TYPE Original Research
PUBLISHED 04 April 2024
DOI 10.3389/feduc.2024.1333669

Check for updates

OPEN ACCESS

EDITED BY
Jodye I. Selco,
California State Polytechnic University, Pomona, United States

REVIEWED BY
Md Abdur Rahman Forhad,
Dhaka University of Engineering and Technology, Bangladesh
Cucuk Wawan Budiyanto,
Sebelas Maret University, Indonesia

*CORRESPONDENCE
Zubair Ahmad
✉ zubairtarar@qu.edu.qa

RECEIVED 05 November 2023
ACCEPTED 08 March 2024
PUBLISHED 04 April 2024

CITATION
Sellami A, Santhosh M, Bhadra J and Ahmad Z (2024) Teachers' perceptions of the barriers to STEM teaching in Qatar's secondary schools: a structural equation modeling analysis.
Front. Educ. 9:1333669.
doi: 10.3389/feduc.2024.1333669

Teachers' perceptions of the barriers to STEM teaching in Qatar's secondary schools: a structural equation modeling analysis

Abdellatif Sellami[1], Malavika Santhosh[1], Jolly Bhadra[2] and Zubair Ahmad[2]*

[1]Educational Research Center, College of Education, Qatar University, Doha, Qatar, [2]Qatar University Young Scientists Center (QUYSC), Qatar University, Doha, Qatar

Introduction: Educators play a pivotal role in shaping students' academic achievements, particularly in STEM (science, technology, engineering, and mathematics) fields. The instructional techniques employed by teachers significantly impact students' decisions to pursue or persist in STEM disciplines. This research aims to explore the challenges faced by high school STEM teachers in Qatar in delivering effective STEM instruction.

Methods: Data was collected through a survey administered to 290 high school STEM teachers across thirty-nine schools in Qatar. The survey targeted teachers in the 11th and 12th grades. Structural Equation Modeling (SEM) was utilized to analyze the data and examine teachers' perceived barriers to effective STEM instruction.

Results: The findings revealed various barriers hindering STEM instruction. These barriers were categorized into school-related, student-related, technology-related, and teaching-related factors. All the hypothesized teaching barriers [i.e., (student-related: $\beta = -0.243$, $p < 0.001$); (school-related: $\beta = -0.122$, $p < 0.001$), (technologyrelated: $\beta = -0.123$, $p = 0.040$); and (instruction-related: $\beta = -0.112$, $p < 0.018$)] were negatively related to teachers' STEM teaching. Among the various obstacles, it appears that the most formidable challenges for high school STEM teachers are related to students ($\beta = -0.243$, $p < 0.001$).

Discussion: Understanding these barriers is crucial for informing educational policies and developing strategies to enhance STEM learning in Qatar's high schools. Addressing these barriers is essential to provide adequate resources, professional development opportunities, and support systems. By addressing these challenges, Qatar can foster a conducive environment for effective STEM instruction, thereby nurturing a future generation of STEM professionals.

KEYWORDS

teachers, teaching barriers, high school, STEM education, structural equation modeling (SEM)

1 Introduction

Science, technology, engineering, and mathematics (STEM) education has garnered increased attention in the past decade, prompting calls for a heightened emphasis particularly on the quality of STEM teaching (Btool and Koc, 2017). The STEM education approach advocates for a novel teaching and learning methodology, emphasizing hands-on inquiry and open-ended exploration (Waters and Orange, 2022). This approach facilitates the development of 21st-century quintessential skills, such as problem-solving, creative thinking, collaborative teamwork, and technology literacy, catering to students with diverse interests, abilities, and experiences (Ichsan et al., 2023). In light of the many global challenges and potential threats, the knowledge/skills pertaining to STEM are crucial for comprehending and addressing these pressing issues. This underscores the significance of STEM as a driver of prosperity and sustainable development for present and future generations (AlMuraie et al., 2021).

In this regard, teachers are key figures in driving STEM initiatives globally, with a particular emphasis on those instructing science subjects (Oliveros Ruiz et al., 2014). Numerous studies underscore the significance of science education across various academic levels (Kola, 2013; Oliveros Ruiz et al., 2014). Researchers contend that the primary objective of science education is to equip individuals with the skills required to become scientists and technologists, crucial for advancing research and innovation (Ichsan et al., 2023). This preparation serves as the cornerstone for the economic prosperity and well-being of emerging economies and contributes to the overall development of nations.

In the unique context of Qatar, the past few years have witnessed concerted efforts to shift from an economy that is reliant on gas and oil resource wealth to one centered on knowledge and innovation, as outlined in the Qatar National Vision 2030 (Tan et al., 2014). Underlying this transformation is an earnest and compelling call for action to cultivate national expertise (Ben Hassen, 2021). Indeed, there is a pressing demand for professionals in STEM fields in Qatar, a concern voiced repeatedly by educators, government officials, and industry stakeholders (Cherif et al., 2016, 2021). Despite the increasing demand for STEM professionals in Qatar, the number of Qatari citizens possessing the education and training necessary to support the vital industries of their country's economy remains alarmingly low. This disconnect between education and the job market in Qatar has led to a significant proportion of unskilled and semi-skilled citizens being employed in the public sector (Babar et al., 2019). Consequently, the private sector has had to rely on foreign workers to bridge the gap in STEM professions. With a scarcity of young individuals pursuing STEM careers, Qatar's dependence on expatriate labor in these fields is set to persist.

Adding to the challenges of a foreign-dominated labor force in Qatar is the fact that many highly educated Qatari citizens hold degrees in non-STEM disciplines. Furthermore, there is clear evidence that a significant number of Qataris, particularly males, do not aspire to pursue higher education (Sellami et al., 2017), which has serious implications for efforts to develop a sustainable local STEM workforce (Al-Misnad, 2012). Interestingly, there is a dearth of documented research exploring these issues related to the shortage of skilled professionals in Qatar and the broader Gulf Cooperation Council (GCC) region (Al-Misnad, 2012; Sellami et al., 2017; Babar et al., 2019). Despite notable progress in terms of equitable access to formal education, enrollment rates, and literacy rates in Qatar, critics argue that the country's education system still falls short in producing highly skilled graduates who can contribute effectively to the nation's development and prosperity (Ben Hassen, 2021). This dependence on highly skilled foreign professionals further compounds the issue. To enhance the capabilities of its skilled workforce, Qatar must make concerted efforts to increase the enrollment of both men and women in disciplines aligned with the knowledge economy, on par with developing nations.

In light of the preceding background information, STEM teaching is pivotal to Qatar's economic prosperity. While the country's national development strategy underscores the importance of STEM education for progress and development, the practical implementation of STEM teaching faces numerous challenges, especially in developing countries such as Qatar and the larger GCC region (Cherif et al., 2016). Accordingly, this study aims to explore teachers' perceptions of salient barriers to STEM teaching in Qatar. The uniqueness of this present study lies in providing research-based insights into these obstacles from an Arab Middle Eastern perspective.

This paper is structured as follows. The section below offers a review of the relevant literature that has addressed the main challenges that impede STEM teaching. This is followed by a statement of the theoretical framework guiding this study as well as a description of the problem statement and the research questions. The next section details the research methods employed in our study, including a description of participants, instruments, and data analysis. A presentation of the study's results is provided next, in turn, followed by a discussion and interpretation of these results. The paper concludes with some important recommendations for policy and practice.

2 Review of literature

In view of the growing demand for professionals possessing the critical skills and knowledge that are essential for economic growth and development, the responsibility lies with educational institutions to prepare students equipped with vital STEM skill sets (AlMuraie et al., 2021). Improving students' STEM-related capabilities requires schools to enhance their STEM education offerings and reconfigure their instructional methods. Central to such educational reforms is the imperative to incorporate teachers as a vital element (Antonova et al., 2022).

Serving as essential catalysts in the educational journey, teachers play a central role in providing STEM education (Kim, 2021). They possess the capacity to profoundly influence students' academic performance in STEM subjects and, in the long run, shape their interest in and enthusiasm for pursuing STEM fields of study and eventual careers (Blazar and Kraft, 2017). Students' learning experiences, encompassing both theoretical classroom knowledge and hands-on practical experience, are pivotal factors in augmenting their proficiency in STEM-related skills and knowledge (Romlie et al., 2021; Rohendi et al., 2023). When coupled with the guidance of dedicated teachers and access to high-quality STEM programs and curricula, these experiences create an optimal

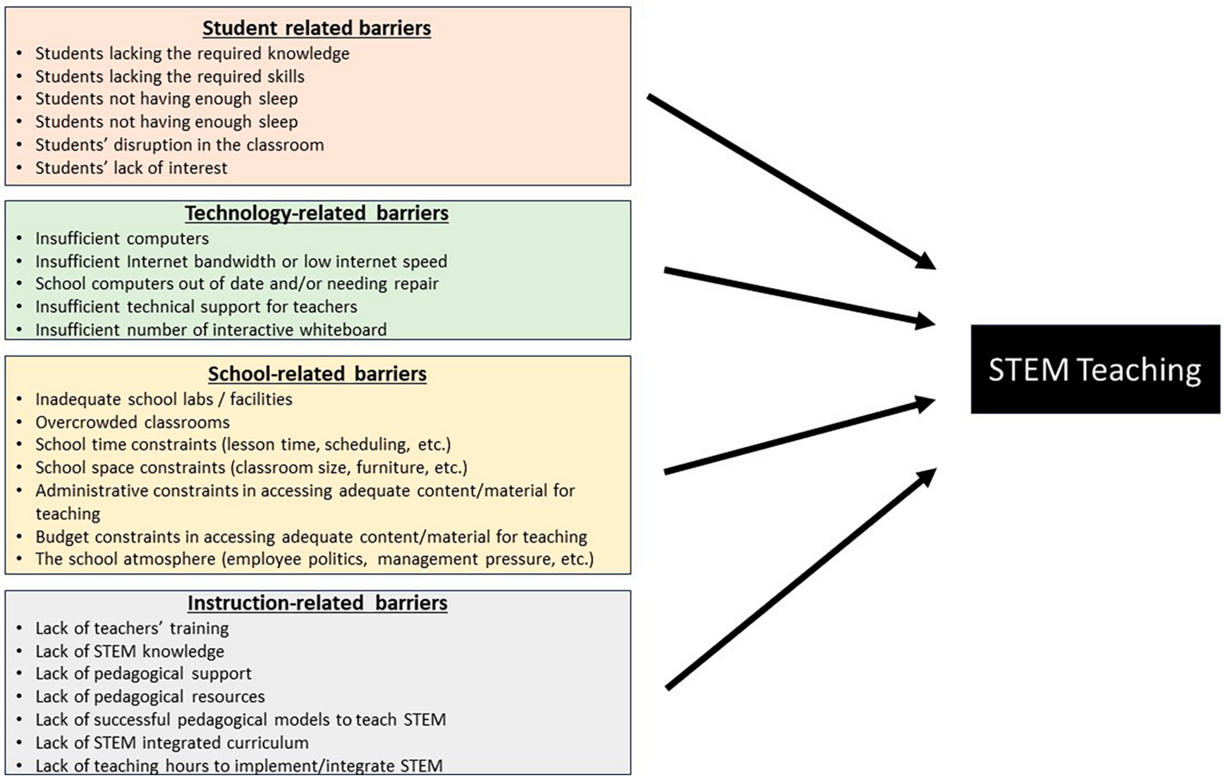

FIGURE 1
Barriers to STEM teaching.

environment for nurturing students' innate talents and capabilities within the realm of STEM disciplines (MacFarlane, 2021).

The existing body of literature sheds light on the intricate interplay of several factors — broadly the individual (personal) and environmental (contextual)—that can either facilitate or impede STEM teaching (Nugent et al., 2015; Sellami et al., 2017). For instance, researchers have proposed a range of social (i.e., contextual, school environment-related, family/peer/teachers support, etc.), individual (student-related, teachers-related in terms of knowledge, interest, self-efficacy, etc.), and instructional (curriculum, student-related, teacher-related, etc.), factors that contribute to the creation of favorable conditions for effective STEM teaching (Nugent et al., 2015; Margot and Kettler, 2019; Wahono and Chang, 2019; Dong et al., 2020; Hamad et al., 2022; Karkouti et al., 2022). One of the studies exemplifies the comprehensive review of teachers' perspectives on STEM education and has pinpointed six primary barriers that pose challenges to STEM teaching (Margot and Kettler, 2019). These barriers are closely tied to the curriculum, pedagogical approaches, assessment methods, teacher support, student factors, and structural systems within the educational landscape (Margot and Kettler, 2019). As outlined in the literature, these barriers, encompass various facets, such as teachers' beliefs, knowledge, and comprehension of STEM, as well as difficulties in applying STEM concepts to specific topics, and challenges in establishing connections between different STEM subjects, etc. (Wahono and Chang, 2019; Dong et al., 2020). Additional obstacles comprise inadequate teacher preparation, limited opportunities for professional development, a shortage of qualified STEM teachers, insufficient integration of cross-disciplinary content, low levels of student motivation, curriculum changes, inadequate resources and facilities, and assessments that may not effectively align with STEM education objectives (Hamad et al., 2022; Karkouti et al., 2022). Ongoing discussions on STEM education highlight obstacles that impede the implementation of effective interdisciplinary teaching methods. At the same time, contemporary dialogues and arguments concerning STEM education underscore the hindrances that obstruct the successful adoption of interdisciplinary STEM teaching approaches.

From a more extensive viewpoint, various obstacles may hinder STEM teaching, encompassing issues related to instruction, students, technology, school, etc. (Al-Misnad, 2012; Sellami et al., 2017; Babar et al., 2019). Drawing from insights into existing literature, this present study seeks to explore the connections among impediments associated with students, technology, schools, and instruction as perceived by STEM teachers (refer to **Figure 1**).

3 Theoretical framework

The conceptual foundation of this study is based on similar research, which delved into the perceptions of high school teachers regarding the obstacles to teaching STEM in Qatar, including student-related, technology-related, school-related, and instruction-related barriers in teaching STEM (Sellami et al., 2022). The study employed descriptive statistics and logistic regression models to understand how teachers perceived these barriers.

However, our current study distinguishes itself by using SEM to investigate the path coefficients and uncover the significant relationships between the investigated constructs.

The theoretical framework underpinning this study (Bandura, 1989) and Attribution Theory (Bandura, 1997; Weiner, 2010). In this research, the social cognitive theory (SCT) serves as a valuable theoretical framework, offering insights into the barriers impeding STEM teaching by considering both individual factors (related to students and teachers) and environmental factors (associated with the context or school). In contrast, AT, a well-established research paradigm in social psychology, offers insights into understanding why specific behaviors or events occur and how individuals contribute to these occurrences. In this research, Atribution theory which focuses on how individuals explain the causes of events, can be applied to understand the barriers to STEM teaching. The theory can provide insights into how teachers attribute the challenges and successes in STEM education, shedding light on the factors impacting their STEM teaching.

The use of SCT focuses on *what* aspects of STEM were perceived as barriers whereas AT highlights *how* individuals *attribute* STEM teaching barriers. Therefore, guided by the existing literature, our study postulates that high school STEM teachers in Qatar should confront challenges that impact their teaching processes. These challenges are examined through the lenses of SCT and AT, which consider the interplay between individual beliefs and environmental factors in shaping STEM education.

3.1 Problem statement and research questions

As discussed, one of the key components of Qatar's educational reform is to improve the standards of education by enhancing the quality of schoolteachers (Nasser, 2017). In this respect, this study is important as it intends to investigate salient barriers to STEM education from a teacher's perspective. Therefore, this study will extend knowledge related to the challenges that thwart STEM education. As such, this research aligns with Qatar National Vision-2030, which highlights Qatar's need to transform into a knowledge-based economy. Based on the preceding deliberations, this study employs SEM to facilitate a comprehensive exploration of teachers' perspectives on key obstacles to STEM education. After undergoing a critical literature review, this study put forth four hypotheses, as is shown in **Figure 2** below:

> H1: Student-related barriers negatively influence STEM teaching in higher education.

> H2: Technology-related barriers negatively influence STEM teaching in higher education.

> H3: School-related barriers negatively influence STEM teaching in higher education.

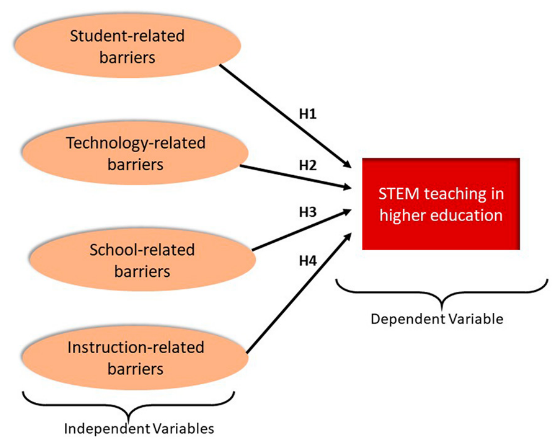

FIGURE 2
Hypothesized model.

> H4: Instruction-related barriers negatively influence STEM teaching in higher education.

4 Research methods

An exploratory quantitative research approach was adopted to examine teachers' perceptions of the main impediments to STEM education. This research design involved a review of the relevant literature on STEM-teaching barriers (Al-Misnad, 2012; Nugent et al., 2015; Sellami et al., 2017; Babar et al., 2019), where themes were identified to guide the creation of a quantitative instrument. This instrument is then employed to delve deeper into the research problem (Creswell et al., 2011; Berman, 2017). A survey questionnaire was then developed to explore the barriers related to STEM teaching (i.e., student-related, technology-related, school environment-related, and teaching methods.

The survey was conducted both in person and virtually during the 2021 Spring Semester, spanning from March to April 2021. The survey administration involved physical questionnaires [paper-and-pencil interviewing (PAPI)] and computer-assisted personal interviews (CAPI). The latter involved gathering survey data through face-to-face interviews conducted by interviewers, using computers, smartphones, and tablets. This technique allowed the interviewers to input responses directly into these devices, enabling real-time data collection and reducing the need for manual data entry (Blazar and Kraft, 2017).

4.1 Sample

For the purpose of this study, data was gathered from thirty-nine high schools randomly selected from across Qatar. These schools were a combination of both local government schools (56.4%) and private schools (43.6%) in Qatar. Following the approval process from Qatar University's research ethics board (IRB), the research team contacted school board superintendents

TABLE 1 Teacher-related variables (*n* = 290).

Variable	Sub-categories	Percentage
Gender	Male	54.5
	Female	45.5
Age group	30 or less	8.7
	31–40	40.1
	41–50	33.8
	51 or more	16.7
Nationality	Qatari	1.7
	Non-Qatari	96.0
Educational qualification	Diploma	4.0
	B. A. degree	59.5
	Master's degree	32.8
	Doctorate/Ph.D.	2.7
Grade level of teaching	Grade 11	25.8
	Grade 12	24.7
	Both grades 11 and 12	45.8

and teachers to secure their consent for data collection within their respective schools. After excluding teachers who did not complete the entire survey, a total of 290 STEM teachers participated in this research study. The study involved a nationwide survey and the sample was representative of the entire country. With the given number of completions, the maximum sampling error for a percentage in the teacher survey was approximately +/−2.4 percentage points. The computation of this sampling error accounts for design effects, encompassing influences from weighting, stratification, and clustering. One possible interpretation of sampling errors is that if the survey is repeated 100 times using the same procedure, the sampling errors would encompass the "true value" in 95 out of the 100 surveys. It is important to note that the calculation of sampling errors was feasible in this survey due to the sample being derived from a known probability-based sampling scheme set by the Ministry of Education.

Table 1 provides an overview of the teacher-related variables, showing their gender distribution (54.5% males and 45.5% females) and age groups, with the majority falling between the ages of 31 to 40 (40.1%). A significant portion of the participants had a bachelor's degree (59.5%) and nearly most of the teachers were expatriates (96%). In terms of their teaching assignments, the largest group of teachers taught both grades 11 and 12 (45.8%), while 25.8% exclusively taught grade 11, and 24.7% exclusively taught grade 12.

4.2 Survey instrument

The survey had three primary objectives: (a) Gathering fundamental background information, (b) Systematically documenting teaching approaches, and (c) Structurally documenting the key challenges encountered in effective STEM teaching. The 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 develop the survey, we examined existing research on STEM teaching barriers (Shadle et al., 2017; Sturtevant and Wheeler, 2019; Karkouti et al., 2022; Kayan-Fadlelmula et al., 2022; Sellami et al., 2022). The review of existing literature provided valuable insights into the specific target areas of the study. It helped us gain a better comprehension of how teachers perceive STEM teaching and the associated barriers. The survey employed a five-point Likert scale to assess close-ended items across five distinct constructs: i.e., (a) Student-related barriers, (b) technology-related barriers, (c) school-related barriers, (d) teaching-related barriers, and (e) implementation of STEM instruction. For each construct, teachers were presented with various response options tailored to the type of question. This included disagree-agree questions (ranging from 1 = strongly disagree to 6 = strongly agree); Frequency questions (ranging from 1 = never to 5 = always); Percentage questions; Rating questions (ranging from 1 = very poor to 5 = very good), Emphasis questions (ranging from 1 = none to 5 = heavy), and significance questions (ranging from not important at all = 1 to very important = 5). These diverse set of question types allowed for a comprehensive assessment of teachers' perceptions and experiences related to STEM education.

Step 2: During this phase, the survey that was designed was pilot-tested with two focus groups, one conducted in Arabic and the other in English. This step was crucial for refining the survey instrument. The discussions within these focus groups proved invaluable in addressing concerns related to the wording of the survey questions. This process enabled us to rephrase and clarify questions that were inadequately worded or potentially confusing. The insights gained from the focus group discussions helped ensure that the survey was clear, and concise, and effectively collected the necessary data to achieve these goals.

Step 3: The third phase of survey execution involved the distribution of questionnaires after the reception of signed consent forms from both teachers and school authorities. Teachers were given the option to respond to the survey in either English or Arabic. On average, it took participants between 13 and 17 min to complete the study.

4.3 Data measures

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 constructs, including student-related, technology-related, and school-related teaching barriers, as well as teacher STEM pedagogy implementations. The rationale behind selecting these measures stemmed from prior analyses that highlighted the existence of numerous obstacles impeding effective STEM teaching, such as restrictive teaching hours, curriculum challenges, student-related conflicts, evaluation difficulties, and lack of teacher support (Margot and Kettler, 2019; Dong et al., 2020; Hamad et al., 2022; Karkouti et al., 2022). Below are the details of the formulation of these measures:

4.3.1 Student-related teaching barrier

The student-related teaching barrier explored the extent to which the teaching methods of educators were influenced by issues related to students. These issues covered the following areas: a lack of necessary skills, a lack of requisite knowledge, inadequate sleep, classroom disruptions, and reduced interest. Teachers' perceptions of student-related barriers were reverse coded due to negative statements and the codes "−2" and "1 was assigned to the responses "often" and "always", respectively. Meanwhile, a value of "0" was assigned to "undecided" "1" and "2" for "rarely" and "never", respectively. Technology-related teaching barrier: For this barrier, teachers were responsible for evaluating the degree to which technology-related challenges affected their teaching. These challenges included several factors, including insufficient computers, lack of internet speed or bandwidth, outdated or malfunctioning computers, lack of technical support, and insufficient interactive whiteboards. The responses provided by teachers were coded using the same methodology adopted for student-related barriers to represent technology-related barriers

4.3.2 School-related teaching barrier

Here, teachers were tasked with assessing the degree to which their teaching was influenced by various challenges within the school environment. These challenges were represented by a variety of factors, which include technical support, STEM training, and pedagogical assistance, curriculum and teaching hours, availability of instructional materials and supplies, adequacy of classroom facilities, the state of school computers, organization of school spaces, administrative and budgetary constraints, the overall school environment, and the level of support and interest from fellow teachers. Similar coding on a 5-point Likert scale has been followed.

4.3.3 Instruction-related teaching barrier

The fourth construct utilized in this analysis is referred to as a school-related teaching barrier. Teachers were asked to detail the extent to which their teaching was impacted by school-related challenges. These challenges included insufficient school laboratory resources, overcrowded classrooms, inefficient school time management, administrative limitations, budget constraints, and the pressure to prepare students for examinations. For consistency, a coding system similar to the other barriers was implemented, the 5-point Likert scale.

4.3.4 STEM teaching

The fifth and final construct is STEM teaching, where teachers were presented with a scale to indicate the degree to which they utilized pedagogical approaches. This scale covered a spectrum from (Btool and Koc, 2017) 0–20% to (Oliveros Ruiz et al., 2014) 81–100%. The pedagogical approaches under consideration include project- and problem-based methods, collaborative learning, and the flipped classroom model as examples. To streamline the analysis, the responses provided by teachers were translated into numerical values. Each specified percentage range was assigned a numerical code, ranging from 1 to 5, as follows: 0–20% corresponded to 1, 21–40% to 2, 41–60% to 3, 61–80% to 4, and 81–100% to 5.

4.4 Data analysis

The data analysis was conducted using the Statistical Package for the Social Sciences (SPSS) statistics software and SPSS AMOS (Analysis of Moment Structures), version 29.0.0.0. Initially, an Exploratory Factor Analysis (EFA) was employed to gain insights into data reliability, item quality, and construct validity. Five steps were involved in implementing factor analysis. (1) Data adequacy and evaluation: This step involved assessing the suitability of the data for factor analysis, (2) Construct extraction: Factors or constructs were extracted from the data, (3) Factor selection: criteria were applied to determine which factors should be retained/removed, (4) Rotation technique: A rotation approach was employed to optimize factor interpretability, (5) Results Analysis: The results of the factor analysis were analyzed and non-contributing factors were removed, resulting in the construction of a structural model containing significant constructs. For EFA, statistical indicators such as Kaiser Meyer Olkin's value and Bartlett's test of sphericity were computed to assess the appropriateness of the data for factor analysis.

To better understand how the different components (questions) overlap or differ in explaining the variance in their respective indicators, the study evaluated the construct validity of each component, specifically focusing on convergent validity and discriminant validity. Convergent validity was assessed using the average variance extracted (AVE), which represents the average of the squared loadings of the indicators associated with each component. Discriminant validity, on the other hand, was gauged using the heterotrait–monotrait ratio (HTMT) of correlations. HTMT compares the average correlations between indicators measuring different components to the average correlations among indicators measuring the same component.

Additionally, the survey model's internal consistency reliability was evaluated using two tests: Cronbach's Alpha and MacDonald's Omega. These tests provide insights into the reliability and consistency of the survey's measurement scales. Descriptive statistics were computed for the overall analysis of the data based on the data evaluations according to the paper's scope. Finally, SEM was employed to address the stated hypotheses.

4.4.1 Goodness of fit measures for SEM

The study assessed various goodness-of-fit measures to evaluate the model's fit in SEM. These measures included the chi-square divided by degrees of freedom (χ^2/df), Tucker-Lewis Index (TLI), Comparative Fit Index (CFI), Root Mean Residual (RMR), and Root Mean Square Error of Approximation (RMSEA), Root Mean Square Residuals (RMSR), Normed Fit Index (NFI) (Hair et al., 2012).

4.5 Validation of the instruments

To derive constructs that would adequately tackle the research questions in this study, factor analysis was utilized. This analysis encompassed principal component analysis and varimax rotation, with a minimum factor loading requirement of 0.50. The suitability of the data for factor analysis was verified by its significance, as indicated by the chi-squared test (χ2) = 5561.089, $p < 0.001$). To further confirm the adequacy of the sample, the Kaiser–Mayer–Olkin and Bartlett's test of sphericity was employed. The Kaiser–Mayer–Olkin value, which stood at 0.919, indicated that the data was appropriate for factor analysis. To evaluate construct validity, convergent validity was determined by computing the AVE for all indicators within each construct. The AVE was calculated to be above 0.7, which is considered an acceptable value (Fornell and Larcker, 1981).

Discriminant validity was evaluated using the HTMT ratio of correlations, and the resulting value was found to be 0.8, which is also considered an acceptable value. Moreover, to validate the internal consistency, Cronbach's Alpha and MacDonald's Omega were computed. All the values were within the acceptable range (>0.7) (Cohen et al., 2002). At the same time, composite reliability (CR) was calculated, and all these values fell within the acceptable threshold (>0.6). The results of factor loadings and internal reliability are provided in **Table 2** below. Finally, to evaluate the hypotheses, the study employs a SEM approach to analyze the relationship between the constructs concerning teachers' barriers and STEM teaching.

5 Findings

The findings of this study provide valuable insights into the main obstacles encountered by STEM teachers in their teaching. These findings are presented and structured in alignment with the four research hypotheses of the study, and they should serve as a compelling call to action for educators, scholars, and policymakers, urging them to implement necessary reforms in the field within the context of Qatar. Before delving into the research hypotheses, it is essential to examine the descriptive analysis of teachers' responses concerning the different teaching barriers, namely student-related, technology-related, school-related, and teaching-related. This step is crucial for gaining an understanding of which barrier presents the greatest challenge to teachers.

The results indicate that of the obstacles linked to students, the most significant challenge for teachers is the issue of "inadequate sleep among students" (mean = 3.35, S.D. = 1.08). In terms of technology-related hindrances, "insufficient internet bandwidth or speed" (mean = 2.60, S.D. = 1.24) is the foremost challenge. Concerning school-related factors, the greatest challenge arises from the "pressure to prepare students for exams" (mean = 2.69, S.D. = 1.29). Lastly, regarding barriers connected to instruction, the most prominent challenge is "teachers having an excessive number of teaching hours" (mean score of 3.34 and a standard deviation of 1.08).

5.1 Structural model and hypothesis testing

In our SEM, the construct "STEM teaching" was employed as a dependent observed variable while the other barriers (student-related, school-related, technology-related, and instruction-related) were considered as independent observed variables. We utilized the maximum-likelihood method for estimating the model's parameters, and all analyses were based on the variance-covariance matrices. The Goodness-of-Fit model was established and found to be satisfactory (Hair et al., 2012). The Goodness-of-Fit indices fell within the acceptable range, which includes criteria such as chi-squared divided by degrees of freedom ($\chi 2$ / DF) < 5, Goodness-of-Fit Index (GFI) > 0.9, Adjusted Goodness-of-Fit Index (AGFI) > 0.8, Comparative Fit Index (CFI) > 0.9, Root Mean Square Residuals (RMSR) < 0.1, Root Mean Square Error of Approximation (RMSEA) < 0.08, Normed Fit Index (NFI) > 0.9, and Parsimony Normed Fit Index (PNFI) > 0.6 (refer to **Table 3**). In summary, the structural model's good fit has been verified, paving the way for further examination of the structural model.

Figure 3 and **Table 4** present the results of the SEM analysis. The findings indicate that all the teaching barriers [i.e., (student-related: $\beta = -0.243$, $p < 0.001$); (school-related: $\beta = -0.122$, $p < 0.001$), (technology-related: $\beta = -0.123$, $p = 0.040$); and (instruction-related: $\beta = -0.112$, $p < 0.018$)] were negatively related to teachers' STEM teaching. These results illustrated that all the hypotheses formulated in the study have been supported (**Table 4**). All the path coefficients established emerged as significant at 0.05 level. Among the various obstacles, it appears that the most formidable challenges for high school STEM teachers are related to students ($\beta = -0.243$, $p < 0.001$). Teachers reported several student-related barriers, including students lacking the necessary skills and knowledge, students not getting sufficient sleep, classroom disruptions caused by students, and a lack of student interest.

6 Discussion

This study delves into the barriers that high school teachers in Qatar encounter in teaching STEM subjects. Our research examined a series of variables, including those related to students, technology, the school environment, and instructional factors from teachers' perspectives. As was stated previously, the SCT and AT provided the theoretical foundation for exploring these factors (Heffernan, 1988). The research findings presented below are interpreted through the lenses of SCT and AT, which serve as the theoretical models underpinning our study. AT aided in comprehending *how* teachers attribute challenges in STEM teaching to individual and contextual factors. On the other hand, SCT furnished a valuable framework for understanding *what* social and cognitive factors affected STEM teaching and – similar to AT – offered insights into personal and environmental barriers. Both models were useful in exploring the significant inter-relationships within the teaching context (i.e., STEM teaching and associated barriers).

The findings derived from the present study indicated that student-related teaching barriers are negatively correlated to STEM teaching. The results disclosed three specific barriers to STEM teaching as reported by teachers: students' lack of the required skills (mean = 3.34), students' lack of the required knowledge (mean = 3.34), and students not having enough sleep (mean = 3.45). These results are in alignment with recent research conducted by Tran and Moskovsky (2022) and Børte et al. (2023). These studies have unveiled teaching barriers associated with students encountering challenges in solving STEM-related problems, displaying lower academic performance, and struggling to apply their knowledge to independent STEM-related tasks. Whether or not this could be an indication of declining interest

TABLE 2 Results of confirmatory factor analysis and reliability tests (n = 290).

Construct	Questions	FL	α	ω	AVE	CR	*p*-value
Teachers' STEM teaching (Q13)	Project/problem-based approach	0.74	0.768	0.768	0.55	0.83	*
	Collaborative learning	0.72					*
	Flipped classroom	0.76					*
	Integrated learning	0.75					*
Technology-related barriers (Q27)	Insufficient number of computers	0.65	0.867	0.865	0.60	0.82	*
	Insufficient Internet bandwidth or speed	0.72					*
	School computers out of date and/or needing repair	0.78					*
	Insufficient technical support for teachers	0.62					*
	Insufficient number of interactive whiteboards	0.58					*
Student-related barriers (Q25)	Students lacking the required skills	0.82	0.832	0.819	0.45	0.65	*
	Students lacking the required knowledge	0.84					*
	Students not having enough sleep	0.79					*
	Students' disruption in the classroom	0.66					*
	Students' lack of interest	0.74					*
School-related barriers (Q29)	The school labs are not adequate	0.55	0.946	0.946	0.48	0.79	*
	Classrooms are overcrowded	0.77					*
	School time organization (lesson time, scheduling, etc.)	0.77					*
	School space organization (classroom size, furniture, etc.)	0.76					*
	Administrative constraints in accessing adequate content/material for teaching	0.69					*
	Budget constraints in accessing adequate content/material for teaching	0.59					*
	The school environment	0.74					*
	Pressure to prepare students for exams and tests	0.68					*
Instruction-related barriers (Q28)	Lack of adequate training of teachers	0.77	0.938	0.938	0.50	0.91	*
	Insufficient pedagogical support for teachers	0.75					*
	Insufficient support from colleagues	0.72					*
	Lack of content in national language	0.71					*
	Lack of pedagogical models on how to teach STEM	0.67					*
	Understanding the curriculum	0.73					*
	Implementing the school's curriculum	0.76					*
	Teachers have too many teaching hours	0.57					*
	Teachers do not have adequate instructional supplies	0.66					*
	Teachers do not have adequate instructional materials	0.69					*

CR, composite reliability; AVE, average variance extracted; α, Cronbach's Alpha; ω, Mc Donald's Omega; FL, factor loadings; *significant *p*-value.

among students in STEM learning is yet to be confirmed by future research. Further, empirical research is necessary to delve into the underlying causes and mechanisms that perpetuate these challenges.

Results suggest that technology-related teaching barriers are negatively correlated to STEM teaching. Teachers cited obstacles associated with the availability of technical resources and technical assistance/support. While teachers in Qatar emphasized the

TABLE 3 Measures of goodness-of-fit.

χ2/DF (<5)	GFI (>0.9)	AGFI (>0.8)	CFI (>0.9)	RMSR (<0.1)	NFI (>0.9)	RMSEA (<0.08)	PNFI (>0.6)
1.562	0.933	0.964	9.895	0.023	0.930	0.065	0.789

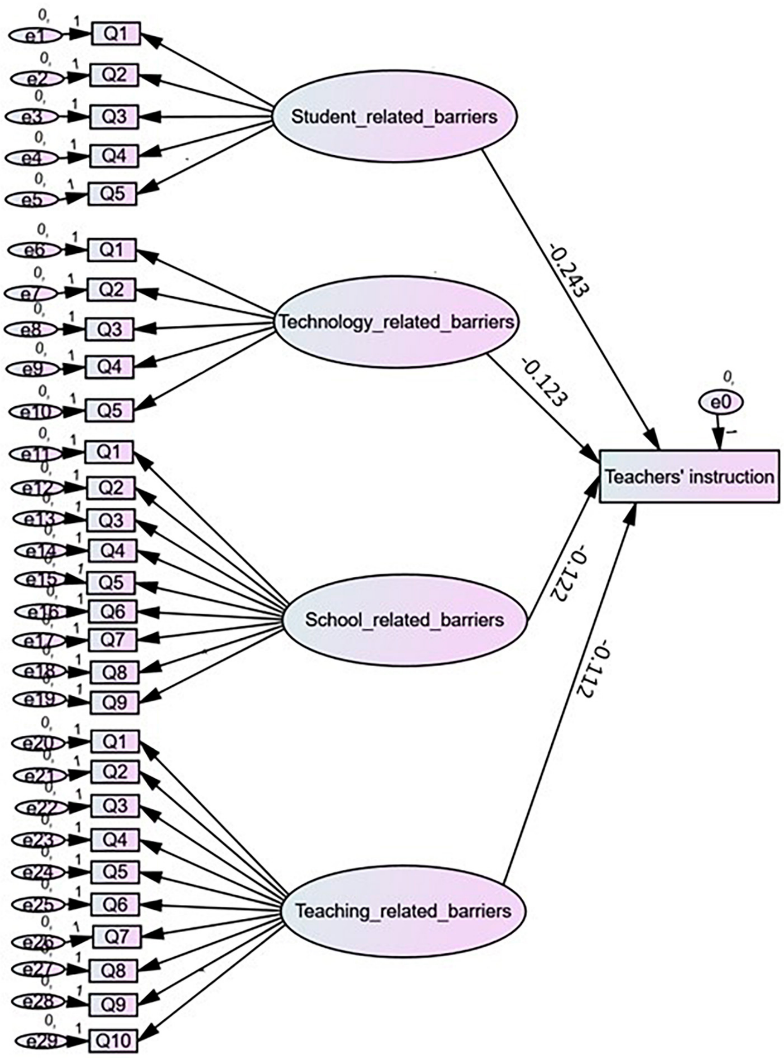

FIGURE 3
Diagrammatic representation of SEM approach, illustrating the correlation between teachers' STEM teaching and associated barriers.

TABLE 4 Results from SEM.

Hypothesis (H)	Path	Path coefficients	Standard error	Effect types	*p*-value	Results
H1	Student-related barriers → STEM teaching	−0.243	0.037	Negative effect	<0.001**	H1 supported
H2	Technology-related barriers → STEM teaching	−0.123	0.052	Negative effect	0.040*	H2 supported
H4	School-related barriers → STEM teaching	−0.122	0.004	Negative effect	<0.001**	H4 supported
H3	Instruction-related barriers → Teaching	−0.112	0.048	Negative effect	0.018*	H3 supported

** Denotes significance at 0.001 level; * denotes significance at 0.05 level.

importance of having access to technology resources, they also reported that schools often lacked suitable or sufficient educational software (Moyo, 2017). Additionally, teachers indicated they had limited access to information and communication technology (ICT) infrastructure due to a restricted curriculum (Moyo, 2017). Alshaboul et al. (2022) report that teachers' positive or negative beliefs also play a significant role in determining their access to electronic devices/ technology in the classroom.

Discomfort and inconvenience in integrating/using technology in the classroom can be considered technology-related barriers to STEM teaching. Various factors may contribute to this, including insufficient skills, such as a lack of self-efficacy, and confidence, difficulties in classroom management, or appropriate online assessments, concerns about privacy, and a shortage of effective ICT-based training. According to Al-Thani et al. (2021), there is a notable absence of professional development (PD) opportunities in Qatar, and the existing PD strategies lack clear direction, purpose, or progress. Findings from a study conducted by Said et al. (2023), which involved 245 preparatory and secondary school teachers from 16 different schools in Qatar, highlight the pressing need for substantial PD to help teachers deliver STEM effectively. Teachers also emphasize the necessity for adequate PD to address pedagogical challenges associated with the adoption of new technology-enhanced teaching methods (Said et al., 2023).

Teachers also expressed a desire for improved teacher training workshops that are held annually but repetitively (Al-Thani et al., 2021). Certain studies advocated for validated models that assist teachers in overcoming technology-related barriers and enhancing effective pedagogical delivery. One such model is the mentoring model, which involves providing professional support from experienced teachers to newly hired teachers (Abu-Tineh and Sadiq, 2018). Similarly, Said et al. (2023) focused on teachers' PD using the Technological Pedagogical and Content Knowledge (TPACK) model. This model helps teachers effectively use/integrate technology during instruction. Another noteworthy model is PICRAT, which is student-centered, pedagogy-driven, tailored to specific contexts, and practical for teachers as it guides all considerations for effective technology use in classrooms (Kimmons et al., 2020). In the PICRAT model, "PIC" stands for Passive, Interactive, Creative Learning, and it refers to how students engage with technology within a specific educational context or field. On the other hand, "RAT" stands for Replacement, Amplification, and Transformation, and it signifies the influence of technology on a teacher's practices when it's integrated into their teaching methods (Kimmons et al., 2020). Although there are several PD models for effective technology integration and combating technology-related barriers, only the TPACK model and mentoring model have been reported in the context of Qatar.

The third variable that we investigated, namely school-related teaching barriers, was found to have a negative correlation with STEM teaching. Teachers reported various school-related challenges, including the pressure to prepare students for exams, constraints related to the budget and the administration when accessing adequate teaching materials, concerns about the school environment, dealing with overcrowded classrooms, and facing limitations with inadequate school laboratories. These results echo findings in a recent study that looked at the context of Qatar by Sellami et al. (2022). While the influence of school-related variables and their connection with STEM in STEM Qatar is a largely understudied area, some recommendations to address the relevant challenges are proposed in this study. For instance, the issue of limited access to adequate teaching resources could potentially be resolved by enhancing school libraries through the expansion of library resources and the improvement of information technology facilities (Gunasekera and Balasubramani, 2020).

To address the issue of the pressure teachers feel in preparing students for exams, potential remedies include stress management interventions, such as cognitive-behavioral-based and mindfulness-based interventions (von Keyserlingk et al., 2020). Cognitive-behavioral-based interventions involve cognitive training and the practice of strategic behaviors, equipping teachers with both knowledge and skills to effectively manage work-related stress (von Keyserlingk et al., 2020). On the other hand, mindfulness-based interventions emphasize cognitive and behavioral strategies that focus on the experience of feelings and thoughts, rather than the specific content of those thoughts. These strategies aim to promote awareness and acceptance without judgment, making them integral components of mindfulness-based approaches (von Keyserlingk et al., 2020).

Instruction-related teaching barriers have also been identified as having a negative correlation with STEM teaching. Teachers reported several challenges, including inadequate training in STEM education and a lack of pedagogical models tailored for STEM teaching. They also highlighted issues related to the imposed school curricula, excessive teaching hours, and a shortage of teaching materials. Existing literature demonstrates a positive relationship between the pressure stemming from imposed curricula and the perceived stress among teachers (Putwain and von der Embse, 2019; von Keyserlingk et al., 2020). Research has also shown a negative relationship between teachers' self-efficacy and their perceived stress (Putwain and von der Embse, 2019). In simple terms, when teachers possess a high level of self-efficacy in STEM, they tend to experience less stress in response to curriculum changes (von Keyserlingk et al., 2020). This underscores the importance of implementing PD programs for teachers, specifically targeting STEM education, to enhance their self-efficacy and better equip them to handle curriculum changes with reduced stress. The literature has also shown that excessive teaching hours constitute a real challenge for teachers (Ismail et al., 2019). Demonstrably, this challenge has been consistently cited as a significant factor that greatly impacts teachers' motivation to teach STEM subjects contributes to increased stress levels, and leads to lower job satisfaction among teachers when they are teaching STEM (von Keyserlingk et al., 2020).

A comprehensive systematic review that drew data from 25 articles spanning the globe also reinforces the importance of providing support to teachers to enhance their capacity to implement STEM education effectively (Margot and Kettler, 2019). This support includes collaborations with colleagues, ensuring access to well-crafted curricula, receiving support from the school, drawing upon past experiences, and having access to impactful professional development opportunities (Margot and Kettler, 2019). As a result of these study findings, there is a clear and compelling need for school management to offer robust support to teachers. This support should encompass the provision of PD programs geared toward enhancing their skills in STEM education, as well as implementing stress management interventions to help teachers effectively manage the stress associated with their teaching responsibilities (Karkouti et al., 2022).

Conclusively, the study's main limitations stem from its exclusive reliance on quantitative survey data, specifically from high school teachers in Qatar, looking at their perceptions of challenges to STEM teaching. To gain a more informed insight and understanding of the factors influencing technology integration, the study would benefit from also utilizing qualitative data. For instance, conducting focus group interviews, in-depth one-on-one discussions, and follow-up interviews would enable an in-depth exploration of the underlying reasons behind these barriers. Another limitation is that the study primarily focuses on high school teachers' perspectives, overlooking those of educators in lower grade levels. Incorporating data from primary and preparatory teachers would broaden the study's insights and offer a comparative viewpoint. It is worth noting that different results and conclusions might arise when considering teachers with diverse demographics. However, we believe that the study's reliability is supported by robust statistical analysis, using a more stringent significance level (e.g., $p < 0.01$). Furthermore, it is important to acknowledge the need for a longitudinal analysis of teachers' perceptions of barriers to STEM instruction. Because teachers' beliefs and attitudes change and evolve, a longitudinal study would capture these shifts and changes, and provide valuable insights into long-term trends in STEM education.

7 Conclusion and recommendations

Teachers are the cornerstone of educational excellence and hold significant sway over students' academic achievements in STEM. Specifically, the teaching methods utilized by teachers and their skillful application in the classroom play a pivotal role in influencing whether students choose to pursue and persist in STEM fields of study and future careers. Therefore, it is important to understand teachers' experiences of teaching STEM and the challenges they encounter. Guided by SCT and AT, this study identified a range of factors impeding STEM teaching: school-related, student-related, technology-related, and teaching-related barriers.

This research intends to explore the experiences of high school STEM teachers in Qatar, focusing specifically on the barriers they face in teaching STEM. The research findings underscore the importance of barriers related to schools, students, technology, and teaching methods in the context of STEM teaching within the classroom. Additionally, the study highlighted that student-related barriers were the most prominent impediments affecting STEM instruction. We believe that these findings provide crucial insights that can inform the development of effective STEM learning practices in high schools in Qatar.

Overall, this study calls for investing in teachers' knowledge and expertise and for the need to provide support for them in terms of emotional, informational, instrumentational, and appraisal aspects in Qatar. Emotional support entails sharing personal experiences, demonstrating empathy toward teachers, and implementing effective stress management strategies to assist them in coping with work-related stress. Informational support involves creating well-thought-out plans and recommending actions to facilitate problem-solving. Instrumental support encompasses offering tangible assistance, direct aid, and PD programs to enable teachers to reach their objectives. Equally significant is the concept of appraisal support, which nurtures an environment promoting self-evaluation, constructive feedback, and affirmation, all contributing to enhancing teachers' motivation and overall well-being.

Data availability statement

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

Ethics statement

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of Qatar University (QU-IRB 1424-EA/20) on 1 March 2020. The participants provided written informed consent for participation in the study.

Authors contributions

AS: Methodology, Writing – review and editing, Conceptualization, Funding acquisition, Project administration. MS: Formal analysis, Methodology, Writing – original draft. JB: Formal analysis, Writing – review and editing. ZA: Methodology, Supervision, Writing – review and editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. The project was funded by the Qatar University (Reference: QUCG-SESRI-20/21-1). This research has been partially supported by Qatar University Exceptional Grant (Ref.: QU-ERC-23_24-1) entitled "Student interest and perseverance in STEM-related fields of study and Careers" from Qatar University.

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.

Publisher's note

References

Abu-Tineh, A., and Sadiq, H. (2018). Characteristics and models of effective professional development: The case of school teachers in qatar. *Profess. Dev. Educ.* 44, 311–322.

Al-Misnad, S. (2012). *The dearth of qatari men in higher education: Reasons and implications*. Washington, DC: Middle East Institute.

AlMuraie, E., Algarni, N., and Alahmad, N. (2021). Upper-secondary school science teachers' perceptions of the integrating mechanisms and importance of STEM education. *J. Baltic Sci. Educ.* 20, 546–557. doi: 10.33225/jbse/21.20.546

Alshaboul, Y., Alazaizeh, M., Al-Shboul, Q., Newsome, M., and Abu-Tineh, A. (2022). University instructors and students' attitudes toward distance education: The case of qatar. *J. Positive Sch. Psychol.* 6, 7940–7959.

Al-Thani, W., Ari, I., and Koç, M. (2021). Education as a critical factor of sustainability: Case study in qatar from the teachers' development perspective. *Sustainability* 13:11525.

Antonova, O., Antonov, O., and Polishchuk, N. (2022). STEM-APPROACH IN EDUCATION AND PREPARATION OF THE TEACHER FOR ITS IMPLEMENTATION. *Zhyto. Ivan Franko State Univers. J. pedagog. Sci.* 3, 267–281. doi: 10.1088/1742-6596/1806/1/012219

Babar, Z., Ewers, M., and Khattab, N. (2019). Im/mobile highly skilled migrants in Qatar. *J. Ethn. Migr. Stud.* 45, 1553–1570. doi: 10.1080/1369183X.2018.1492372

Bandura, A. (1989). "Social Cognitive Theory," in *Annals of Child Development*, ed. R. Vasta (Greenwich: Jai Press LTD), 1–60.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York, NY: WH Freeman.

Ben Hassen, T. (2021). The state of the knowledge-based economy in the Arab world: Cases of Qatar and Lebanon. *Euromed J. Bus.* 16, 129–153. doi: 10.1108/EMJB-03-2020-0026/full/html

Berman, E. (2017). *An exploratory sequential mixed methods approach to understanding researchers' data management practices at UVM: Integrated findings to develop research data services*. Burlington, VT: University of Vermont.

Blazar, D., and Kraft, M. (2017). Teacher and teaching effects on students' attitudes and behaviors. *Educ. Eval. Policy Anal.* 39, 146–170. doi: 10.3102/0162373716670260

Børte, K., Nesje, K., and Lillejord, S. (2023). Barriers to student active learning in higher education. *Teach. High. Educ.* 28, 597–615.

Btool, H., and Koc, M. (2017). Challenges and drivers for Qatar's transformation into a knowledge-based economy and society-work in progress in education system reforms. *PressAcad. Proc.* 4, 281–288. doi: 10.17261/Pressacademia.2017.545

Cherif, R., Hasanov, F., and Pande, A. (2021). Riding the energy transition: Oil beyond 2040. *Asian Econ. Policy Rev.* 16, 117–137. doi: 10.1111/aepr.12317

Cherif, R., Hasanov, F., and Zhu, M. (2016). *Breaking the oil spell: The Gulf falcons' path to diversification*. Washington, DC: International Monetary Fund.

Cohen, L., Manion, L., and Morrison, K. (2002). *Research methods in education*. Milton Park: Routledge.

Creswell, J., Klassen, A., Plano Clark, V., and Smith, K. (2011). Best practices for mixed methods research in the health sciences. *Bethesda (Maryland)* 2013, 541–545. doi: 10.1016/B978-0-323-91888-6.00033-8

Dong, Y., Wang, J., Yang, Y., and Kurup, P. (2020). Understanding intrinsic challenges to STEM instructional practices for Chinese teachers based on their beliefs and knowledge base. *Int. J. STEM Educ.* 7, 1–12. doi: 10.1186/s40594-020-00245-0

Fornell, C., and Larcker, D. (1981). *Structural equation models with unobservable variables and measurement error: Algebra and statistics*. Los Angeles, CA: Sage Publications.

Gunasekera, C., and Balasubramani, R. (2020). Use of information and communication technologies by school teachers in sri lanka for information seeking. *Libr Philos Pract.* 2020:3979.

Hair, J., Sarstedt, M., Ringle, C., and Mena, J. (2012). An assessment of the use of partial least squares structural equation modeling in marketing research. *J. Acad. Market. Sci.* 40, 414–433. doi: 10.1108/IJCHM-10-2016-0568/full/html

Hamad, S., Tairab, H., Wardat, Y., Rabbani, L., AlArabi, K., Yousif, M., et al. (2022). Understanding science teachers' implementations of integrated STEM: Teacher perceptions and practice. *Sustainability* 14:3594. doi: 10.1186/s40594-018-0101-z

Heffernan, C. (1988). Social foundations of thought and action: A social cognitive theory, Albert Bandura Englewood Cliffs, New Jersey: Prentice Hall, 1986, xiii+ 617 pp. Hardback. US $39.50. *Behav. Change* 5, 37–38.

Ichsan, I., Suharyat, Y., Santosa, T., and Satria, E. (2023). The effectiveness of STEM-based learning in teaching 21st century skills in generation Z student in science learning: A meta-analysis. *J. Penelit. Pendidik. IPA* 9, 150–166.

Ismail, M., Salleh, M., and Nasir, N. (2019). The issues and challenges in empowering STEM on science teachers in Malaysian secondary schools. *Int. J. Acad. Res. Bus. Soc. Sci.* 9, 430–444. doi: 10.6007/IJARBSS/v9-i13/6869

Karkouti, I., Abu-Shawish, R., and Romanowski, M. (2022). Teachers' understandings of the social and professional support needed to implement change in qatar. *Heliyon* 8:e08818. doi: 10.1016/j.heliyon.2022.e08818

Kayan-Fadlelmula, F., Sellami, A., Abdelkader, N., and Umer, S. (2022). A systematic review of STEM education research in the GCC countries: Trends, gaps and barriers. *Int. J. STEM Educ.* 9, 1–24. doi: 10.1186/s40594-021-00319-7

Kim, M. (2021). A systematic review of the design work of STEM teachers. *Res. Sci. Technol. Educ.* 39, 131–155. doi: 10.1080/02635143.2019.1682988

Kimmons, R., Graham, C., and West, R. (2020). The PICRAT model for technology integration in teacher preparation. *Contemp. Issues Technol. Teach. Educ.* 20, 176–198.

Kola, A. (2013). Importance of science education to national development and problems militating against its development. *Am. J. Educ. Res.* 1, 225–229. doi: 10.12691/education-1-7-2

MacFarlane, B. (2021). *Infrastructure of comprehensive STEM programming for advanced learners. STEM education for high-ability learners*. Milton Park: Routledge, 139–160.

Margot, K., and Kettler, T. (2019). Teachers' perception of STEM integration and education: A systematic literature review. *Int. J. STEM Educ.* 6, 1–16. doi: 10.1186/s40594-018-0151-2

Moyo, C. (2017). Evaluating the current usage and integration of ICTs in education: A review of teachers' usage and barriers to integration. *TEXILA Int. J. Acad. Res.* 4, 107–115.

Nasser, R. (2017). Qatar's educational reform past and future: Challenges in teacher development. *Open Rev. Educ. Res.* 4, 1–19.

Nugent, G., Barker, B., Welch, G., Grandgenett, N., Wu, C., and Nelson, C. (2015). A model of factors contributing to STEM learning and career orientation. *Int. J. Sci. Educ.* 37, 1067–1088.

Oliveros Ruiz, M., Vargas Osuna, L., Valdez Salas, B., Schorr Wienner, M., Sevilla Garcia, J., Cabrera Cordova, E., et al. (2014). The importance of teaching science and technology in early education levels in an emerging economy. *Bull. Sci. Technol. Soc.* 34, 87–93.

Putwain, D., and von der Embse, N. (2019). Teacher self-efficacy moderates the relations between imposed pressure from imposed curriculum changes and teacher stress. *Educ. Psychol.* 39, 51–64.

Rohendi, D., Wahyudin, D., and Kusumah, I. (2023). Online learning using STEM-based media: To improve mathematics abilities of vocational high school students. *Int. J. Instruct.* 16, 377–392.

Romlie, M., Sudjono, I., and Subandi, M. (2021). Integrating STEM into the formal and instructional curriculum to support machine construction design. *Teknol. Kejuruan* 44, 100–107.

Said, Z., Mansour, N., and Abu-Tineh, A. (2023). Integrating technology pedagogy and content knowledge in Qatar's preparatory and secondary schools: The perceptions and practices of STEM teachers. *EURASIA J. Maths. Sci. Technol. Educ.* 19:em2271.

Sellami, A., Ammar, M., and Ahmad, Z. (2022). Exploring teachers' perceptions of the barriers to teaching STEM in high schools in qatar. *Sustainability* 14:15192.

Sellami, A., El-Kassem, R., Al-Qassass, H., and Al-Rakeb, N. (2017). A path analysis of student interest in STEM, with specific reference to qatari students. *EURASIA J. Maths. Sci. Technol. Educ.* 13, 6045–6067.

Shadle, S., Marker, A., and Earl, B. (2017). Faculty drivers and barriers: Laying the groundwork for undergraduate STEM education reform in academic departments. *Int. J. STEM Educ.* 4, 1–13. doi: 10.1186/s40594-017-0062-7

Sturtevant, H., and Wheeler, L. (2019). The STEM faculty instructional barriers and identity survey (FIBIS): Development and exploratory results. *Int. J. STEM Educ.* 6, 1–22. doi: 10.1186/s40594-019-0185-0

Tan, T., Al-Khalaqi, A., and Al-Khulaifi, N. (2014). Qatar national vision 2030. *Sustain. Dev.* 19, 65–81.

Tran, L., and Moskovsky, C. (2022). Students as the source of demotivation for teachers: A case study of Vietnamese university EFL teachers. *Soc. Psychol. Educ.* 25, 1527–1544.

von Keyserlingk, L., Becker, M., Jansen, M., and Maaz, K. (2020). Leaving the pond—Choosing an ocean: Effects of student composition on STEM major choices at university. *J. Educ. Psychol.* 112:751. doi: 10.1037/edu0000378

Wahono, B., and Chang, C. (2019). Assessing teacher's attitude, knowledge, and application (AKA) on STEM: An effort to foster the sustainable development of STEM education. *Sustainability* 11:950. doi: 10.3390/su11040950

Waters, C., and Orange, A. (2022). STEM-driven school culture: Pillars of a transformative STEM approach. *J. Pedagog. Res.* 6, 72–90. doi: 10.33902/JPR.202213550

Weiner, B. (2010). The development of an attribution-based theory of motivation: A history of ideas. *Educ. Psychol.* 45, 28–36.