision-making by Qatari policymakers to enhance STEM education in alignment with the Qatar National Vision (QNV) 2030. Given the observed relationships between students' STEM identities and their interest, performance, recognition, and sense of belonging in STEM subjects, several key policy implications emerge. (1) Strengthening Early STEM Engagement: The results indicate that fostering strong math, science, and IT identities is crucial for developing a robust STEM identity. To achieve this, policymakers should consider implementing early intervention programs that enhance students' interest and confidence in STEM subjects. Integrating STEM-focused extracurricular activities, mentorship programs, and hands-on learning experiences at the preparatory level can help nurture students' engagement and motivation. (2) Enhancing STEM Pedagogy and Teacher Training: The study highlights the role of performance and recognition in shaping students' STEM identities. This underscores the need for continuous professional development for STEM educators, equipping them with innovative teaching strategies, that can significantly impact student engagement and learning outcomes. (3) Promoting an Inclusive STEM Environment: A sense of belongingness plays a significant role in shaping students' STEM identities. Thus, fostering an inclusive classroom culture where all students feel valued and supported in STEM fields is essential. Policymakers

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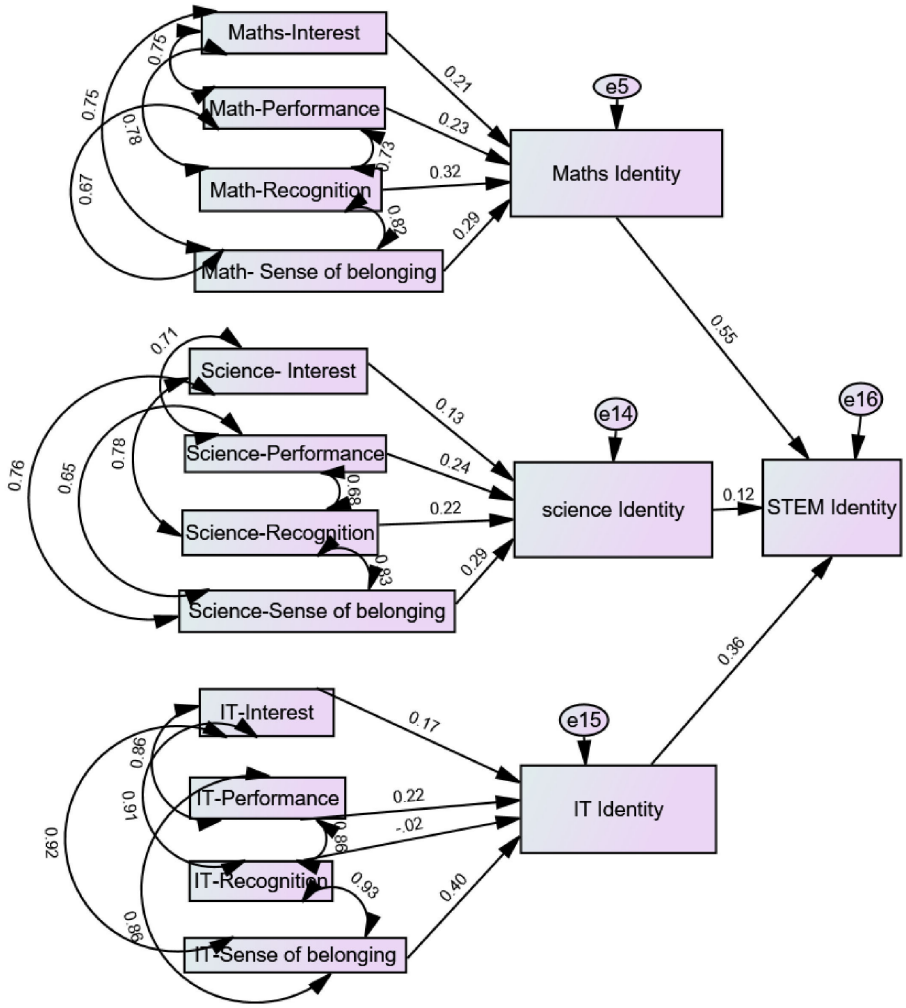

FIGURE 3
Finding from SEM analysis: diagrammatic representation of relationships between the students' overall STEM identity, disciplinary identities, and the related constructs.

should promote initiatives that encourage gender diversity and inclusion, ensuring that STEM education is accessible and appealing to students from diverse backgrounds. By implementing these targeted policy recommendations, Qatari policymakers can take meaningful steps toward enhancing STEM education, fostering a strong STEM workforce, and achieving the educational and economic goals outlined in QNV 2030.

In conclusion, the findings of this research should be interpreted with consideration of the study's limitations. One limitation of this research is its cross-sectional approach, which restricts the grasp of students' perception of STEM identity to a specific point in time. Using a longitudinal study would facilitate capturing the evolution of disciplinary identity over the course of students' school experiences. Gender disparities may be more pronounced among Qatari female participants compared to male and expatriate counterparts, presenting a potential avenue for future research. Similarly, the exclusion of parents' perceptions of their children's STEM experiences deprives the study of an important social contextualization that would otherwise allow for a better understanding of students' familial settings. Further research would benefit from incorporating teachers' perspectives through the development of a comprehensive data collection tool that captures the insights of students, parents, and teachers. This would enable a comparative analysis of various contextual influences on the formation of students' STEM identity. Additionally, incorporating qualitative analysis and a mixed-methods approach could provide deeper insights into the interrelated contextual factors influencing STEM identity, offering a more holistic understanding of students' experiences and perceptions.

8 Conclusion

This research aims to provide a better understanding of students' STEM identity components at high school levels. Analyzing students' perspectives on their own disciplinary identity should empower educational practitioners, policymakers, and

academics to develop their ability to support students' interest in STEM subjects and improve retention in these key specialties for countries transitioning to knowledge societies. To capture students' perspectives, a quantitative data collection tool was designed and administered to 1,428 high school students in the state of Qatar. An overall STEM identity is reinforced and enhanced by nurturing and developing the disciplinary identities in STEM subjects (i.e., Mathematics, IT, and Science) in this research. All of these three disciplinary identities positively influence the existence of an overall STEM identity. This is of particular interest for education practitioners and policymakers trying to enhance and develop, students' retention in STEM subjects as well as when striving to develop a skilled and qualified STEM workforce in the country. The present research confirms some of the main findings from previous studies, but more importantly, affirms the understanding of the need to consider the specific socio-cultural context of local society. It highlights the importance of integrating the collective dimension of GCC culture by acknowledging the relevance of the social dimension in building students' disciplinary identities.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Qatar University Institutional Review Board with approval number QU-IRB-1867-EA/23 on May 2023. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional requirements.

Author contributions

AS: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. MS: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. IM: Investigation, Writing – original draft, Writing – review & editing, Methodology.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2025.1449528/full#supplementary-material

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